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THE EFFECT OF WATER STRESS ON TOMATO UNDER DIFFERENT EMITTER DISCHARGES AND SEMI-ARID CLIMATE CONDITION

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Abstract

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The aim of this study was to determine the effect of water stress on tomato. The experiment was conducted in a loamy soil under semi-arid climate conditions of Konya in 2010 and 2011. Irrigation water was applied using Class A pan evaporation (Kpc = 0.60, 0.80, 1.00, and 1.20) with six days irrigation intervals and with two different emitter discharges ratios. Drip irrigation laterals were arranged for every row. Significant differences in fruit yields were found among all treatments ($p<0.01$). Maximum marketable fruit yield (83.8 - 73.9 t ha^{-1}) was obtained under conditions of AS_1 and BS_1 applications, respectively. Maximum irrigation water applied of the mention applications were determined as 507.1 mm and 365.1 mm and seasonal evapotranspiration were determined as 657.0 mm and 538.1 mm, respectively. The crop yield response factor was 2.28 - 2.04 under conditions of BS_1, and 1.45 - 1.53 under conditions of AS_1 by years, respectively. Hand harvest tomato varieties *(Lycopersicon esculentum* cv.H2274) responded to water restraint with a significant proportional decrease on yield under semi-arid climate conditions. In addition, water stress increased the susceptibility of plants to attack by pathogens.

Key words: Crop yield response factor, water restraint, emitter discharges ratios, evapotranspiration, tomato

Abbreviations: WUE=water use efficiency; IWUE= irrigation water use efficiency; k_y= crop yield response factor; EDR= emitter discharges ratio; IRc= irrigation water / cumulative pan evaporation; $[\![1-(Ya/Ym)]\!]$= Relative yields decrease; $[\![1-(ETa/ETm)]\!]$=relative evapotranspiration deficits; A= 4 Litter $hour^{-1}$ emitter discharges treatment; B= 2 Lh^{-1} emitter discharges treatment; S= kpc treatments according to water deficit

Introduction

Tomatoes, which consume large quantities of water in semi arid climate conditions, are one of the most planted vegetables in Turkey. Moreover, water allocation for agriculture is decreasing steadily and sufficient irrigation water is not available in Turkey as in many parts of the world. In addition, water availability is an important constraint for plant productivity, mostly affecting the growth of leaves and roots, stomatal conductance, photosynthesis, and dry matter accumulation (Blum, 1997).

Deficit irrigation is one way of maximizing for higher yields per unit of irrigation water (English 1990) and WUE usually increases depending on increases in irrigation (Howel, 2006). Furthermore, tomato plants are sensitive to water stress (Nuriddin et al., 2003), 15% and 30% of irrigation reductions would reduce gross revenue by 15% and 22%, respectively (Obreza et al., 1996). Shinohara et al. (1995) maintained that fruit yield was decreased with increasing water stress. Similarly, in the study of Pervez et al. (2009) plant height, number of leaves and number of fruits per plant were reduced significantly by drought imposed. According to Doorenbos and Kassam (1979), tomato plants should be irrigated frequently with small amounts of water and need to receive water between 400-600 mm during the growth period. The plants should not be allowed to consume more than 40% of the available moisture in the soil. In addition, According to Dickenson and Wheeler (1981); Rishbeth (1991); Boyer (2001) and Mc Elrone et al. (2001) stress increases the susceptibility of plants to attack by pathogens.

