



The effects of water stress on yield performance of drip-irrigated pepper (*Capsicum annum* L. cv. *Capya* var. *Yalova yağlık 28*) in the Central Anatolian region of Turkey

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Abstract

The aim of this study is to investigate the effects of conventional deficit irrigation strategy on yield components and water use efficiency in the red pepper. The field study was performed in Çumra, a town in the province of Konya in the years of 2012 and 2013. The irrigation treatments were applied as follows: (i) full irrigation regime (100% of water requirement for plant, I_{100}) and (ii) two conventional deficit irrigations regime at the rate of 80% (I_{80}) and 60% (I_{60}) of I_{100} at 5-day intervals. The irrigation water was used based on soil water content measurement through the gravimetric method where evaporation was measured by a class A pan cup simultaneously. The maximum marketable yields were obtained in the treatment of I_{100} with 22.0 and 24.0 t ha⁻¹ for the years of 2012 and 2013, respectively. The seasonal crop water requirement was calculated as 454, 591, and 726 mm for 2012 and as 498, 652, and 806 mm for 2013, respectively. The values of crop yield response factors (k_y) at I_{80} and I_{60} were found as 1.03 and 1.37 in 2012 and 0.66 and 1.54 in 2013, respectively. The highest levels of water use efficiency (WUE) and irrigation water use efficiency (IWUE) were determined for the treatment of 20% deficit during the period of study. The complete irrigation levels (FC) were calculated through 0.87 times the pan A evaporation. The results reveal that full irrigation strategy is the best choice to obtain maximum yield or net return while 20% deficit irrigation is a viable solution for water poor environments.

Keywords Crop yield response factor · Red pepper · Water deficit · Yield maximization

Introduction

The capia-type pepper is an industrial type and is typically used in the pepper paste and grilled pepper industry, which is a source of natural colors and antioxidant compounds (Govindarajan 1986; Howard et al. 2000). In regular use, the consumption of red pepper leads to a higher level in response to the conditions of embolism and thrombi, and capsaicin, among its ingredients, defends the body against cardiovascular diseases and apoplexy (Golcz et al. 2012). It is commonly cultivated in semi-arid areas where the water should be efficiently used in such an environment (Debaeke and Aboudrare 2004). Red pepper is commonly planted in the drought-prone areas in Turkey where climatic conditions are so hot and dry that water sources are scarce. Under these circumstances, the

option of deficit irrigation is likely to promote the efficient use in water resources management unless there occurs a significant reduction in crop yields. Researchers have recently reported that water stress has a key impact on plant production depending on its period and level, and its different types put up higher resistance to drought. It is noted that the most resistant types for drought should be determined based on the studies made on its type and origin in order to achieve a proper landscape planning in dry lands (Yigit et al. 2016; Cetin et al. 2018). In a study of Sevik and Cetin (2015), it is stated that -4, -6, -8 bar water stress all diminished germination of seeds as a percentage, and Cetin et al. (2018) reported that a number of micromorphological characteristics of plants vary by climate and species. Cetin (2015) and Yigit et al. (2016) highlighted that bioclimatic maps can offer key data in land use planning, recreation, urban and rural planning, ecological and economic decision-making, and tourism planning.

In the water-scarce regions, it may be more important to obtain maximum yield for unit water. Irrigation scheduling should be convenient to maximize yield and water productivity (Antony and Singandhupe 2004). English and Raja (1996),

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Kirda (2002), Dorji et al. (2005), Cicogna et al. (2005), Geerts and Raes (2009), and Talozzi and Waked (2016) showed in a study on the water-limited areas that deficit irrigation (DI) provided more income than maximum output to produce per unit area. Moreover, as it creates less humid conditions for crops compared to full irrigation, the risk of fungal and other related diseases will be lower (Cicogna et al. 2005). The gravimetric method is the most accurate technique to determine soil water content, although it is time-consuming and maybe impractical for most farmers (USDA 2005). Class A pan is widely used in irrigation programs thanks to its simplicity and economy (Eliades 1988). As it is difficult to determine the irrigation water level in agricultural conditions to raise the soil to FC or the desired deficit level based on the climate of the day, people usually apply irrigation water more than necessary. Therefore, in the case that the evaporation level for the pan A cup that is calibrated through the gravimetric method for this, this method may provide practical applications in irrigation planning and is easily in potential farming conditions, as well.

