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ORIGINAL PAPER

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ALLEVIATION OF DROUGHT STRESS IN *Phaseolus vulgaris* L. CULTIVARS USING PHYTOSTIMULATORS IN ORGANIC AGRICULTURE

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ABSTRACT

This research was conducted to investigate the effects of phytostimulators application (Messenger, Crop-Set, ISR-2000) on yield and morphological parameters of common bean cultivars grown under four irrigation regimes [25% (I_{25}), 50% (I_{50}), 75% (I_{75}) and 100% (I_{100})]. Phytostimulators reversed the negative effect of drought on plant growth. Significant interaction was determined for all parameters except stem diameter and stomatal conductivity between phytostimulator and drought applications. The best effect on stomatal conductivity was provided from ISR-2000 (23.5% reduction) application. The highest yield was obtained from the 25% water deficiency applied with 1.91 ton per hectare. It was determined that the best results were obtained from Messenger in Efsane and Asya cultivars and ISR-2000 in the Öz Ayşe cultivar on yield. Therefore, it was concluded that the use of phytostimulators under drought stress is important for the effective use of water.

Key words: common bean, abiotic stress, plant activator, vegetative growth, yield

INTRODUCTION

Drought is one of the most important abiotic stress problems limiting agricultural production in the world. Approximately 45% of the world's agricultural land is constantly exposed to drought stress and it is estimated that two thirds of the world's population will be affected by water scarcity between 2010–2050 [Bot et al. 2000, Mancosu et al. 2015]. Common bean, which is widely cultivated in all continents except Antarctica, is the second most important green vegetable with an annual production of 21,720,588 tons [Fao 2019]. Around 60% of the production of *Phaselous vulgaris* in the world is at risk of drought [Beebe et al. 2008]. Although tolerance to drought stress occurs in almost all plants, the level of this tolerance may vary depending on species, varieties, degree of stress and plant development stages [Demirevska et al. 2009]. Some physiological activities such as photosynthesis change in common beans in drought conditions [França et al. 2000, Lizana et al. 2006, Rosales et al. 2012, Rosales et al. 2013, Ruiz-Nieto et al. 2015]. Reduced carbon dioxide diffusion due to decreased stomatal conductivity in the early drought phase causes reduced photosynthesis and cell growth. This situation is the primary process affected by drought. It is very important to develop some strategies to ensure drought tolerance in regions with Mediterranean coasts where plants are exposed to more severe drought especially in the summer period [Sedlar et al. 2019]. However, increased drought stress caused a significant reduction in growth parameters, photosynthetic

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pigments, total carbohydrates and phytohormones, pod and seed yield, 100-seed weight, days to maturity and stomatal conductivity [Terán and Singh 2002, Szilagyi 2003, Abass and Mohamed 2011, Darkwa et al. 2016, Gonçalves et al. 2019]. In order to eliminate the agricultural problems created by decreasing water resources in recent years, it has become necessary to investigate alternative materials and methods that can increase the adaptation ability of plants and their resistance to drought. One of these methods is phytostimulators. The preparats that increase the growth and efficiency of the plant by activating the expression of genes that provide higher water absorption and ion transport or activate the primary and secondary metabolism are also classified as plant activators [Castro et al. 2009]. Castro and Pereira [2008] described these preparats as complex organic substances that have an effect on plant growth, which may affect the plant's DNA transcription, gene expression, membrane proteins, metabolic enzymes and mineral uptake. Although there have been many studies investigating the effects of phytostimulators, researches in common beans are quite limited. Studies in common beans have focused particularly on seaweed extracts and Nano-Gro, an oligosaccharide compound supplemented with sulphated compounds. These preparats have a positive effect on plant growth and yield in common beans, and also have supplemented resistance to plant diseases and pests [Kocira et al. 2013, Kocira et al. 2015b, Kocira et al. 2018a, Kocira et al. 2018b, Paulert et al. 2009].

It is obvious that research is needed to maximize water use efficiency and minimize synthetic agrochemical use in vegetable production all over the world. Phytostimulators used in greenhouse bean cultivation can increase drought stress tolerance and yield according to the beneficial microorganisms they contain. In studies investigating the effects of drought stress on common beans, it is noteworthy that there are differences between genotypes. The aims of this study are a) development of a method to increase water usage efficiency in common bean cultivation; b) assessment the effects of different phytostimulators on yield, quality and development characteristics of common bean cultivars exposed to drought stress; c) determination water regimes that optimize yield and quality in organic growing conditions, particularly when phytostimulator application is used.

MATERIALS AND METHODS

Plant materials and phytostimulators. In this research, three standard common bean cultivars (Asya, Efsane, Özayşe) with different growth habits and three different phytostimulators (Crop-Set, Messenger and ISR-2000) were used. Information on the contents of plant phytostimulators is given in Table 1.

Growing conditions. This study was conducted with three common bean cultivars in an unheated plastic greenhouse of the Department of Horticulture, Faculty of Agriculture of Akdeniz University. The greenhouse had already been used for organic vegetable cultivation for three years before the experiment started and had a roof wing ventilation system, lateral curtains and electric fans for ventilation. Two weeks before the seed sowing, soil samples which were collected at a depth of 0–30 cm and 30–60 cm in order to determine the physical and chemical properties. The experimental area had a sandy loam soil and the other soil properties are shown in Table 2. The experiment was carried out in a greenhouse, which was sufficient for organic matter and macro nutrients and also not previously used for conventional farming. Regarding the temperature values of the period in which the research was carried out, the average temperatures between March and June were recorded as 12.9°C and 25.3°C, respectively.