A study conducted by Smajstrla and Locascio (1994) to evaluate the effect of irrigation on yield showed that total

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marketable yields doubled and while yields of high value extra large fruit tripled with irrigation. Similarly, May (1993) indicated that low stress levels resulted in maximum yields, while high stress resulted in the lowest yields. Birhanu and Tilahun (2010) conducted a study to determine the effect of irrigation (0%, 25%, 50% and 75% crop evapotranspiration deficit) on fruit yield and quality on drip-irrigated tomatoes. Almost all the plant attributes were directly related to water stress level. Candido et al. (2000) conducted an experiment on tomatoes with the aim of evaluating the influence of different irrigation regimes on yield. Four irrigation levels were applied (100%, 66, 50 and 33 of ET). The highest yields were obtained under condition of 100% of ET application. Yavuz et al. (2007), studied an experiment on tomatoes (Kpc₌0.25, 0.50, 0.75, 1.00 and 1.25). In this research, the highest yield was obtained when conditions of 1.00 Kpc (on the field capacity). On the other hand, tomato yields were significantly higher at a high irrigation rate (six L h^{-1}) than at a low irrigation rate (two L h^{-1}) in both seasons (Abdulrasoul et al., 2010).

Aksic et al. (2011) conducted a study on tomato, observing dynamics of soil moisture by tensiometers. In this research, the highest yield (64.6 t ha^{-1}) was obtained in 583.9 mm ET condition. The greatest values of WUE were 11.3 kgm^{-3} and IWUE were 8.2 kgm^{-3}. Çetin and Uygan (2008) conducted an experiment on tomatoes, where the maximum yield was obtained from the treatment in which both the lateral spaces and row spacing was one meter. Irrigation water amounts of 551mm, and yields of 121.1 t ha^{-1} were obtained in this treatment. IWUE ranged from 14.3 to 25.8 kg m^{-3}. Özbahçe and Tari (2010); Özbahçe et al. (2012) carried out an experiment on tomatoes. The highest seasonal evapotranspiration, the highest irrigation water amount, maximum harvested yield and k_y were 525–619 mm, 426–587 mm, 73.4– 74.0 t ha^{-1} and 1.22-0.84 in 2004 and 2005, respectively. On the other hand, WUE values usually increased with an increasing in irrigation. The average IWUE values increased generally with decreasing seasonal irrigation water amounts. There were significant differences between IWUE and WUE values according to the years

According to Kırda et al. (1999), the crop yield response factor gives an indication of whether the crop is tolerant to water stress. A response factor greater than unity indicates that the expected relative yield decreases for a given evapotraspiration deficit is proportionately greater than the relative decrease in evapotranspiration. Thus, only those crops and growth stages with a lower crop yield response factors (k_y<1.0) can generate significant savings in irrigation water through deficit irrigation (Kirda, 2002).

The objective of this study was to determine whether water stress affected crop yield and disease resistance for tomatoes (*Lycopersicon esculentum* cv.H2274) in Turkey's semiarid climate Konya region.

Materials and Methods

Experimental site

This study was conducted in the fields of the Soil and Water Research Institute in Konya from 2010 to 2011. The experimental site is situated at latitude 37°52´ ´N and longitude 32°30´E in a semi-arid climate.

The precipitation on meteorological data and evaporation values measured on class A pan during the vegetation period from May to October by years were recorded at 55.8–845.2 mm and 59.2–776.9 mm by years, respectively. The long-term (from 1970 to 2011) averages for annual totals or the growing period of climatic values are summarized in Table 1.

The experimental site soil has a loamy texture, irrigation water with medium salt and low alkalinity was classified C_2S_1. Some of the soil properties are presented in Table 2.

Irrigation treatments

The research was conducted with two main factors and three replications in randomized blocks. The first main factors were (A) 4 litter hour $^{-1}$ (L h^{-1}) EDR and (B) 2 L h^{-1} EDR and the second factors were coefficients of Class A pan evaporation (S_1) Kpc = 1.2, (S_2) Kpc = 1.0, (S_3) Kpc = 0.8 and (S_4) Kpc = 0.6. According to the experimental design, four water supply levels

Table 1
Climatic data in the experimental site for averages and the years of the study

