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Derinkuyu dry bean irrigation planning in semi-arid climate by utilising crop water stress index values

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Abstract: This study was conducted to determine crop water stress index (*CWSI*) values and irrigation timing in the case of Derinkuyu dry bean (*Phaseolus vulgaris* L.). In 2017, dry beans were grown as the main crop according to the field design consisting of plots divided into randomised blocks. Irrigation treatment comprised full irrigation (I100) and irrigation issues with three different levels of water stress (I66, I33, I0). This study applied 602 mm of water under the I100 irrigation. The yield of Derinkuyu dry beans was equal to 3576.6 kg·ha^{-1} in I100 irrigation. The lower limit (LL) value, which is not necessary for the determination of *CWSI*, was obtained as the canopy–air temperature difference ($Tc - Ta$) versus the air vapour pressure deficit (*VPD*). The upper limit (UL) value, at which the dry beans were wholly exposed to water stress, was obtained at a constant temperature. The threshold *CWSI* value at which the grain yield of dry beans started to decrease was determined as 0.33 from the measurements made with an infrared thermometer before irrigation in I66 irrigation treatment. As a result, it can be suggested that irrigation should be applied when the *CWSI* value is 0.33 in dry beans. Furthermore, the correlation analysis revealed a negative correlation between grain yield and crop water stress index and a positive correlation between yield and chlorophyll content. According to variance analysis, significant relationships were found between the analysed parameters at $p \leq 0.01$ and $p \leq 0.05$.

Keywords: dry bean, crop water stress index (*CWSI*), irrigation time, plant water stress index, Turkey

INTRODUCTION

The optimisation of surface and groundwater management has become a priority in the face of extreme events occurring with increasing frequency, particularly droughts. According to scientists, including Sümbül and Sönmez (2021), the largely human-induced increase in air temperature can warm the atmosphere and oceans, alter the global water cycle, reduce snow and glaciers, increase sea surface, reduce precipitation and increase the frequency and severity of natural disasters, such as droughts, floods, and hurricanes. Over the 2010–2019 period, in central European countries, droughts were twice as frequent as in previous decades. In the last decade, the frequency of droughts was once every 2.5 years and previously once every five years. Projections of adverse climate change, particularly an increase in air temperature by the end of the 21st century (IPCC, 2014), encourage various measures to increase the efficiency and rational use of water resources in the industrial and agricultural sectors. According to Bah and Acar (2017), agriculture is more affected by climate change than other sectors as it depends on nature and natural conditions. Studies to date show that some agricultural regions are increasingly exposed to drought (Rolbiecki *et al.*, 2022). Furthermore, according to Clark (2007), adverse climate change projections may make it difficult for certain crop species in some areas of Europe to respond to such changes by migrating or developing adaptive mechanisms. Moreover, such problems may limit species distribution or even cause their extinction. As Bakkenes, Eickhout and Alkemade (2006) report, the progressive adverse conditions of global climate change could completely disappear between 15 and 37% of crop species by 2050.

In countries with arid or semi-arid climates, such as Turkey, crops are dominated by legume species with lower water requirements, such as dry beans and chickpeas. In their research, Yavaş and Ünay (2018) stated that temperature stress is one of the most important determinants of legume growth. Therefore, in the face of unfavourable climatic forecasts, several studies were carried out, especially in regions with low rainfall totals, on the efficient use of water for crop irrigation, designed to select an optimal irrigation system. The optimal choice of irrigation system and irrigation rates should be based on analysis that takes into account climatic conditions, water demand from the crop or other similar indicators, such as *CWSI* (Alderfasi and Nielsen, 2001; Colaizzi *et al.*, 2003; Rolbiecki *et al.*, 2023; Ucar *et al.*, 2023).