Application of drought stress. Three common bean cultivars with different growth habits were grown under four different irrigation (I) regimes which consisted of a non-stress treatment (I_{100} : 100%), mild-stress (I_{75} : 75%), moderate stress (I_{50} : 50%) and severe stress (I_{25} : 25%). Irrigation treatments were made by a drip irrigation system. Lateral drip lines which have 2.1 L h^{-1} inline drippers spaced at 40 cm were placed for each plant row. All treatments were irrigated at the same time. Irrigation frequency was based on the solar radiation achieved in the greenhouse. The amount of water applied was calculated to meet the solar radiation. The irrigation scheduling was automatically implemented by a digital timer. A radiation-based evapotranspiration method was used to determine the crop water requirement. For this purpose, a solar radiation sensor, placed in the greenhouse roof, was used to apply the four irrigation rates, 25% (I_{25}), 50% (I_{50}), 75% (I_{75}) and 100% (I_{100}).

Table 1. Content and properties of phytostimulators used in this research [Anonymous 2020]

Phytostimulator	Contents
Crop-Set	It contains *Lactobacillus acidophilus* and mineral substances, vitamins and natural binders and nitrogen catalysts (Improcrop)
ISR-2000	It is a fermentation product of *Lactobacillus acidophilus* which contains Yucca plant extract, yeast extract, riboflavin, benzoic acid, nicotinamide and thiamine (Improcrop)
Messenger	It contains 3% harpin protein (Harpin Ea) of *Erwinia amylovora* (Eden Bioscience)

Table 2. Soil properties of the experimental area

Content	0–30 cm depth	30–60 cm depth	Evaluation
pH (1 : 2.5)	8.8	8.9	strong alkaline
Lime	29.3	35.6	too much chalk
EC (micromhos cm^{-1})	142	124	salt-free
Sand (%)	59	65	
Clay (%)	10	6	sandy loam
Mil (%)	31	45	
Organic matter (%)	1.5	1.6	
P (ppm)	40	41	20–25
K (ppm)	135	117	200–320
Ca (ppm)	3039	2959	1440–6120
Mg (ppm)	380	388	117–400

Table 3. Variance analyses results with respect to plant and pod properties of three common bean cultivars

Source of variation	df	SC	SL	RL	SD	PW	LW	LL	PL	PW	PT	PCS
Cultivar (C)	2	**	*	*	*	NS	*	*	*	*	*	*
Irrigation (I)	3	**	*	*	*	NS	*	*	*	*	NS	*
Phytostimulator (P)	3	NS	*	*	*	NS	*	NS	*	*	*	*
C × I	6	*	*	*	*	*	*	*	NS	NS	NS	NS
C × P	6	NS	*	*	*	NS	*	*	*	*	*	*
I × P	9	NS	*	*	NS	*	*	*	*	*	*	*
C I × P	18	NS	*	*	*	*	*	*	*	*	*	*

SC: Stomatal conductance, SL: Shoot length, RL: Root length, SD: Stem diameter, PW: Plant weight, LW: Leaf width, LL: Leaf length, PL: Pod length, PW: Pod width, PT: Pod thickness, PCS: Pod cross section
NS: not significant. * Significant at $P < 0.05$. ** Significant at $P < 0.01$

Phytostimulator application. Twenty days after the seed sowing, phytostimulator applications were done four times with an interval of 15 days. Each phytostimulator was applied in the form of spraying to the leaves at the recommended doses (ISR-2000: 100 ml 100 L^{-1}, Crop-Set: 60 ml da^{-1} and Messenger: 6 g da^{-1}). The control group, in which no stimulator application was performed, was also included in the experiment.

Experimental design. The experiment included three cultivars, four water regimes and three phytostimulator treatments, in a randomised complete block design with three replicates for two consecutive seasons. The constant distance between rows was 100 cm. The within-row spacing used was 40 × 40 cm. The plot size was 8.4 m^2. The greenhouse was divided into 144 experimental plots. Each plot consisted of 30 plants. Five plants were chosen per plot to determine morphological evaluation.

Measurements and observations in plants and pods. Stomatal conductance was measured using the Decagon SC-1 Leaf Porometer (Decagon Devices, Inc., Pullman, Washington) on the abaxial surface of the ear leaf as mmol m^{-2} s^{-1}. The measurements were carried out in full clear air conditions at 11.00 am and 02.00 pm. Morphological evaluation, fruit yield and quality measures were determined on per replicate plots of five randomly chosen plants and ten marketable fruits each in the experiment every week. After the last harvest, five plants from each plot were used to determine the plant weight (g), root and shoot length (cm), stem diameter (mm), leaf width (cm) and length (cm), pod length (mm), pod width (mm), pod thickness (mm) and pod cross section (mm). In addition, the average number of pods (pod $plant^{-1}$), pod weight (g) and yield (t ha^{-1}) values of the cultivars were calculated according to the harvest results.

Statistical analysis of data. The experiment was set up in a completely randomised design with a factorial arrangement in triplicates. Statistical analyses were conducted using analysis of variance (ANOVA) using the SPSS 23 programme. The mean separation between the treatments' averages was made by Duncan's Multiple Range Test ($P \leq 0.01$ and $P \leq 0.05$).

RESULTS

Solar radiation and water consumption. Daily solar radiation and cumulative water consumption amounts are given in Figure 1. Daily solar radiation