Owusu-Sekyere et al. (2010) and Sam-Amoah et al. (2013) suggested that 20% of water limitation may not lead to much decline in hot pepper yield and a considerable reduction can be observed in yield above the mentioned threshold. Demirtas and Ayas (2009) reported that irrigation water level had significant effect on yield, dry matter ratio, height, diameter, and fruit weight in Demre pepper, and then recommended K_{2cp} (75% of evaporation) treatment in the regions with water shortage. In another study of Costa and Gianquinto (2002) and Aladenola and Mardamootoo (2014), it was demonstrated that water stress significantly reduced total fresh fruit, and the highest and the lowest marketable yields occurred at the irrigation levels of 120 and 40% of ET, respectively. Dorji et al. (2005) found reductions in the weight and number of hot pepper fruits per plant through conventional deficit irrigation (CDI) and the partial root drying (PRD) in comparison of full irrigation. Sen (2015) reported that irrigation intervals had no effect on processing pepper fruit yield while irrigation regimes had a positive effect. Besides, Sezen et al. (2011) stated that deficit irrigation can create an acceptable net income by a gain of 17.6% in irrigation water and a loss of 8.9% in yield compared to full irrigation. Seasonal evapotranspiration varied from 327 to 517 mm by irrigation application. As a result of the financial efficiency analysis, Sezen et al. (2015) and Koksall et al. (2017) concluded that full irrigation strategy is the most profitable strategy for red pepper. There is similar evidence in several close studies (Jaimez et al. 2000; Delfine et al. 2001; Antony and Singandhupe 2004; Dorji et al. 2005; Gencoglan et al. 2006; Demirtas and Ayas 2009; Saleh 2010; Sezen et al. 2016; Nagaz et al. 2012).

Accordingly, the objectives of this study were established (i) to determine the effectiveness of deficit irrigation and the efficiency of water use for yield crops of red pepper under

water-limited conditions in a semi-arid region and (ii) evaluate the evaporation level in the pan A cup (K_{pc} coefficient) that is calibrated through the gravimetric method to raise the soil to FC or the desired deficit level.

Methodology

This field study was conducted in 2012 and 2013 in Çumra, a town in the province of Konya, Turkey, located around 1016 m above the sea level. The experimental soil at 60 cm in depth had several physical characteristics, such as clay texture, bulk density (1.35 g cm^{-3}), weight percentage of field capacity (FC) (35.0%), and permanent wilting point (PWP) (22.7%). Using the current data, the level of available water capacity (AWC) was calculated as 167 mm/m. The climatic parameters in Çumra are given in Table 1.

Based on the long-term climatic data (from 1970 to 2013), the experimental site was identified as a semi-arid climate in which summers are hot and dry and winters are freezing. The soil samples were analyzed in the laboratory of Konya Soil, Water and Deserting Control Research Institute, a public entity.

For the years 2012 and 2013, the relationships between the parameters of monthly relative humidity and monthly average temperature as well as soil moisture content are illustrated in Fig. 1.

Three types of irrigation treatments were used in the study by their percentage of use of water required for plants: 100% (full irrigation, I_{100} : non-stressed), 80% (I_{80}), and 60% (I_{60}). The amount of irrigation water to apply for 5 days at regular intervals was identified as the difference between the actual soil moisture content and the field capacity in the root zone. Soil moisture content was measured using the gravimetric technique. Soil water was monitored between 30 and 90 cm in depth throughout each cultivation season. The irrigation water was quantified through a flowmeter. In order to determine the evaporation level corresponding to the water amount that was calculated through the gravimetric method to bring the soil to FC level, the simultaneous measurements were made from the class A pan for evaporation considering the irrigation intervals, and K_{pc} coefficients were calculated.