The *CWSI* index obtained from the canopy–air temperature difference ($Tc - Ta$) versus the air vapour pressure deficit (*VPD*), i.e. $Tc - Ta = 3.07 - 2.82\ VPD$, developed by Jackson *et al.* (1981), is a promising tool for quantifying crop water stress. As reported by Yuan *et al.* (2004), the *CWSI* calculation based on definition by Idso, Jackson and Pinter (1982) is based on the assumption of two baselines: a baseline without water stress (lower limit), which represents a fully irrigated crop, and a maximum so-called stressed baseline (upper limit), which corresponds to a crop without sprinkler irrigation (stomata fully closed). Several detailed studies have been conducted in many regions on determining the *CWSI* for different crops and locations. In these studies, authors highlighted the direct correlation of yields with average index values. This can be extremely useful in the context of planning effective irrigation timing (Gençoğlan and Yazar, 1999; Irmak, Haman and Bastug, 2000; Alderfasi and Nielsen, 2001; Orta, Erdem and Erdem, 2002; Colaizzi *et al.*, 2003). However, according to Erdem *et al.* (2006), plant response to water stress depends on the climate and varies from one specific crop to another. Therefore, critical *CWSI* values should be determined for a specific crop considering the characteristics of climatic and soil conditions.

According to Sharma and Rai (2022), it is essential to take steps to develop an effective irrigation strategy for a specific crop. This strategy must consider the quantitative crop water requirements and the amount of water deficit the crop can withstand before a significant reduction in yield occurs. A study by Yonts *et al.* (2018) in western Nebraska found that a 25% reduction in irrigation compared to full irrigation for a dry bean crop increased irrigation water use efficiency by 26% and decreased seed yield by only 6%. Therefore, detailed studies on the plants response to irrigation levels and the relationship between different crop ecophysiological and morphological parameters are still needed. According to Rai, Sharma and Heitholt (2020), this type of analysis can help identify and select a sustainable irrigation management strategy to achieve maximum yield and efficient water use.

This research was carried out to measure canopy temperature values of main (1^{st} crop) dry beans grown under semi-arid climate conditions at different irrigation levels (I0, I33, I66, I100) with a Testo type infrared thermometer and to determine the *CWSI* by using these temperature values and to plan the irrigation time by using this index value and to determine the correlation between grain yield of dry beans and the *CWSI*.

STUDY MATERIALS AND METHODS

PLANT MATERIAL AND METHODS USED

- **Site description and experiment design**

The study was conducted at the Siirt University, Faculty of Agriculture (Turkey) field during the growing season of the first crop of Derinkuyu dry bean in 2017. The study was conducted according to a randomised block design with three replications. The length of the plot was 6 m. The row spacing was 45 cm, and the distance above the row was 15 cm. Moreover, the thinning process was carried out when the plants reached a 10–15 cm height. Each plot was planted with four rows of beans, and the plot size was 6 m × 1.8 m. Thus, the area of the plot was 10.8 m^2. Before planting, the experimental area was deeply ploughed in the spring (April 19, 2017) with a plough and a crowbar to prepare the seed bed for planting.

- **Fertigation practice**

Pure nitrogen, phosphorus (P_2O_5) and potassium (K_2O) were applied at 40 $kg \cdot ha^{-1}$. Planting was slightly delayed. It was caused by the delay in the maturation of soil due to the rainfall in that year (2017) (Arslan and Gür, 2018). As a base fertiliser before planting, 15–15–15 kg nitrogen-phosphorus and potassium compounds were applied at 400 $kg \cdot ha^{-1}$. For plant height, urea fertiliser with an average nitrogen content of 46% was used with 100–150 $kg \cdot ha^{-1}$ with the second irrigation. In order to increase the productivity and durability of dry beans during the grain formation period, top fertilisation was made with calcium nitrate fertilisers at 50–60 $kg \cdot ha^{-1}$.

- **Maintenance**

In addition, maintenance, agricultural control, weed control and other cultural operations were carried out on time. Harvested area in the middle two rows (yield obtained from plot area was converted to decare) was considered during yield calculations.