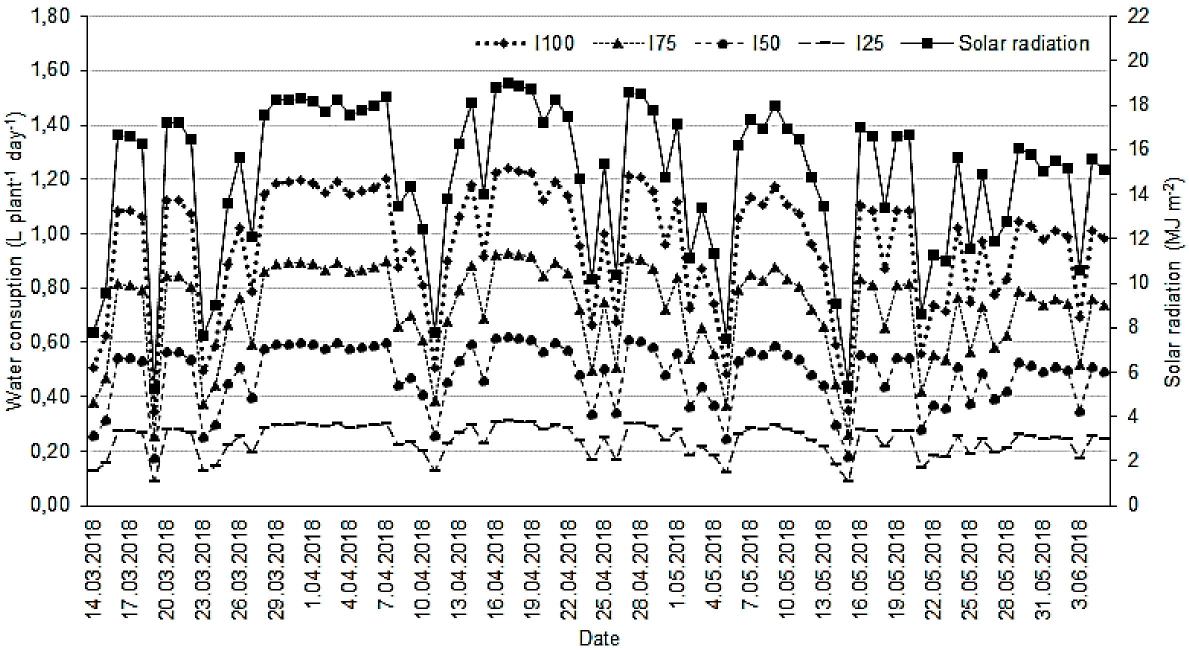


Fig. 1. Daily solar radiation and water consumption

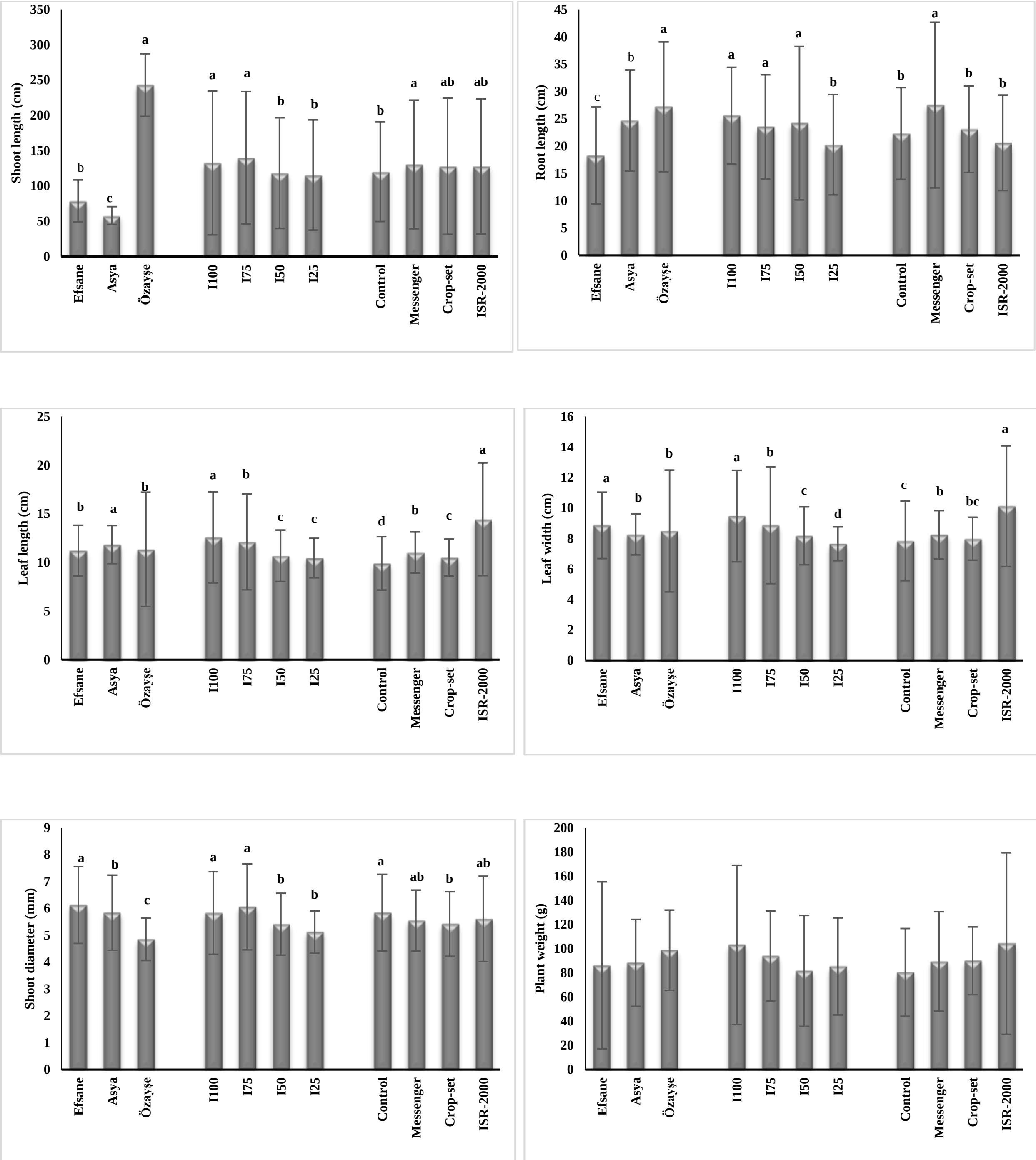
ranged from 5.2 to 18.8 MJ m^{-2} day^{-1}. Seasonal water used varied from 80.8 L $plant^{-1}$ (its equal 505.0 mm) in the I_{100} treatment, 60.6 L $plant^{-1}$ (its equal 379 mm) in the I_{75} treatment, 40.4 L $plant^{-1}$ (its equal 253 mm) in the I_{50} treatment and 20.2 L $plant^{-1}$ (its equal 126 mm) in the I_{25} treatment.