During the study period, soil moisture was monitored in the I_{100} treatment. Waters were delivered to the deficit irrigation plots in accordance with the arrangement by the water amount needed for the application. The evapotranspiration (ET) level was calculated using the water balance equation suggested by James (1988):

$$ET = I + P + Cr - Dp - Rf \mp \Delta S \quad (1)$$

where ET is evapotranspiration (mm); I , the water applied to the individual plots (mm); P , the precipitation (mm); Cr , the

Table 1 The climatic parameters in Çumra (1970–2013)

Parameters	The consecutive months in a year												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Relative humidity (%)	76.0	72.1	64.0	59.2	58.2	53.2	49.2	49.9	53.2	63.8	71.6	76.4	
Temperature (°C)	0.1	1.1	5.7	11.2	15.7	20.0	23.0	22.3	17.9	12.2	6.0	1.9	
Precipitation (mm)	37.8	28.3	31.2	40.9	36.0	19.6	5.4	3.1	8.9	30.6	34.5	42.6	318.9
Wind speed (m s ⁻¹)	0.9	1.1	1.2	1.2	0.9	1.0	1.1	0.8	0.7	0.5	0.7	0.8	
Evaporation (mm)	0.0	0	0	48.4	126.2	174.0	219.7	206.2	144.2	71.5	6.4	0	99.6
Max. temperature (°C)	4.8	7.1	11.9	17.5	22.3	26.7	30.2	30.1	26.1	19.9	12.9	6.6	
Min. temperature (°C)	-3.9	-3.2	0.1	4.5	8.7	12.8	16.1	15.7	11.2	6.0	0.8	-2.3	

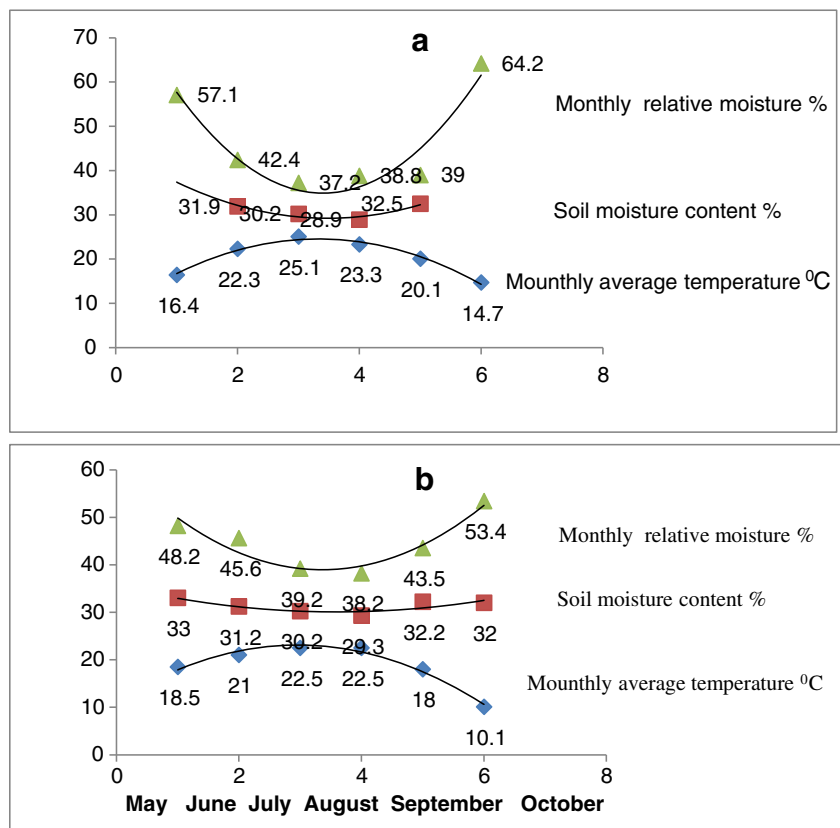
capillary rise (mm); Dp, the deep percolation (mm); Rf, the runoff (mm); and ΔS, the change in the soil moisture content in a given period within the plant root zone (mm). The precipitation rate was daily measured. Cr was accepted as zero since there was no water table problem in the study area. Rf was assumed to be zero. To calculate ΔS, gravimetric measurements were made to determine soil water contents in the soil profile. In the irrigation treatment, the water amount was sufficient simply to bring it up to the field capacity to close the deficit; so, deep percolation was ignored.

The fertilizer doses were equally applied to all the experimental plots. As a result of the soil analysis, with farmyard manure (20 tons ha⁻¹), di-ammonium phosphate (4 tons ha⁻¹),

and potassium nitrate (2 tons ha⁻¹) were applied as base fertilizer during the study period. Potassium nitrate was applied three times using the drip irrigation system, starting from the flowering stage. The experimental design of plots is illustrated in Fig. 2.