- **Yield components measurements and irrigation practices**

At harvest, the yield was evaluated by taking one row from the edges of the plot (first and fourth rows) and 50 cm from the beginning and end of the plot (the remaining 5 m) and the seed yield of the plot was determined by taking the middle two rows (Arslan, Hatipoğlu and Karakus, 2014). Harvesting was done on 17 September 2017 (the first year). Thinning, hoeing and throat filling were carried out 15 cm above the row for weed control when the plants had 3–4 leaves.

In this experiment, irrigation was provided by a drip irrigation method according to the weekly (every seven days) irrigation programme. The quantity of irrigation water applied each time was brought to the field capacity (timely and sufficient amount). Moreover, seed yield, *CWSI*, chlorophyll content (*CC*), yield or water use efficiency (*WUE*), and plant water consumption (*ET*) were calculated. This study used Derinkuyu dry beans from the Nevsehir region as plant material. The different irrigation levels in this experiment consisted of full irrigation, where 100% of water consumed in a 90 cm soil profile every seven days (I100, control treatment) was applied and restricted irrigation treatments, where 66% (I66), 33% (I33) and 0% (I0) of no irrigation was applied. Thus, a total of four irrigation treatments were formed; one full (I100) and three restricted irrigation treatments (I66, I33, I0). The irrigation schemes were applied with the drip irrigation method. In 2017, seven irrigation treatments were applied, and the gravimetric method was used to monitor soil water content change. The seven irrigation treatments can be related to the high evapotranspiration in the region during July and August. Climatic data are given in Table 1. During the summer season, the field area is mostly under the impact of dry and hot tropical air masses situated in the Basra low-pressure centre. In July and August, the temperature is quite high throughout the day. In winter, the research area is affected by fronts coming from the Central Mediterranean. The frontal activities cause precipitation that continues until April (Atalay and Mortan, 2008). The average temperature in the study area is 26°C in summer and 2.7°C in winter. The highest average relative humidity is 70.2% and the lowest average is 26.9%. The average annual relative humidity in the study area is 50.41% and the average annual precipitation is 669.2 mm. The lowest precipitation's value is observed in August (1.3 mm), and the highest is in April (103.6 mm). In this study, water holding capacities of soil at field capacity, wilting point and volume weight were determined according to Blake and Hartge (1986).

Immediately after sowing, 66 mm of water was given to all treatments to ensure a homogeneous emergence. When 50% of the moisture in the soil profile was consumed until the plants had six leaves, all treatments were irrigated to bring them to the field capacity. Irrigation was done once a week during the production period. Before irrigation, the gravimetric method helped to determine soil moisture content at 90 cm depth. Accordingly, the amount of irrigation water that would bring the missing moisture at 90 cm soil depth to the field capacity was used for full irrigation (I100). According to the results, moisture content (%) was converted to moisture content at depth using Equation (1).

$$d = \frac{Pw \cdot As \cdot D}{10} \tag{1}$$

where: d = water content of soil (mm), Pw = moisture content (%), As = volume weight of soil (g·cm^{-3}), D = depth of soil (cm).

Each layer's water depth was calculated to obtain the total water content (d_T) for the 90 cm soil profile (Eq. 2).

$$d_T = d_{(0-30)} + d_{(30-60)} + d_{(60-90)} \tag{2}$$

where: $d_{(0-30)}$, $d_{(30-60)}$, and $d_{(60-90)}$ = water content of soil (mm) in soil layers of 0–30, 30–60, and 60–90 cm, respectively.

The volume of water to be supplied to the plots was calculated from Equation (3) by multiplying the total amount of water, curtailment percentage and plot area (1, 0.70, 0.35) by the percentage of cover.

$$V = d_T \cdot A \cdot Uo \cdot P \tag{3}$$

where: V = volume of water to be supplied to the plots (dm^3), A = area (m^2), Uo = curtailment percentage, P = cover percentage.

In the drip irrigation system in this study, the lateral lines were 16 mm outer diameter, and the drippers in the system were transitional and flow rate fixed. Therefore, one lateral was laid in each row (140 cm). The calculated amount of irrigation water to be given to the parcels was passed through meters.