Statistical analysis. The results with respect to stomatal conductance, plant development properties (shoot length, root length, stem diameter, plant weight, leaf width, leaf length) and pod properties (pod length, pod width, pod thickness and pod cross section) of three common bean varieties together with the statistical analysis are presented in Table 3. It was found that, except plant weight, in cultivar treatments were statistically different. Irrigation treatments significantly affect stomatal conductance, shoot length, root length, stem diameter, leaf width, leaf length, pod length, pod width and pod cross section but not plant weight and pod thickness. The effects of the different phytostimulators applied in this study were statistically significant on shoot length, root length, stem diameter, leaf width, pod length, pod width, pod thickness and pod cross section but not stomatal conductance, plant weight and leaf length. Cultivar, irrigation and phytostimulators have been found to be a source of diversity for plant and pod properties except for stomatal conductance. However, in the interactions between variation sources, C × I interaction in plant properties except pod properties, C × P interaction in plant properties except stomatal conductance and plant weight, I × P interaction for all properties except stomatal conductance and stem diameter and finally, C × I × P triple interaction for all properties except stomatal conductance, was determined to be significant at the 0.05 level.

Stomatal conductance. The average values of stomatal conductance are presented in Table 4. It was found that stomatal conductance values were higher in full irrigation treatments as compared to the deficit irrigation treatments. Stomatal conductance varied from 31.5 to 461.2 for Asya, from 44.5 to 388.5 for Efsane and from 106.5 to 481.5 for Özayşe cultivars. For control conditions, compared to phytostimulator treatments, reductions in the stomatal conductance were determined as 26.1%, 24.8% and 23.5% for Messenger, Crop-Set and ISR-2000 treatments, respectively.

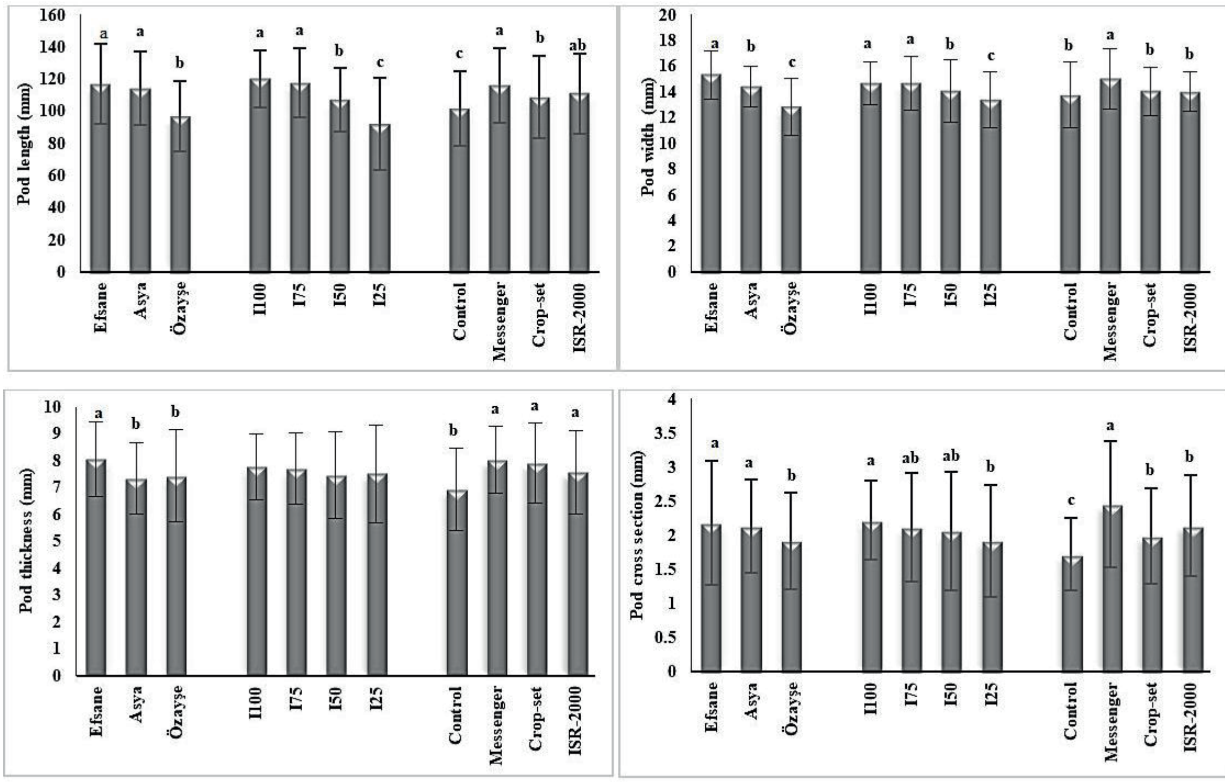
Plant development properties. Shoot length, root length, stem diameter, leaf width and leaf length of common beans showed statistically significant differences according to phytostimulator, irrigation treatments and cultivars (Fig. 2). Increasing the irrigation level enhanced leaf development, stem diameter and root length while adversely affecting shoot length and plant weight. It was determined that the plants to which Messenger was applied as a phytostimulator had better shoot (130.61 cm) and root (27.49 cm) length but ISR-2000 application was more effective in terms of leaf development (10.11 cm, width; 14.43 cm, length). In comparison to the I_{100} irrigation level, root length, leaf length, leaf width and plant weight were significantly reduced by water stress except for stem diameter and shoot length. Plant weight was not affected by either drought stress and phytostimulator application and no statistically significant difference was found. When all data were considered, it was determined that there was a statistically significant relationship among cultivars, irrigation regime and phytostimulator application.