The experiment model with three treatments was established as a randomized complete block design (RCBD) in three repetitions (9 plots in total). The area of each plot was 26.2 m² (= 4.8 m × 5.5 m), and 10 pepper seedlings were planted in 5 rows (50 in total). The amount of spacing was 0.50 m for each plant and 0.80 m for each row. Prior to planting, soil moisture content in 60 cm deep reached the field capacity (FC). The planting dates were May 22, 2012 and

Fig. 1 Relative humidity, monthly average temperature, and soil moisture content in the years of 2012 (a) and 2013 (b)



May 14, 2013. In this study, scheduled irrigations were started in the beginning of the flowering stage on June 7, 2012 and June 11, 2013 and ended on September 25, 2012 and October 4, 2013, respectively. The manual harvests were completed on September 30, 2012 and October 8, 2013.

The irrigation water compensation for evapotranspiration was calculated using the formula suggested by Howell et al. (1990).

$$I_{rc} = \left(\frac{I}{ET} \right) \times 100 \quad (2)$$

where I_{rc} is the irrigation water compensation for the evapotranspiration, (%). Yield response factor (ky) indicates yield sensitivity matching per unit water deficit. It was determined using the following equation as suggested by Doorenbos and Kassam (1979):

$$(1 - Y/Y_m) = ky (1 - ET/ET_m) \quad (3)$$

where Y is the actual fruit yield (kg ha^{-1}), Y_m , the maximum fruit yield (kg ha^{-1}), ky , the yield response factor, ET , the actual evapotranspiration (mm), and ET_m , the maximum evapotranspiration (mm).

The levels of water use efficiency (WUE , $\text{t ha}^{-1} \text{mm}^{-1}$) and irrigation water use efficiency ($IWUE$, $\text{t ha}^{-1} \text{mm}^{-1}$) were calculated using the formula by Howell et al. (1990):

$$WUE = Y/ET \quad (4)$$

$$IWUE = Y/I \quad (5)$$

Equation 6 was used described by Doorenbos and Pruitt (1977) to calculate K_{pc} .

$$I = A * E_{pan} * K_{pc} \quad (6)$$

K_{pc} irrigation water (I)/pan A evaporation (E)
 I irrigation water amount (mm)
 A parcel area (m^2)
 E_{pan} evaporation from the class A pan (mm)
 K_{pc} K_{pc} coefficient (including pan coefficient k_p , crop coefficient k_c , and application efficiency E_a)

As yield attributes, the following parameters were considered, and a row on side of each plot was eliminated to avoid the border effect as follows:

Fruit number: respecting the numbers of fruits of ten sample plants in the middle of each plot

Marketable yield (kg ha^{-1}): the weight of the marketable yield per plant and plot, as converted to the yield of t ha

Fruit diameter (cm): the measurement for marketable fruits from ten plants using a venire caliper

Fruit length (cm): the measurement using a steel measuring tape

Analysis of variance (ANOVA) was performed to evaluate the effects of irrigation levels on yield and fruit quality parameters, using the SPSS software. Duncan's multiple range test was conducted to compare and rank treatment means. The significant level was statistically identified as at $P < 0.05$.

Results and discussion

The amount of seasonal crop water was calculated as 454, 591, and 726 mm and as 498, 652, and 806 mm in 2012 and 2013, respectively. The maximum evapotranspiration were found at full irrigation (I_{100}) and the minimum at I_{60} treatment. The quantity of irrigation water varied with the irrigation