Climatic data	May	June	July	August	September	October	Total
Average temperature, °C	15.7	20.3	23.7	23.1	18.7	12.5	
Average precipitation, mm	41.1	23.9	7.8	5.8	10.4	33.6	
Average evaporation, mm	154.0	194.4	240.8	224.7	155.5	88.0	1057.4
Evaporation in 2010, mm	161.8	196.2	240.4	242.2	165.6	70.7	1076.9
Evaporation in 2011, mm	113.8	162.6	230.1	214.2	159.4	-	880.1
Precipitation İn 2010, mm	6.0	39.8	2.4	0.0	7.6	0.0	55.8
Precipitation İn 2011, mm	28.4	27.2	0.0	1.0	1.2	1.4	59.2

with two EDR were applied at six days a interval, which is 1 day less given by Özbahçe et al. (2012) because of soil texture difference, with irrigation applied 16 times in total.

Soil water content was measured between 25.86% and 26.05% (no water stress) after irrigation for the Kpc = 1.2 treatment. In order to prevent flower drop, the initial irrigation was started at 60% soil moisture depletion level intervals in accordance with Doorenbos and Kassam (1979). Following irrigation applications were applied at six days intervals. To calculate the irrigation water applied, wetted areas were calculated at 53 cm and 38 cm, and measured 55 cm and 40 cm under conditions of A and B treatments respectively. Consequently, the percentage of wetted area accepted as 50% and 36% for A and B treatments respectively. The drip system was placed on the plots immediately following planting. The quantity of the first irrigation water for all the plots was based on the moisture that would be needed to bring a 0-60 cm layer of soil to field capacity. Following the first flowering, subsequent irrigation was applied a 0-90 cm layer of soil considering irrigation intervals and coefficients of Kpc. Soil moisture was monitored through the gravimetric method on soil samples taken from a depth of 30, 60, 90 and 120 cm and dried in 105^0C. None deep percolation or runoff losses was observed in root zone in experimental site, so it was measured on zero under conditions of the experiment with low percentage of wetted area and low irrigation water amounts applied through the drip irrigation system.

The plant row spacing was 1.10 which was similar to Çetin and Uygan (2008). The length of each plot was 6.0 m. There were 1.0 m spaces between all plots and 40 plants were planted each parcel. The planted and harvested areas were 6.0*6.6 m and 5.0*4.4 m, respectively. In total, 36 plots were performed in the third blocks. In addition that, to examine the effects of disease, one block occurred with 12 parcels.

Irrigation system

The emitter spacing and plant spacing was chosen as 0.50 m under conditions of A treatment and as 0.40 m under conditions of B treatment relating to emitter discharges. The drip system consisted of PE laterals 16 mm in diameter laid out along each tomato row at 1.10 m spacing. Each plot had a PE manifold pipeline 32 mm in diameter. The irrigation water was pumped from an irrigation canal by inline emitters at 1.5 atmosphere operating pressure. In addition, the control unit of the system has sand media filters, a fertilizer tank, disc filters, and pressure gauges. The amount of irrigation water was measured by flow-meter. Rainfall and evaporation data were obtained from the records of the climatological station on the experimental site.

Agricultural application

Tomato seedlings were grown in a greenhouse. Young hand harvest variety tomato plants were transferred into plastic tubes and were planted in plots on May 20 and May 25 in 2010 and 2011, respectively. A total of 180 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} fertilizer were applied as recommended by Sefa and Oruç (1990). Half of the phosphorus and approximately one-third of the nitrogen were applied to the soil before planting. The remaining fertilizer, which contained nitrogen, phosphorus, potash, and some minor elements, was applied by fertigation three times. The harvest began at the beginning of August and was finished on September 30 in 2010 and on October 9 in 2011.