Pod properties. The effects of phytostimulators and irrigation levels on pod properties of common bean cultivars are represented in Figure 3. The best pod development was obtained from the I_{100} irrigation regime. When the phytostimulator applications were examined, it was determined that Messenger had the best results in all pod properties (length: 116.08 mm; width: 15.03 mm; thickness: 8.04 mm; cross section: 2.46 mm). It is thought that this situation may be related to the encouragement of root development as shown in Figure 2. Regarding the plant development properties of cultivars, Efsane has shown the best pod development. However, as the results of the statistical analysis showed no interaction between the cultivar and the irrigation regime, it was determined that the triple interaction of the cultivar, phytostimulator and irrigation regime was significant at the 0.05 level (Tab. 3). Accordingly, it was concluded that the use of phytostimulators on pod development is very important. Pod thickness, pod length and pod width properties were not statistically different between the I_{100} and I_{75} irrigation treatments. In this case, it is thought that a water deficit can be applied in common beans by implementing the I_{75} rather than the I_{100} irrigation.



Statistical differences between applications are shown in different letters, $P \leq 0.05$

Fig. 2. Results of variance analysis for plant development criteria from different irrigation levels and phytostimulator treatments in common bean cultivars



Statistical differences between applications are shown in different letters, $P \leq 0.05$.

Fig. 3. Effect of irrigation levels and phytostimulator treatments on pod properties of common bean cultivars

Yield. The results of statistical analysis of the effects of applications on yield are given in Table 5. The highest yield (3.40 t ha^{-1}) was obtained from the I_{100} irrigation regime with ISR-2000 in the Özayşe cultivar, followed by the I_{75} irrigation regime with Crop-Set in the same cultivar with 3.01 t ha^{-1}. The minimum yield (0.44 t ha^{-1}) was obtained from the I_{25} irrigation regime with the control in the Asya cultivar, followed by the I_{25} irrigation regime with Crop-Set in the same cultivar with 0.46 t ha^{-1}.

The I_{100} irrigation regime in Asya (2.50 t ha^{-1}) and Özayşe (3.40 t ha^{-1}) increased the yield but the yields showed differences in phytostimulator applications. Similar to Efsane, the Asya responded positively to the Messenger application. In the Özayşe cultivar, the prominent phytostimulator was determined as ISR-2000. When all yield values were considered, phytostimulator applications have higher results than the control group.

The results of statistical analysis of the effects of applications on total number of pods are given in Figure 4. As shown in Figure 4, the total number of pods of common bean cultivars varied according to irrigation regime and phytostimulator application. It has been concluded that Messenger clearly has a positive effect on the number of pods (24.95 pod $plant^{-1}$) and the irrigation of I_{75} is sufficient to obtain the highest number of pods in the Efsane cultivar. The highest number of pods (29.04 pod $plant^{-1}$) in the Asya cultivar was also obtained from the Messenger application at the I_{100} irrigation level. On the other hand, different from the others, the ISR-2000 application provided the highest number of pods (12.04 pod $plant^{-1}$) in the Özayşe cultivar at the I_{100} irrigation level. A higher number of pods was obtained from the plots to which a phytostimulator was applied at all irrigation levels in all three cultivars. This revealed that the phytostimulator application is extremely useful.

Table 4. The effects of different phytostimulators and irrigation levels on stomatal conductance in three common bean cultivars

Cultivars	Phytostimulator	Irrigation levels			
		I_{25}	I_{50}	I_{75}	I_{100}
Asya	Control	35.9 (8.85)	89.4 (18.40)	71.2 (11.38)	317.1 (241.82)
	Messenger	77.5 (11.01)	79.8 (19.97)	99.9 (28.60)	343.0 (111.85)
	Crop-set	31.5 (8.94)	81.9 (28.27)	93.2 (14.64)	461.2 (84.43)
	ISR-2000	49.3 (22.08)	84.0 (5.21)	90.2 (12.21)	412.4 (129.40)
Efsane	Control	56.8 (17.57)	63.6 (11.08)	76.7 (15.45)	245.1 (80.50)
	Messenger	68.4 (19.76)	66.0 (18.14)	71.8 (7.33)	388.5 (218.54)
	Crop-set	73.5 (22.08)	76.8 (18.05)	90.3 (16.26)	290.8 (99.27)
	ISR-2000	44.5 (6.18)	64.4 (20.84)	96.0 (8.71)	293.5 (121.27)
Özayşe	Control	106.5 (58.73)	181.6 (97.54)	209.2 (40.35)	341.3 (109.08)
	Messenger	229.4 (24.77)	249.4 (64.40)	388.6 (200.74)	363.8 (114.42)
	Crop-set	213.2 (30.03)	165.1 (51.97)	404.7 (198.15)	402.9 (189.50)
	ISR-2000	111.4 (54.31)	198.4 (57.68)	419.4 (159.43)	481.5 (270.71)

Table 5. The effects of different phytostimulator and irrigation levels on yield (t ha^{-1}) in three common bean cultivars

Cultivars	Phytostimulator	Irrigation levels			
		I_{25}	I_{50}	I_{75}	I_{100}
Asya	Control	0.44 (0.03)	0.75 (0.14)	1.11 (0.08)	0.72 (0.12)
	Messenger	0.90 (0.06)	1.05 (0.10)	1.88 (0.06)	2.50 (0.12)
	Crop-Set	0.46 (0.05)	0.93 (0.09)	1.92 (0.07)	1.70 (0.07)
	ISR-2000	0.65 (0.06)	0.90 (0.15)	1.24 (0.03)	1.20 (0.23)
Efsane	Control	0.52 (0.62)	0.68 (0.06)	1.20 (0.10)	1.00 (0.05)
	Messenger	0.88 (0.16)	1.24 (0.08)	1.88 (0.15)	1.71 (0.30)
	Crop-Set	0.75 (0.10)	0.88 (0.16)	1.46 (0.05)	1.03 (0.11)
	ISR-2000	0.85 (0.07)	1.07 (0.19)	1.65 (0.27)	1.47 (0.11)
Özayşe	Control	1.14 (0.06)	2.02 (0.07)	2.14 (0.72)	1.37 (0.12)
	Messenger	1.63 (0.19)	2.34 (0.29)	2.79 (0.48)	2.05 (0.81)
	Crop-Set	2.26 (0.41)	2.56 (0.12)	3.01 (0.83)	2.98 (0.36)
	ISR-2000	2.43 (0.83)	2.52 (0.60)	2.61 (0.66)	3.40 (0.24)