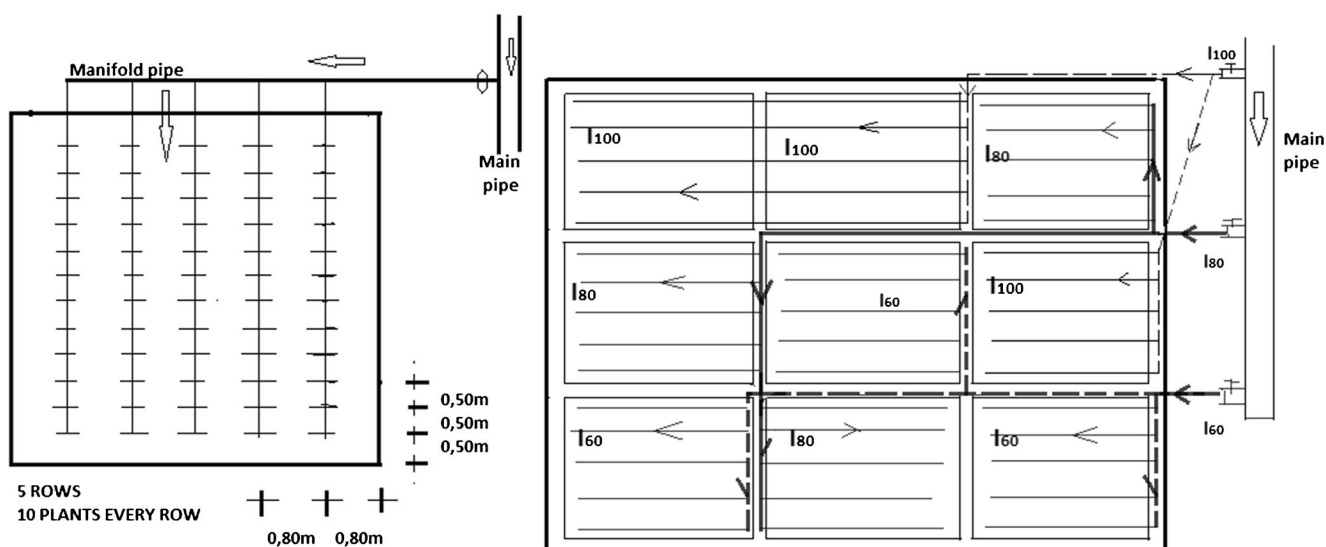


Fig. 2 The experimental design for the red pepper cultivation

levels. The total amount of water that was applied for treatments I_{100} , I_{80} , and I_{60} were calculated as 680, 544, and 408 mm in 2012 and 770, 616, and 462 mm in 2013, respectively. Evaporation from class A pan was measured as 808 mm in 2012 and 864 mm in 2013 from the planting step to the last irrigation. The total rainfall amount was 45.6 mm in 2012 (15.6 mm in May, 21.2 mm in June, 3.1 mm in July, 1.6 mm in September, and 4.1 mm in October), and 35.8 mm in 2013 (9.6 mm in May, 11.2 mm in June, 4.1 mm in July, 3.6 mm in September, and 7.3 mm in October). Şen (2015) reported that irrigation interval had no effect and however irrigation regimes had a positive effect on fruit yield. The same study stated that irrigation water was applied by 495 and 1166 mm. Saleh (2012) concluded that providing 85% of the field capacity led to a saving of 41% from the irrigation water and reduced the total yield by 28.9%. Providing 70% of the field capacity saved 85% of irrigation water; however, 40% of the total yield was lost. He determined that water deficit treatment is a functional technique for water saving. Yang et al. (2018) recommended full irrigation for the highest yield, and a water deficit of 25–50% was also recommended during the late stage if one favored economic benefits and water productivity. Dagdelen et al. (2004) reported that irrigation water and seasonal ET varied between 454 and 669 mm in 2012 and between 530 and 818 mm in 2013, respectively. Yıldırım et al. (2012) stated that total ET values were 200, 260, 317, 367, and 400 mm for the applications of (I_{100}), (I_{80}), (I_{50}), (I_{20}), (I_0), respectively. The findings of this study were in line with the studies by Dagdelen et al. (2004), Saleh (2012), and Yang et al. (2018). However, our results were highly lower than those of Sen (2015) and a bit higher than those of Sezen et al. (2011) and Yıldırım et al. (2012).

The parametric results of the relative water consumption deficit (1,- ET/ETm), relative yield decrease (1,- Ya/Ym), crop water efficiency (WUE), irrigation water use efficiency (IWUE), and IRc are shown in Table 2. The WUE values varied between 3.08 and 2.46 kg m⁻³ in 2012 and 3.25 and 2.04 kg m⁻³ in 2013. The IWUE values varied between 3.26 and 2.42 kg m⁻³ in 2012 and 3.39 and 2.13 to kg m⁻³ in 2013.