Calculated parameters

The amount of irrigation water applied during the irrigation treatments was determined by Class A pan evaporation using the equation given below (James, 1988).

$$I = Ep\mathrm{KpcPw}, \qquad (1)$$

where I amount of irrigation water applied (Litter), Ep cumulative evaporation amount for considering irrigation intervals (mm), Kpc coefficient (including pan coefficient kp, crop coefficient kc, and application efficiency Ea), and Pw wetted area (%). The percentages of wetted area (Pw) were determined by methods from Keller and Bliesner (1990) and Yildirim (2003). The Pw was the average horizontal area wetted in the top 15–30 cm of the crop root zone as a percentage of the lateral line area.

Table 2
Soil data of experimental site

Soil layers, cm	Field capacity, g/100g	Wilting poin,t g/100g	$CaCO_3$ % calcimetric	Organic matter % Walkley Black	Bulk density, g/cm^3	pH	salt	texture	Infiltration rate, mm7h
0-30	25.4	15.8	very high	low		8.5		L	
30-60	27.1	16.0	very high	low		8.5		L	
60-90	25.7	17.1	very high	low		8.5		L	
average	26.1	16.3	very high	low	132	8.5	0.05	L	11.4

$$Sd = 0.9\sqrt{\frac{q}{ir}} \quad (2)$$

$$Pw = \frac{Sd}{Sl}\,100, \quad (3)$$

where Sd: Emitter space (m), q: Emitter Discharge Rate (EDR, L h^{-1}), ır: Infiltration rate (mm h^{-1}), Sl: Laterals interval (m), Pw: Percentage of wetted area

The water balance equation was used in order to determine evapotranspiration (James, 1988).

$$ET = I + P - Dp \pm Roff \pm \Delta S, \quad (4)$$

where ET water consumptive (mm), I the irrigation water applied (mm), P the rainfall (mm), Dp the deep percolation (mm), Roff the runoff (mm), and ΔS the change in soil water storage (mm).

The yield response factor (k_y), which links relative yield decrease to relative evapotranspiration deficit, was as follows (Doorenbos and Kassam, 1979).

$$1 - (Y/Ym) = k_y\{1 - (ET/ETm)\}, \quad (5)$$

where Y: actual yield (t ha^{-1}), Ym: maximum yield (t ha^{-1}), k_y: yield response factor, ET: actual evapotranspiration (mm), ETm: Maximum evapotranspiration (mm).

Water use efficiency (WUE, kgm^{-3}), irrigation water use efficiency (IWUE, kgm^{-3}) and (IRc, %) irrigation water/cumulative pan evaporation was determined using the equation given (Howell et al., 1990) :

$$WUE = Y/ET \quad (6)$$

$$IWUE = Y/I \quad (7)$$

$$IRc = \frac{I}{ET}\,100 \quad (8)$$

Experimental results were subjected to a variance analysis according to a procedure described by Gomez and Gomez (1984) and mean differences were tested using Duncan's Multiple Range Test at ($p<0.01$ and $p<0.05$) level of probability. Analysis of variance was computed using the MSDAT-C software package. Split plots in randomized blocks with three replications were used to evaluate the effects of treatments on the yield.

Results

According to our study tomato yield was significantly ($p<0.01$ and $p<0.05$) affected by water supply level and EDR. The highest fruit yield was recorded at 87.0 t ha^{-1} and 76.2 t ha^{-1} with A and B treatments respectively, which were under the most favourable moisture conditions of S_1 (on field capacity condition) and the lowest fruit yield (41.2 and 26.7 t ha^{-1}) was obtained from the condition of S_4 treatment under the most severe stress conditions.

The results of seasonal irrigation water applied, evapotranspiration, marketable fruit yields and statistical gradation are summarized in Table 3. Marketable yield decreased from 16% and 14% with AS_2 up to 53% and 49% with AS_4 in comparison to the yield obtained with the highest irrigation level in 2010 and 2011 respectively. Similarly, marketable yield decreased from 22% and 18% with BS_2 up to 49% and 46% with BS_4 respectively depending on water stress. Irrigation water applied decreased from 17% and 18% with AS_2 up to 52% and 51% with AS_4 in comparison to the highest irrigation water applied level in 2010 and 2011 respectively.