The effect of the irrigation regime and phytostimulator application on pod weight is given in Figure 5. When the pod weight was compared with regard to the irrigation regime, the highest pod weight values of Efsane cultivar (6.61 g pod^{-1}) and Asya cultivar (3.80 g pod^{-1}) were obtained from the I_{75} irrigation level with the Messenger application. In the Özayşe cultivar, the highest pod weight (8.28 g pod^{-1}) was derived from the plots applied the I_{100} irrigation regime with the Crop-Set application. When only the effects of phytostimulants were examined, it was seen that the application of Messenger in Efsane (4.5 g pod^{-1}) and Asya cultivars (2.92 g pod^{-1}) and Crop-Set application in Özayşe cv (6.03 g pod^{-1}) were prominent. In addition, the effect of irrigation regimens on pod weight was highest in the different varieties as follows: Efsane I_{75} (4.61 g), Asya I_{100} (3.18 g) and Özayşe I_{100} (5.72 g). The triple interaction results obviously demonstrate the effectiveness of phytostimulator applications under water constraint conditions.

DISCUSSION

Phytostimulator, one of these new approaches, produced from natural materials have started to attract attention in the last 25 years [Yakhin et al. 2017]. Phytostimulators have been applied not only in common beans but also in other crops to improve the morphological and physiological development, while at the same time encouraging tolerance to stress conditions. *Raphanus sativus* L. [Basha and El-Aila 2015], *Cucumis sativus* L. [Boehme et al. 2006], *Lycopersicon esculentum* Mill. [Gajc-Wolska et al. 2010], sweet cherry [Świerczyński et al. 2019] and *Brassica oleracea* L. [Posmyk et al. 2009] are some plant species to which phytostimulators have been applied and positive results obtained.

Boutraa and Sanders [2001] and Sezen et al. [2008] reported that beans are very sensitive to drought stress and water stress has a negative effect on yield and quality during vegetative and flowering periods. Common beans are sensitive to drought as well as excessive watering. The highest efficiency is obtained from 300 to 600 mm water in common beans. The water requirement of the plant reaches its highest level after flowering. The most critical period from the standpoint of water deficiency in common bean cultivation is the period between flowering and grain filling. Water stress causes a decrease in the photochemical activity of common beans [Magalhaes et al. 2017]. Water requirements vary according to varieties. Sezen et al. [2008] reported water use of beans ranging from 276 to 472 mm; El-Noemani et al. [2010] recommended applying 371 mm for maximum yield in open field conditions; Bozkurt and Mansuroglu [2018] reported that the seasonal evapotranspiration changed from 270 to 566 mm in unheated greenhouse conditions. Magalhaes et al. [2017] obtained the highest pod and grain yield from plots with 614.5 mm of irrigation, while Şehirali et al. [2005] reported that they obtained the best results at 596 mm irrigation water quantities and 20% of water deficiency could be applied. As all of these results show, water restriction applications differ depending on genotype and similar results were obtained in this study. In this study, the highest yield values of the control groups of all varieties were obtained at the I_{75} irrigation level and it was determined that the I_{100} irrigation level affected the yield negatively. Additionally, the efficacy of phytostimulators was clearly demonstrated, with their efficacy varying according to cultivar. Considering the statistical results of yield values only, Messenger and ISR-2000 applications are prominent. Additionally, all phytostimulators provided higher yields than the control group in water deficit conditions. Jiang et al. [2006] and Torabian et al. [2018] reported that stomatal conductance is one of the key dynamics affecting the photosynthesis of plants influenced by water stress. When control parcels and phytostimulator applied parcels were compared, the most positive result of stomal conductivity reduction was obtained from ISR-2000 with 23.5%. Application of low irrigation water resulted in lower stomatal conductance and compared to other cultivars, the Özayşe cultivar could do more transpiration under water stress conditions in this study, possibly due to its root length.

The most basic approach in the management of irrigation water is that excessive water is not used when the water supply is sufficient and in cases where the water supply is insufficient, the highest yield is obtained with the existing water [Köksal et al. 2010]. Non-synthetic chemical applications such as phytostimulators optimise water usage, increase plant growth and yield, and prevent environmental