The highest values of WUE and IWUE were determined for the 20% deficit treatment. Costa and Gianquinto (2002)

found that WUE values varied between 10.4 and 12.3 kg m⁻³ in Italy. Dagdelen et al. (2004) found WUE and IWUE values as 4.1–6.7 and 3.3–5.1 kg m⁻³, respectively. Demirel et al. (2012) determined that these values varied between 2.4 and 7.0 kg m⁻³ and between 0.3 and 9.1 kg m⁻³, respectively. Sezen et al. (2016) stated that WUE varied between 5.5 and 7.1 kg m⁻³ and between 5.8 and 7.5 kg m⁻³ and that IWUE varied between 6.2 and 9.5 kg m⁻³ and between 6.2 and 10.2 kg m⁻³. The WUE and IWUE values obtained from the present study were lower than those of Costa and Gianquinto (2002), Demirel et al. (2012), Sezen et al. (2016). IRc varied from 95 to 96% depending on the irrigation treatment.

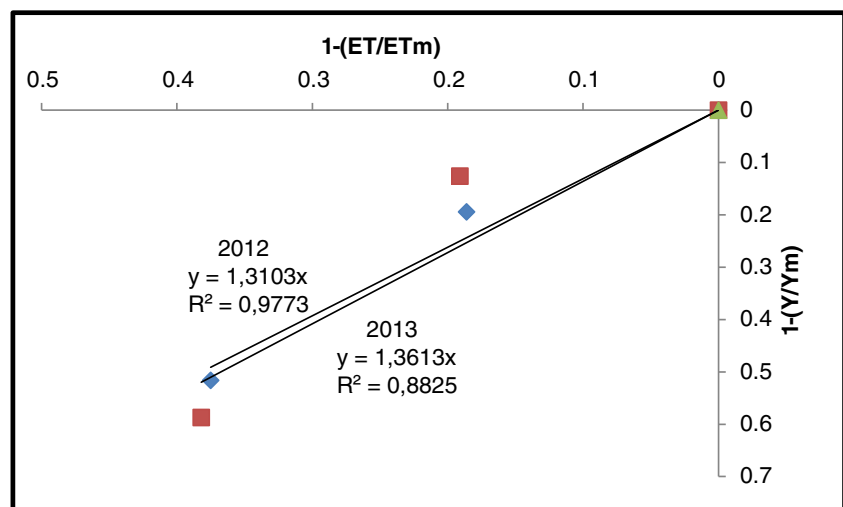
The yield response factors (ky) values were found as 1.03 and 1.37 in the treatments I_{80} and I_{60} in 2012, whereas the ky values in 2013 were 0.66 and 1.54, respectively. The relationships between relative water consumption deficits and relative yield decreases are shown in Fig. 3.

The application of 20% deficit irrigation (I_{80}) resulted in yield reductions about 19% in 2012 and 13% in 2013 (Table 2). For the 40% deficit irrigation treatment (I_{60}), the yield values decreased by 52 and 59% in comparison with the full irrigation treatment (I_{100}). The findings of this study clearly showed that red pepper plant is highly sensitive to deficit irrigation. Çevik et al. (1996) and Saleh (2012) concluded that providing 86 and 85% of the field capacity reduced the total pepper yield by 3 and 28.9%, respectively. The yield reduction in our study was lower than those obtained by Saleh (2012) and higher than those obtained by Çevik et al. (1996). If farmers' goal is to obtain maximum income, full irrigation is strongly suggested when irrigation water is available in the region. In arid and semi-arid environments where water resources are limited, application of 20% deficit irrigation could be beneficial. Gencoglan et al. (2006) and Yavuz et al. (2015) stated that, when water is scarce and irrigable fields are abundant, the optimum water deficit strategy would be to irrigate with the reduction of 27 and 25% (7-day interval for pumpkin). Our recommendation obtained from the study analysis was in agreement with several previous studies (Çevik et al. 1996; Antony and Singandhupe, 2004; Dorji et al. 2005; Gencoglan et al. 2006; Demirtas and Ayas, 2009; Geerts and Raes 2009; Saleh, 2010; Owusu-Sekyere

Table 2 The parametric results of relative water consumption deficit (1,- ET/ETm), relative yield decrease (1,- Ya/Ym), crop water efficiency (WUE), irrigation water use efficiency (IWUE), and irrigation water/ ET (IRc) in the experiments