Both the highest irrigation water and the highest marketable fruit yields and the highest evapotranspiration occurred in conditions of AS_1 treatment. Irrigation water amounts ranged according to the Kpc treatments (from S_1 to S_4) from 507.12 to 253.56 mm in 2010 and ranged from

Table 3
Results of Water applied evapotranspiration, marketable fruit yields and statistical gradation obtained in the experimental years

Treatment	Yield, t ha^{-1}							Water applied, mm		Evapotranspiration, mm	
	2010			2011			means				
		$P^{<0.01}$	$P^{<0.05}$		$P^{<0.01}$	$P^{<0.05}$		2010	2011	2010	2011
AS_1	87.01	a	a	80.57a	a	a	83.79	507.12	476.2	657.01	609.62
AS_2	73.35	b	b	69.66b	b	b	71.51	422.60	388.5	577.00	545.71
AS_3	60.08	c	c	51.62c	c	c	55.85	338.08	310.8	500.80	478.87
AS_4	41.19	d	d	41.38d	d	d	41.29	243.56	231.1	425.78	411.69
BS_1	76.17	a	a	71.63a	a	a	73.90	365.12	335.6	538.05	510.99
BS_2	52.56	b	b	58.54a	a	b	55.55	304.27	279.7	480.06	458.65
BS_3	35.84	c	c	42.31b	b	c	39.08	243.41	223.7	423.95	408.23
BS_4	26.72	c	c	27.75c	c	d	26.98	169.04	167.8	369.04	357.92

466.20 to 233.10 mm in 2011with treatment A. For treatment B, irrigation water amount ranged according to the Kpc treatments from 364.78 to 182.39 mm in 2010 and ranged from 335.60 mm to 167.8 mm in 2011. Evapotranspiration decreased from 12% and 10% with AS_2 up to 35% and 32% with AS_4 in comparison to the highest evapotranspiration level in 2010 and 2011 respectively. Similarly, evapotranspiration decreased from 11% and 10% with BS_2 up to 31% and 30% with BS_4.

Irrigation water use efficiency, water use efficiency, irrigation water / cumulative pan evaporation, Relative yields $\llbracket 1-(Ya/Ym) \rrbracket$ decrease and relative evapotranspiration deficits $\llbracket 1-(ETa/ETm) \rrbracket$ are summarized in Table 4. Relationship between relative evapotranspiration deficits and relative yield decrease is shown in Figure 1. Reduction on tomato yield corresponding to unit water deficits were more from S_1 to S_4 for each experimental year and EDR. The difference between relative tomato yield and proportional plant water consumption $\llbracket 1-(Ya/Ym) \rrbracket - \llbracket 1-(ETa/ETm) \rrbracket$ increased from Kpc = 1.00 (0.04 in 2010 and 0.03 in 2011) to Kpc = 0.60 (0.18 and 0.16 respectively) with A treatment. The difference was even higher with B treatment than A.

The yield reductions due to water stress (i.e., the seasonal values of k_y) varied within the range of 1.45- 2.28 for the experimental years (Figure 1). On the other hand, ky values were higher in 2011 than 2010. This result probably appeared due to differences on evapotranspiration, yields and precipitation between 2010 and 2011.

IWUE values did not change significantly from kpc=1.20 to kpc= 0.60 with treatment A. But, IWUE values reduced by 30% from kpc=1.20 to kpc= 0.60 with treatment B. The difference on treatments probably appeared due to more reduction on yield corresponding to unit water deficits with treatment B than A depending on irrigation rate as given (Abdulrasoul et al., 2010).

IRc values ranged according to the kpc 0.77-0.60 in 2010 and 0.76-0.57 in 2011 with treatment A, ranged 0.66-0.49 in 2010 and 0.66-0.47 in 2011 with B treatment. IRc were more in 2011 than 2010 because of differences on ET and precipitation.