Table 1. Climate characteristics of the study area

Year	Month	Temperature (°C)			Average humidity (%)	Average wind speed (m·s^{-1})	Average time of sunny hours per day (h)	Total precipitation (mm)
		maximum	average	minimum				
Average 1990–2016	May	35.3	19.4	9.0	49.3	1.0	9.1	36.9
	June	35.3	26.0	17.8	34.9	1.1	11.6	11.5
	July	39.1	30.5	23.4	30.3	1.1	12.3	0.6
	August	39.0	30.3	27.0	29.5	1.0	11.4	2.7
	September	38.3	25.1	14.7	37.4	1.0	10.1	7.0
	October	24.5	17.9	12.7	42.0	1.0	7.2	50.9
2017	May	34.8	19.29	14.52	50.87	1.0	8.7	39.6
	June	39.5	28.16	20.0	35.50	1.1	11.5	10.6
	July	42.2	31.45	24.35	32.69	1.0	12.4	0.1
	August	41.3	31.19	24.23	32.95	1.0	11.3	0.4
	September	41.3	25.43	21.5	39.90	1.1	10.0	9.2
	October	34.9	16.8	11.5	42.3	1.1	7.0	55.1

Source: own elaboration.

The water balance equation given in Equation (4) was used to calculate the plant water consumption (Zeleke and Wade, 2012).

$$ET = P + I - Rf - Dp \pm \Delta S \tag{4}$$

where: ET = evapotranspiration (mm), P = precipitation (mm), I = irrigation water (mm), Rf = surface runoff (mm), Dp = deep infiltration (mm), $\pm\Delta S$ = soil moisture change in the root zone or storage difference between the beginning and end of the period (mm).

Since the flow rate of the drippers was lower than the soil infiltration rate, no runoff occurred. Since irrigation water was applied each time to bring soil moisture to field capacity, no deep infiltration was assumed. Some parameters (P, Rf and Dp) were assumed to be zero since they did not occur.

• **Soil and water properties**

Some chemical and physical properties of the experimental soil are given in Table 2. According to the results of the soil samples analysis before the establishment of the field trials, it was determined that the soil types under the study included clay-textured, salt-free, slightly alkaline, moderately calcareous and had a sufficient level of available K content. Moreover, it was determined that the organic matter content of the soil was low, and also the available P content was low (Özyazıcı and Açıkbaş, 2019).

Table 2. Characteristics of soils of the study area

Feature	Value/feature in soil depth (cm)		
	0–30	30–60	60–90
Clay (%)	62.00	58.00	55.00
Silt (%)	20.00	25.00	32.00
Sand (%)	18.00	17.00	13.00
Texture	clay	clay	clay
Field capacity (Pw)	33.52	36.04	35.38
Wilting point (Pwp)	24.44	26.08	25.57
Volume weight ($g \cdot cm^{-3}$)	1.42	1.39	1.41
pH (1.25 sw^{-1})	7.50	7.66	7.91
Electrical conductivity ($dS \cdot m^{-1}$)	1.55	1.77	1.75
Organic matter (%)	3.09	2.06	1.80
$CaCO_3$ (%)	6.40	1.90	1.90
Available P (kg $P_2O_5 \cdot ha^{-1}$)	23	43	43
Available K (kg $K_2O \cdot ha^{-1}$)	1630	1150	1150

Source: own elaboration based on data of analyses conducted at Siirt University, Science and Technology Application and Research Center Laboratory.

When the soil properties are examined, it is stated that the electrical conductivity is low, there is no problem in terms of lime content, there is no salinity problem, and it has a clay soil structure. In the irrigation water analysis, the specified methods determined electrical conductivity, pH values, anions and cations. The irrigation water quality class was determined to be C_2S_1 as a result of the analysis. In addition, the electrical conductivity of the water was determined at 0.34 $dS \cdot m^{-1}$ and pH at 7.20. Therefore, irrigation water does not pose a problem for irrigation of bean plants.