Treatment	Pan A cup evaporation (mm)		1- (Y/Ym)		ET (mm)		1- (ET/ETm)		WUE		IWUE		IRc (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
S1 (I 100)	807.7	864	0	0	726	806	0	0	3.05	2.97	3.23	3.1	94.5	95.9
S2 (I 80)			0.194	0.126	591	652	0.186	0.191	3.08	3.25	3.26	3.39	94.4	95.8
S3 (I 60)			0.516	0.587	454	498	0.375	0.382	2.46	2.04	2.42	2.13	94.5	95.8

Fig. 3 Relationship between relative water consumption deficits and relative yield decreases



et al. 2010; Nagaz et al. 2012; Saleh 2012; Sam-Amoah et al. 2013; Sen, 2015; Talozzi and Waked 2016; Koksall et al. 2017).

The K_{pc} values were calculated as 0.84 and 0.89 for I_{100} for years 2012 and 2013, respectively, and as 0.67 and 0.71 for I_{80} . This was calculated to provide complete irrigation levels (FC) by implementing 0.87 times the pan A evaporation on the average.

The results of the statistical evaluation of the yield parameters are shown in Table 3. The marketable fruit yield of red pepper in the growing season in 2012 was lower than that in 2013. The mean values of monthly relative humidity, precipitation, and air temperature were higher in 2012 than those in 2013. In experimental years, the highest marketable yield (21.96 and 23.89 t ha⁻¹; 1.15 and 1.25 kg/per plant) was obtained from the treatment I_{100} . Gencoglan et al. (2006) stated that the dry yield of red pepper decreased as the depth of water applied decreased. Yıldırım et al. (2012) reported that total yields were 27.7, 20.1, 16.9, 8.6, and 3.3 t ha⁻¹ for I_{100} , I_{80} , I_{50} , I_{20} , and I_0 treatments, respectively. Demirel et al. (2012) stated that red pepper yields were 10.9, 20.2, 26.6, and 44.9 t ha⁻¹ in 2012 and 44.7, 26.4, 38.7, and 63.6 t ha⁻¹ in 2013 depending on the irrigation regimes (respectively for I_0 , I_{33} , I_{66} , and I_{100}) in the province of Çanakkale in Turkey. Sezen et al. (2016) reported that red pepper yields varied between .2

and 36.0 t ha⁻¹. Sen (2015) stated that processing pepper yields were 54 and 30 t ha⁻¹ depending on the irrigation regimes for 125 and 25% of evaporation in 2013, respectively. Duman et al. (2018) also reported that yields, average fruit weight, and fruit pericarp were 45.2 t ha⁻¹, 99.7 g, and 5.1 mm respectively. The results obtained from this study were in agreement with Gencoglan et al. (2006) and Yang et al. (2018); lower than those of Sen (2015), Sezen et al. (2016), and Duman et al. (2018); and a bit higher than those of Costa and Gianquinto (2002) and Yıldırım et al. (2012). It is thought that the difference may be due to environmental differences among study regions.

According to the statistical analysis, the differences in fruit yields were found significant among all treatments ($p < 0.05$) in 2012. However, in 2013, no significant difference was found between I_{100} and I_{80} , while all other treatments differed significantly. Aladenola and Mardamootoo (2014) stated that 120% ETC had significantly higher yields than the other treatments in 2011, whereas yields from 120% ETC and 100% ETC were not significantly different from each other in 2012. Sezen et al. (2016) reported that there were no significant differences between full irrigation and 75% of full irrigation in 2011. These results are similar to those in previous studies (Demirtas and Ayas, 2009; Aladenola and Mardamootoo 2014; Sezen et al. 2016). According to Fernandez et al.