27.1-23.4% less water consumption was recorded for the unit product between AS_1 and AS_4 treatments in 2010 and 2011 respectively. Reduction in water consumption for the unit product between BS_1 to BS_4 was recorded as 49.3-45.0% by years.

Fungi which covered all leaves and branches was seen on 80, 86, 120 and 120 plants with treatments AS_1, AS_2, AS_3 and AS_4 respectively. After spraying whole plots, all diseased branches and leaves pruned in 12 plots. While none of the plants stool on S_4, 36 plants on S_3, 120 plants on S_2 and S_1 became healthy again and fruits were obtained normal levels.

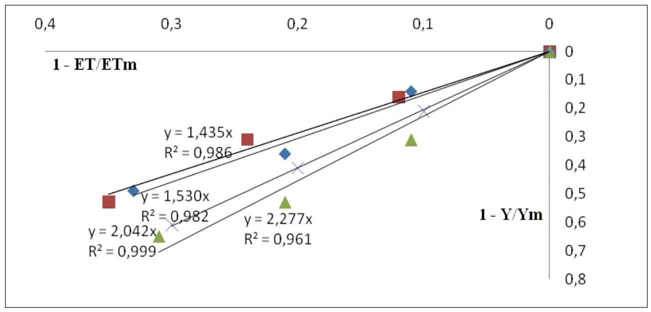

Fig. 1. Relationship between relative evapotranspiration deficits and relative yield decrease

Table 4
Irrigation water use efficiency, water use efficiency, irrigation water / cumulative pan evaporation, relative evapotranspiration deficits and relative yield decrease

Treatment	IWUE	WUE	IRc	IWUE	WUE	IRc	1-(Y/Ym)		1-(ET/ETm)	
	2010	2011	2010	2011	2010	2011				
AS_1	17.2	13.3	0.77	17.3	13.2	0.76	0	0	0	0
AS_2	17.4	12.7	0.73	17.9	12.8	0.71	0.16	0.14	0.12	0.11
AS_3	17.8	12.0	0.67	16.6	10.8	0.65	0.31	0.36	0.24	0.21
AS_4	16.3	9.7	0.60	17.8	10.1	0.57	0.53	0.49	0.35	0.33
BS_1	20.9	14.2	0.66	21.3	14.0	0.66	0	0	0	0
BS_2	17.3	10.9	0.64	20.9	12.8	0.61	0.31	0.21	0.11	0.10
BS_3	14.7	8.4	0.57	18.9	10.3	0.55	0.53	0.41	0.21	0.20
BS_4	14.6	7.2	0.49	16.5	7.7	0.47	0.65	0.61	0.31	0.30

Discussion

The highest fruit yield was recorded under the most favourable moisture conditions of S_1 (on field capacity condition with kpc=1.20) and the lowest fruit yield was obtained under the most severe stress conditions. Similar observations were reported by (May, 1993; Yrisarry et al., 1993; Shinohara et al., 1995; Candido et al., 2000; Yavuz et al., 2007; Pervez et al., 2009). On the other hand, the amount of water applied was within the limits as given by Doorenbos and Kassam (1979). Decreasing the water applied (16.6% and 18.4%) resulted in decreased (15.6% and 13.5%) the fruit yield under conditions of AS_1 by years. Similar results were reported by (Obreza et al., 1996).

Data on the Table 3 showed that tomato yield was significantly ($p<0.01$) affected by Emitter Discharges as reported by Abdulrasoul et al. (2010). Similarly, the reduction in irrigation water led to significant yield reduction. Fruit yield was higher than Özbahçe et al. (2012) and Aksic et al. (2011) but, lower than Çetin and Uygan (2008). Similar results are also reported by other authors (Smajstrla and Locascio**,** 1994; Obreza et al., 1996 and Nuriddin et al., 2003) in terms of substantial economic loss depending on water stress.