OBSERVATIONS AND MEASUREMENTS IN THE STUDY

In this study, water use efficiency was specified, through Equation (5) (acc. to Howell *et al.*, 1995). Also, the empirical method was used to determine the *CWSI* (Idso, Jackson and Pinter, 1982) – see Equation (6).

$$WUE = Y / ET \tag{5}$$

where: WUE = total water use efficiency ($kg \cdot ha^{-1} \cdot mm^{-1}$); Y = yields of genotypes obtained under irrigation treatments ($kg \cdot ha^{-1}$),

$$CWSI = [(Tc - Ta) - LL] / UL - LL \tag{6}$$

where: $CWSI$ = plant water stress index, Tc = crown temperature (°C), Ta = air temperature (°C), LL = lower limit of no water stress (where plants transpire at the potential rate), UL = upper limit of complete plant stress (where plants are assumed not to transpire).

Moreover, a SPAD device was used to measure chlorophyll in the leaf.

DATA EVALUATION

The analysis of variance helped to evaluate the findings. According to the analysis, statistically significant treatments were compared by applying the least significant difference (*LSD*) test. Correlation analysis was also applied to determine the relationship between the treatments. In addition, the relationship significance level and positive or negative aspects were determined, and it was evaluated each year (Der and Everitt, 2002).

RESULTS AND DISCUSSION

In the study, yield and some other parameters of Derinkuyu dry beans were analysed according to different irrigation treatments. Table 3 shows the changes in yield and other dry bean characteristics depending on the irrigation water amount. As can be seen in Table 3, according to the analysis of variance, the irrigation treatment was found to be statistically significant ($p \leq 0.01$). The highest yield (3576.6 $kg \cdot ha^{-1}$) was obtained from the I100 irrigation treatment, while the lowest yield (572.0 $kg \cdot ha^{-1}$) was obtained from the I0 irrigation treatment. These results are in line with previously published findings by researchers. They determined that water restriction decreased the yield levels of dry beans at varying rates for severe and moderate stress levels applied above the recommended water application, and these decreases were statistically significant and insignificant, respectively (Allen *et al.*, 1998; Bourgault *et al.*, 2013; Yonts *et al.*, 2018). Moreover, in this study, different levels of irrigation applications caused the irrigation treatments to be in different groups statistically in terms of yield. While the I100 irrigation treatment was in group a, the I0 irrigation treatment was in group c. The other irrigation treatments

Table 3. Yield and other analysed parameters of dry bean concerning the amount of irrigation water

Treatment	Yield** ($kg·ha^{-1}$)	*CWSI***	*CC***	Irrigation	*ET*	*IWUE**	*WUE**
				mm		($kg·ha^{-1}·mm^{-1}$)	
I_{100}	3576.6 a	0.25 d	39.93 a	602.00	658.00	5.9 b	5.4 ab
I_{66}	3218.0 a	0.32 c	36.05 b	428.00	489.50	7.5 ab	6.5 a
I_{33}	1365.3 b	0.54 b	33.29 c	224.70	238.68	6.6 b	5.8 a
I_0	572.0 c	0.59 a	32.49 c	66.00	121.00	8.6 a	4.3 b
CV (5%)	12.58	6.51	3.00			11.48	12.80
LSD (0.05)	54.72	0.056	2.12			0.16	0.14

Explanations: ** significant at 0.01 level, * significant at 0.05 level, *CWSI* = plant water stress index, *CC* = chlorophyll content, *ET* = plant water consumption, *IWUE* = irrigation water use efficiency, *WUE* = water use efficiency, *CV* = coefficient of variation, *LSD* = least significant difference test; the values with different letters are significantly different.
Source: own study.

were between these two groups. It was determined that the I100 irrigation treatment achieved the highest efficiency when compared to other irrigation (Tab. 3). It has been reported that irrigation levels or curtailed irrigation practices significantly affect yield in dry bean cultivation (Köksal, Üstün and İlbeyi, 2010; Sözen *et al.*, 2019). Furthermore, it has so far been found that the flowering period is the most sensitive to water deficit, resulting in significant yield reductions (Uçak *et al.*, 2022). In addition, Köksal, Üstün and İlbeyi (2010) reported that water stress application significantly decreased yield, plant height, seed number, leaf area index and leaf relative water content. These results are consistent with the results obtained by some researchers (Köksal, Üstün and İlbeyi, 2010; Çolak *et al.*, 2015).