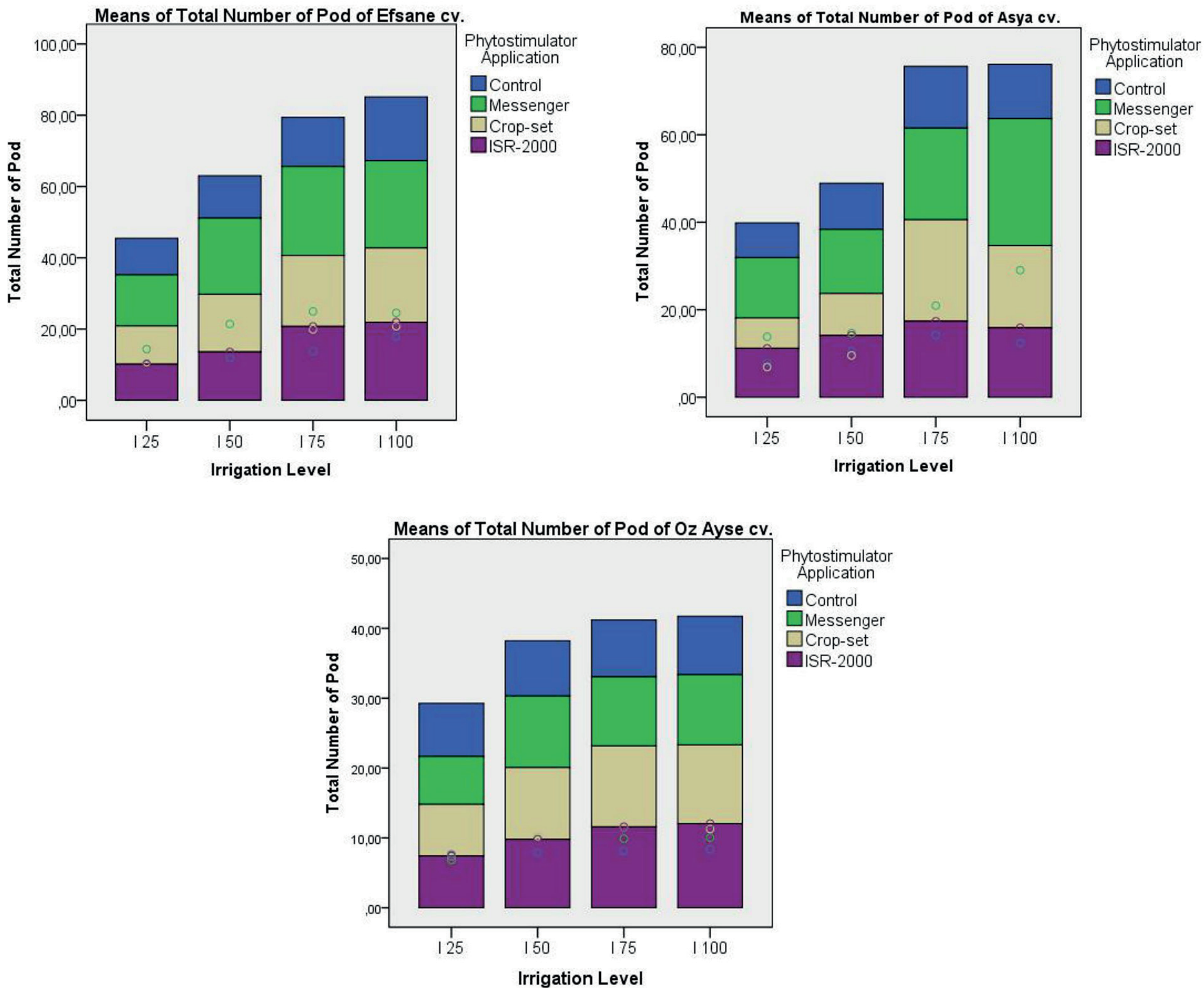


Fig. 4. Effect of drought stress and phytostimulator applications on total number of pods according to cultivars

damage caused by synthetic chemicals. Studies on the development of vegetative organs of common bean plants exposed to drought stress have shown decreases compared to controls [Kaya and Daşgan 2013]. Ramirez-Vallejo and Kelly [1998] reported that stem diameter can be used to determine the tolerance of drought in common beans due to easy measurement, being non-destructive and highly heritable. According to stem diameter results, the Efsane cultivar stands out in terms of drought tolerance. In addition, the highest stem diameter value (6.06 mm) was obtained from the I_{75} irrigation regime. Although they are in different statistical groups, the fact that ISR-2000 (5.61 mm) and Messenger (5.55 mm) applications give very close results to the control group (5.84 mm) shows that these applications have a positive effect. However, in the overall evaluation based on statistical analysis, the Messenger treatment was put forward in terms of shoot length and root length (which are extremely important for drought stress) and supporting root development. Increasing the root length and development is one of the most important mechanisms to improve drought tolerance through maximum utilisation of the limited amounts of water in the soil. Montero-Tavera et al. [2008] expressed that the root vasculature system of the tolerant vari-