Table 3 The statistics of marketable yield, fruit number of per plant and fruit diameter

Subj.	Yield kg/ha		Yield kg/per plant		Fruit number Per plant		F. diameter (cm)		Fruit length interval (min-max) cm		Fruit thickness interval (mm)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
I_{60}	10620 _c	9860 _b	0.56 _c	0.52 _b	6.7 _c	5.0 _c	3.53 _b	3.47 _b	13.1–16.1	10.0–20.0	3.5–5.0	3.6–6.0
I_{80}	17707 _b	20873 _a	0.93 _b	1.09 _a	10.1 _b	10.2 _b	4.63 _a	4.30 _a	11.0–17.2	10.0–21.3	3.5–6.0	4.0–5.5
I_{100}	21963 _a	23887 _a	1.15 _a	1.25 _a	13.7 _a	14.7 _a	4.77 _a	4.67 _a	12.1–19.1	12.4–22.0	3.9–6.5	4.1–7.5

$P < 0.05$ significance

^a firstgroup, ^b second group, ^c third group (statistically different)

(2005) and Gencoglan et al. (2006), the reduction in fruit yield of hot pepper under deficit irrigation might be attributed to the reduction in fruit size and numbers.

In both experimental years, important differences were found in the numbers of fruits. The maximum fruit numbers were obtained from I_{100} , whereas the lowest fruit numbers were obtained from I_{60} . Yalap (2013) reported that the number of fruits per plant ranged between 9.75 and 33.34 depending on irrigation schedule Sezen et al. (2011); Sezen et al. (2015) and Sezen et al. (2016) also reported that fruit weight, fruit width, fruit length, and fruit thickness were higher in the full irrigation treatment. The findings of our study were in agreement with those in the studies by Fernandez et al. (2005), Gencoglan et al. (2006), Sezen et al. (2011), and Sezen et al. (2016). However, the numbers of fruits per plant were lower than those found by Yalap (2013).

I_{100} and I_{80} were in the same group with regard to the diameter of fruit, but an important difference was found in I_{60} . Yalap (2013) reported that the diameter of fruits varied between 5.06 and 5.88 cm. Duman and Elmaci (2014) reported that fruit diameter varied within the range of 4.63 and 6.05 cm. Our results were in line with those of Sezen et al. (2016). The values of fruit diameters were a little lower in comparison to those reported Yalap (2013) and Duman and Elmaci (2014). It is believed that the difference arose from the characteristics of different varieties, soil, climate, and different implementations.

The minimum and maximum values of fruit length (cm) and pericarp thickness were very close to other treatments. The longest fruit lengths were measured as 16.1–22.0 cm, 16.5–20.0 cm, and 16.1–21.3 cm depending on treatment (respectively I_{100-80} and I_{60}). Sezen et al. (2016) found the longest fruit length (15.06 and 13.88 cm) for the full irrigation treatment, whereas a significant difference was not determined among the irrigation treatment based on fruit flesh thickness (4.08 and 3.97 mm). Yalap (2013) reported that fruit length values ranged from 13.35 to 15.91 cm, and fruit flesh thickness ranged from 4.68 to 6.41 mm depending on the variety (Göktürk and Semerkant Fı) and type of implementations. Duman and Elmaci (2014) reported that fruit lengths ranged between 13.38 and 15.8 cm, and fruit flesh thickness ranged from 4.35 to 5.5 mm. The maximum fruit lengths here were longer than the findings of these authors (Yalap 2013; Duman and Elmaci 2014; Sezen et al. 2016), similarly fruit flesh thickness was higher than the findings of Sezen et al. (2016). It is thought that the difference arose from the characteristics of different varieties, soil, and climate.

Conclusion

In arid and semi-arid regions, water shortage is the most important environmental problem restricting agricultural activities. This study revealed that red pepper is highly sensitive to

water stress. For the maximum yield, full irrigation is highly recommended. For sustainable use of water resources in water-scarce regions, deficit irrigation is a practical solution to maximize the efficient use of water. In this regard, in such environments, the water saving rate of 20% could be beneficial for drip-irrigated red pepper in the semi-arid Central Anatolia region of Turkey.

On the other hand, it is hard and workload to observe soil moisture using gravimetric methods under an irrigation schedule, which requires special equipment. Alternatively, the pan A evaporation method calibrated by the obtained results from a gravimetric technique can be easily applied by farmers. In cases where it is considered to supply irrigation water depending on evaporation, complete irrigation (FC) and 20% deficit irrigation (I_{80}) levels could provide 0.87 and 0.69 times evaporation from the pan A cup. There is limited evidence in the literature accessible on the application of irrigation water based on evaporation from class pan A cup calibrated by the gravimetric method. So, further research should be developed to better understand the interactions related to evaporation from pan A cup calibrated by gravimetric methods for deficit irrigation.

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