Moreover, research to date has shown that short-term water stress can cause important losses in yield (Aksu, 2016). Additionally, it was reported that moisture deficiency might negatively affect the plant yield (Çolak *et al.*, 2015). There are similarities between the findings obtained by the researchers mentioned above (Köksal *et al.*, 2010; Çolak *et al.*, 2015; Uçak and Arslan, 2023) and the results in this study. However, partial differences can be attributed to many external environmental factors (climate) affecting yield from sowing to harvest, irrigation program applied, yield potential of the genotype used in the study, cultural treatments applied, biotic or abiotic stress factors of the genotype (Uçak *et al.*, 2020). The results of the analysis of variance on the data obtained in the study showed that irrigation was statistically significant ($p \leq 0.01$). A previous study determined that plants' yield values decreased under restricted irrigation practices (Uçak *et al.*, 2022). In another study, it was found that fatty acids protect the cell membrane according to environmental conditions, provide membrane flow and are effective in the survival and adaptation of the plant against some stress conditions (Aslantaş, Karakurt and Karakurt, 2010). In the analysis of variance, irrigation was found to be statistically important for *CWSI* ($p \leq 0.01$). According to the first year results, the highest crop water stress index was obtained from the irrigation treatment I0 (0.59), while the lowest value was from the full irrigation treatment (I100) – 0.25. The I0 irrigation treatment was in group a, and the I100 irrigation treatment was in group d. It was determined that the highest plant water stress index (0.59) was obtained from the I0 irrigation treatment, and the lowest plant water stress index (0.25) was obtained from the I100 irrigation treatment. Statistically, the I100 irrigation case was in group d, and the I33 irrigation treatment was in group b. The other irrigation treatments were located between these two groups at varying rates. The lower and upper limit relationships for the basic graph to be used in determining *CWSI* in bean plants in the experiment are given in Figure 1. The change of *CWSI* values according to time in the research year can be seen in Figure 2.

The highest chlorophyll content value was obtained from the full irrigation treatment (I100) – 39.93, while the lowest value was from the restricted irrigation treatment (I0) – 32.49. Irrigation treatment I100 was in group a, while irrigation treatment I0 was in group c. The other irrigation treatments were between these two groups at varying rates. Rai, Sharma and Heitholt (2020) determined the effects of five different irrigation treatments on chlorophyll values in dry beans. Their study found that the highest chlorophyll values were in full irrigation and 25% water restriction treatments. It can be said that these results are in line with those obtained in this study. The highest *IWUE* value was obtained from no irrigation treatment (I0) – 8.6 $kg·ha^{-1}·mm^{-1}$, while the lowest value was obtained from full irrigation treatment (I100) – 5.9 $kg·ha^{-1}·mm^{-1}$. Irrigation treatment I100

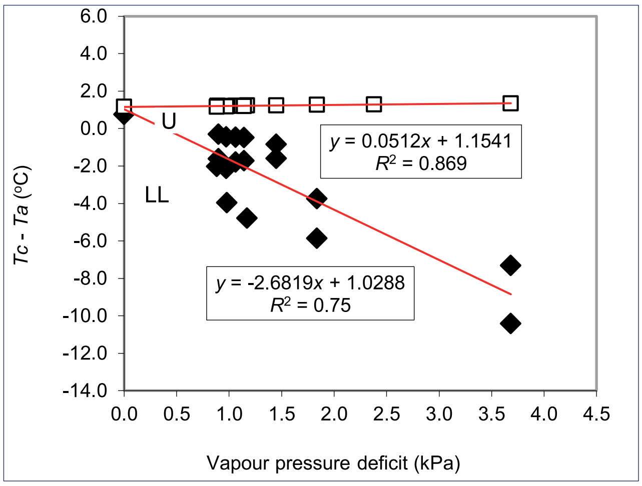

Fig. 1. Lower (LL) and upper bound (UL) relations for the basic graph to be used for determining of crop water stress index (*CWSI*); *Tc* = canopy temperature, *Ta* = air temperature; source: own study