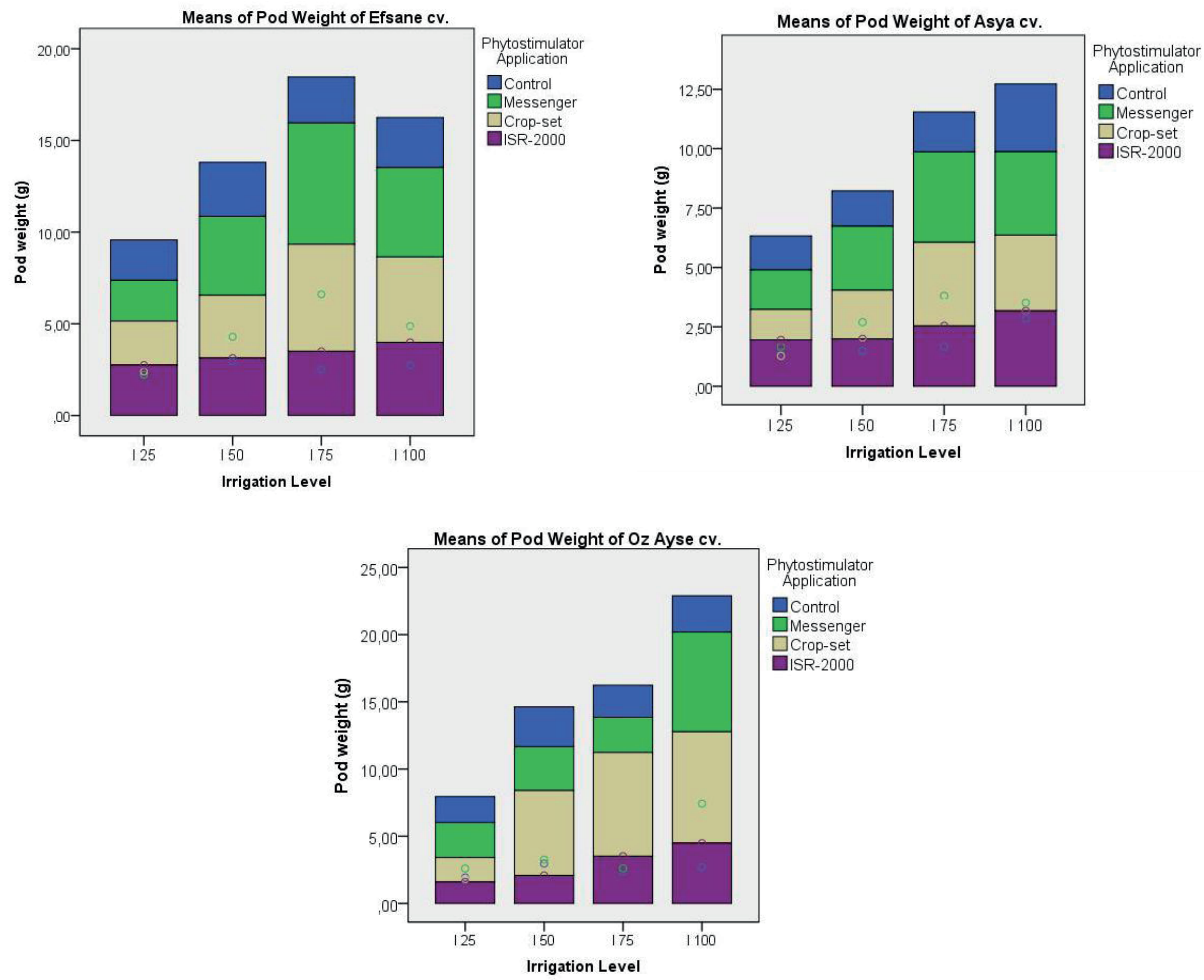


Fig. 5. Effects of drought stress and phytostimulator applications on pod weight according to cultivars

ety is better developed. The root and shoot lengths in the I_{100} (shoot 132.58 cm; root 25.5 cm) and I_{75} (shoot 139.97 cm; root 23.5 cm) irrigation regimes were in the same statistical group and gave the best results. However, it is seen in Figure 2 that the Messenger application (shoot 130.61 cm; root: 27.49 cm) gives the best results as the phytostimulator. On the other hand, the best treatment to promote leaf development in drought stress was the ISR-2000 (leaf width 10.11 cm; leaf length 14.43 cm). Plants reduce the transpiration area to minimise water wastage in stress conditions by reducing leaf surface area. Cell division is affected negatively, leaves become smaller and thus, decrease photosynthesis products [Ashraf and Iram 2005, Gholamin and Khayatnezhad 2011]. In this study, it is seen that the decrease in irrigation water causes a decrease of leaf development, and the negative effect is aggravated in parallel with the increase in water deficiency (Fig. 2). However, phytostimulator applications have reversed this negative effect and all phytostimulators have positive effects on leaf development. The constructive effect of ISR-2000 on the leaf area indicates that this application has a positive effect on the struggle against stress. ISR-2000 application has been determined as a prominent application in terms of leaf development.

Boutraa and Sanders [2001] showed that water deficiency in common beans adversely affects plant growth in accordance with the results of this study. However, in contrast to other studies, the effect of drought or phytostimulators on plant weight was not found in this study. The obtained plant weight values show decreases with increasing irrigation deficiencies. There are also differences compared to the applied phytostimulators but these values were not statistically significant (Fig. 2). There are different studies on the effect of different phytostimulators on yield and vegetative growth criteria in common beans. The use of amino acid-containing phytostimulators in common beans has been reported to have a positive effect on the number of seeds, the protein content of the seeds and the mass [Kocira et al. 2018b]. In a study using Thiometoxam as a bioactivator, it was observed that physiological performance of common beans in drought stress conditions increased [da Silva et al. 2014]. In another study investigating the effect of a phytostimulator called 'Asahi SL' on common beans, it was found that Asahi SL had an advantageous effect on common bean yield, increased the number of seeds, seed weight and number of pods [Kocira et al. 2015a]. Pod properties of common beans are associated with yield [Lima et al. 2012, Rivera et al. 2013]. The best pod development was obtained from the I_{100} irrigation regime. When the phytostimulator applications were examined, it was determined that Messenger had the best results in all pod properties. It is thought that this situation may be related to the encouragement of root development as shown in Figure 2. Regarding the plant development properties of cultivars, Efsane cultivar has shown the best pod development. However, as the results of the statistical analysis showed no interaction between the cultivar and the irrigation regime, it was determined that the triple interaction of the cultivar, phytostimulator and irrigation regime was significant at the 0.05 level. The differences between the number of pods and pod weight are due to harvest time. The increase in the number of pods towards the end of the harvest time but the decrease of the pod length caused differences in their weights. Accordingly, it was concluded that the impact of phytostimulators on pod development is very important. Pod thickness, shoot length, pod length, pod width, root length and stem diameter properties were not statistically different between the I_{100} and I_{75} irrigation. In this case, it is thought that water deficits can be applied in common beans by implementing the I_{75} rather than the I_{100} irrigation. All phytostimulators are effective by activating Systemic Acquired Resistance mechanism in plants. In this context, these preparations play a role in the activation of different defence genes, leading to the production of certain plant hormones such as salicylic acid, jasmonic acid and changes in their levels [Reddy 2012]. According to the applied phytostimulators, it is concluded that different genes are activated depending on the genotype and therefore the effects of phytostimulators differ between genotypes. As a result, the highest yield values were obtained from Messenger in Efsane and Asya cultivars, on the other hand, the best yield was recorded in Öz Ayşe cultivar from ISR-2000 application.

CONCLUSION

This study showed that exogenous phytostimulator applications can increase the yield of common beans. The pod properties, which play an important role in the quality and yield of beans, have been significantly affected by the water constraint. The phytostimulant applications have been successful in reversing this negative effect. The results showed that the application containing harpin protein in the cultivars with dwarf and semi-dwarf growth habit, and ISR-2000 application in the cultivar with climbing growth habit is more effective in drought conditions. This has been associated with the genetic structure of plants and the different defense genes activated by phytostimulators. In addition, it is determined that I_{75} irrigation is sufficient in bean cultivation, and effective use of water can be achieved by application of phytostimulators at this level.

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