Seasonal irrigation water, fruit yield and evapotranspiration were significantly decreased from 4 L h^{-1} EDR to 2 L h^{-1} EDR and from S_1 to S_4 in every experimental year. The significant reduction probably appeared due to significantly lower percentages of wetted area under conditions of 2 L h^{-1} EDR than 4 L h^{-1}. If the percentage of wetted area is much closer to the insufficient irrigation limit, it can cause to significant reductions in tomato yield because of severe water stress.

Very high k_y values were evaluated at the survey because of percentage of wetted area (36%) to proximity insufficient irrigation limit under conditions of treatment B. Furthermore, ky values were significantly higher under conditions of B than A for each experimental year. Very high k_y values show that increasing the irrigated areas with the water saved by restraint would not compensate for any yield loss on tomatoes (*Lycopersicon esculentum* cv. H2274) as maintained by Kırda (2002). Our findings regarding k_y were higher than (Özbahçe and Tari, 2010; Yavuz, 2007). The difference appeared due to the differences on kinds of tomatoes and wetted area- canopy cover.

Irrigation water applied increases depending on increasing in wetted area or canopy cover. Evaporation should be seen as a function of the fraction of ground surface coverage and the fraction of the surface wetted. Çetin and Uygan (2008) and Allen et al. (1998) argued that the water might be lost to evaporation at the beginning of the growth stage because of application with water amount based on a higher percentage of wetted area throughout the irrigation season. Canopy cover varies depending on the growth season but, wetted area is fixed. Thus, the amount of irrigation water increased depending on increasing percentage of canopy cover during the growing season. In this way, it might be a clarified situation where the majority of soil wetted by irrigation may be beneath the canopy and therefore may be shaded as given by Allen et al. (1998). The method of determination of irrigation water amount based on the percentage of canopy cover instead of percentage of wetted area was the most reasonable and effective in terms of both the yield and IWUE as proposed by Çetin and Uygan (2008). This is in agreement with the results obtained by Hartz (1993).

IWUE values are considerable different between treatments A and B, generally tends to increase with a decline in irrigation. Water productivity can be increased by increasing yield per unit land area or by producing more crops with less water. Findings are similar to Özbahçe and Tarı (2010) in terms of tendency but, are lower than Çetin and Uygan (2008) and higher than Aksic et al. (2011). The reason of the difference between IWUE values probably appeared due to the differences on tomato yield. WUE showed an upward trend with an increasing in irrigation. This is an agreement with the results obtained by other authors (Howell, 2006; Özbahçe et al., 2012).

In plants exposed to stress, diseases spread more quickly and made more damage. As a result, it can be said that water stress reduces disease resistance of plants as given by other authors (Dickenson and Wheeler, 1981; Rishbeth, 1991; Boyer, 2001; McElrone et al., 2001).

Conclusion

Tomato yields decreased significantly ($P^{<0.01}$ and $P^{<0.05}$) from Kp_c= 1. 20 to Kp_c= 0.60 and from 4 Lh^{-1} to 2 L h^{-1} EDR. The highest fruit yield was recorded in field capacity condition with kpc=1.20. Under conditions of lower than kpc= 1.00, a sharp reduction occurred on yield. One of the most important objectives of irrigation in agriculture is to maximize the economic benefits. Not only decreases in relative tomato yield corresponding to proportional plant water consumption, but also costs of water and net income from saving water must be considered. In this context, (treatment AS_1) 4 L h^{-1} EDR and Kpc=1.00 may be recommended depending on tomato and water price.

Irrigation water and tomato yield decreased depending on decreasing emitter discharge and percentage of wetted area. The percentage of wetted area is an important parameter in drip irrigation affecting the amount of irrigation water. For this reason, low emitter discharge can cause inadequate irrigation and excessive stress in permeable soil as in the study under condition of B. In the context, the percentage of canopy cover may be suggested for calculation of the amount of irrigation water applied instead of percentage of wetted area as given by Çetin and Uygan (2008).

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