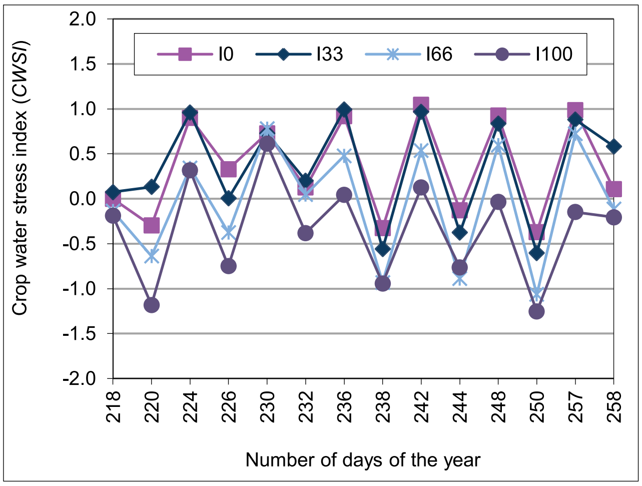

Fig. 2. Changes of crop water stress index values according to time; source: own study

was in group b, while irrigation treatment I0 was in group a. The other irrigation treatments were located between these two groups at varying rates. As reported by many researchers, *IWUE* yield increased as the amount of irrigation water to be applied decreased (Kırnak and Gençoğlan, 2001). Moreover, the highest *WUE* value was obtained from the irrigation treatment (I66) – 6.5 $kg \cdot ha^{-1} \cdot mm^{-1}$, while the lowest was obtained from the irrigation treatment (I0) – 4.3 $kg \cdot ha^{-1} \cdot mm^{-1}$. While the I0 irrigation treatment was in group b, the I66 irrigation treatment was in group a. The other irrigation treatments were between these two groups at varying rates. Moreover, it has been reported that the *WUE* value will decrease as the applied irrigation water decreases (Kırnak and Gençoğlan, 2001).

CONCLUSIONS

The research was conducted under semi-arid climate conditions to assess the quantity of irrigation water applied and plant water consumption values. The findings and statistical analysis results (*LSD* groups) are presented in this manuscript. For research years, it was determined that the average amount of irrigation water varied between 69 and 79 mm according to the irrigation treatments applied every seven days. Moreover, the irrigation water requirement ranged between 5.0 and 5.5 $mm \cdot day^{-1}$ during the early growing season, and it reached its maximum level (8.5–9.0 $mm \cdot day^{-1}$) before flowering. The determined seasonal plant water consumption (*ET*) values varied between 658 mm for irrigation treatment I100 and 238.68 mm for irrigation treatment I33. The high *ET* value in I33 is that despite the stopped irrigation, plants continue to utilise the residual moisture accumulated in the soil from winter precipitation. The water demand of the same plant (genotype) in different climates and regions may differ. It may differ even within the same region. It can be said that differences in plant diversity, soil properties, climatic factors, irrigation schedules and practices, and cultivation techniques are the main reasons. According to the results of variance analysis, the differences among irrigation treatments in terms of yield, crop water stress index (*CWSI*), chlorophyll content (*CC*) and water use efficiency (*WUE*) were found statistically significant (at $p \leq 0.01$ and $p \leq 0.05$) and were subjected to the *LSD* test (grouping). The highest yield was obtained in I100 irrigation, and the lowest was in I33 irrigation. As a result, it was determined that the time to irrigate occurred when the crop water stress index reached 0.33 in dry beans grown under semi-arid climate conditions. When irrigation is applied at the said value, there is no statistically significant loss in yield because they are in the same group statistically. This study also determined that a 33% water reduction can be made in cases when irrigation water is insufficient. Moreover, the yield decrease will start when the *CWSI* is higher than the abovementioned value.

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