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Full Length Research Paper

Yield and quality response of drip-irrigated pepper under Mediterranean climatic conditions to various water regimes

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This study examines the effects of different irrigation regimes on yield and water use of pepper irrigated by a drip system under field conditions during the 2004 growing season at the Soil and Water Resources Research Institute in Tarsus, Turkey under Mediterranean climatic conditions. The field trials consisted of three irrigation intervals (IF_1:20±2, IF_2:40±2 and IF_3:60±2 mm of cumulative pan evaporation) and evaluated by three irrigation levels (DI_1=0.50, DI_2=0.75 and DI_3=1.00). Both the irrigation levels (DI) and intervals (IF) had significantly different effects on pepper yields. The maximum and minimum yields were obtained from the IF_1DI_3 and IF_3DI_1 treatment plots as 35920 and 21390 kg ha^{-1}, respectively. The yields and yield components decreased as irrigation levels decreased for each irrigation interval. However, the larger irrigation interval (IF_3) resulted in lower yields with all irrigation levels. Pepper seasonal evapotranspiration varied from a low 327 mm in the more stressfull treatment (IF_3DI_1) to a high 517 mm in the well irrigated control (IF_1DI_3). Significant linear relations were found between the pepper yield and the total water use for each irrigation interval. Irrigation intervals resulted in similar water use in the treatments with the same irrigation level. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) values were significantly influenced by the irrigation intervals and levels. WUE ranged from 6.0 kg m^{-3} in IF_3DI_2 to 7.8 kg m^{-3} in the IF_1DI_1. The maximum IWUE was observed in IF_1DI_1, and the minimum IWUE was in IF_3DI_3 treatment. Both irrigation levels and frequencies had significantly different effects on quality parameters such as the first and second quality yield, number of fruit, mean fruit weight, pepper length and width, as well as plant height at harvest. In conclusion, the IF_1DI_3 irrigation regime is recommended for field grown pepper in order to attain higher yields with improved quality. Economic evaluation revealed that full irrigation treatment (IF_1DI_3) generated the highest net income. However, under water scarcity conditions, IF_1DI_2 treatment can provide an acceptable net income.

Key words: Pepper, deficit irrigation, water use efficiency, yield response factor, economic evaluation.

INTRODUCTION

Current trends indicate that several regions are facing water shortages, particularly in the Mediterranean region of Turkey, but also in a progressively large number of countries worldwide. In the arid and semi-arid regions of the Mediterranean, for all the practical purposes, fresh water resources are inadequate. Nowadays, the major impasse the developing countries of the region are facing is the balancing of the demand and supply of water to ensure self-sufficiency in agriculture. Thus, this creates the need for continuous improvement in irrigation practices, especially in the commercial vegetable production of the Mediterranean region. Water saving irrigation

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Abbreviations: WUE, Water use efficiency; **IWUE,** irrigation water use efficiency; **ET,** evapotranspiration; **DAT,** days after transplanting.

methods should be followed in order to save water and maximize yield. Due to the severe competition in urban and rural use and other sectors, the value of water will most probably rise shortly (Bouwer, 2000). Thus, appropriate irrigation scheduling is required for maximizing the yield and water use (Antony and Singandhupe, 2004).

Pepper (*Capsicum annuum* L.) production in Turkey is about 390000 metric tons of which 28.8% of this is produced in the Mediterranean region (DIE, 2000). As it is for most crops, due to its susceptibility to water stress, irrigation is a must for pepper production in this area. Such sensitivity has been documented in several reports that studied the yield reductions effected by water stress (Smittle et al., 1994; Delfine et al., 2002; Antony and Singandhupe, 2004; Sezen et al., 2006). The lack of precise irrigation recommendations needed in irrigation scheduling, based on real-time weather data, stand for a limitation to improving irrigation practices for pepper (Simone et al., 2006). Thus, the development of the best management practices for vegetable crops, producing economical yields of vegetables requires an integrated approach to irrigation and fertilization. Irrigation is a comparably significant issue to environmental and topographical factors, which affects the yield and quality of pepper. Irrigation frequencies or different irrigation intervals have beneficial effects on water balance, fruit quality and fruit production. Furthermore, irrigation plays an important role to maintain sustainable growth for every crop, especially by reducing the wilting responsible for a 60 to 80% crop loss (Khan et al., 2005). Recently, there is a demand to enhance vegetable production and develop ways through which maximum benefits can be obtained from the limited available water resources.

Antony and Singandhupe (2004) conducted a study to understand the effect of different irrigation methods and schedules on morphological, biophysical, yield and water use efficiency (WUE) of Capsicum annum. The plants grown under drip irrigation had higher number of branches and plant heights compared to that of surface irrigated plants. The total yield was less at lower levels of irrigation. Above ground matter that included stem and leaf dry weight had positive correlation with yield under drip (r^2=0.992) and surface irrigation (r^2=0.926). Thus, drip irrigation at 100% CPE was determined to be beneficial for the capsicum plant in terms of yield, better plant morphological characters, namely: plant height, number of branches, root finesses and root length. Furthermore, a study in California reveals that the buried drip system resulted in an average of 19% reduction of water use over the sprinkler system. The drip system brought about an average of 30% increase in pepper yield with increased water use efficiency (62 %) in average for the two years of drip irrigation (Anonymous, 1996).

The crop yield dependency on water supply is a critical issue because of the decreasing water sources for irrigation. Accordingly, the primary objective of this study is to determine the effect of water stress occurring during the growing season on yield together with the qualities and water use efficiency of field grown pepper by applying full and various deficit irrigation strategies with a drip system, and of this crop in the Mediterranean region of Turkey.

MATERIALS AND METHODS

The experiment was carried out during the growing season of 2004, between August through December, at Soil and Water Resources Research Institute in Tarsus, Turkey, 37°01'N latitude and 35°01'E longitude, at altitude 30 m above mean sea level. Typical Mediterranean climate prevails in the experimental area. Figure 1 summarizes the monthly mean climatic data compared with the long-term mean climatic data for Tarsus. The 2004 growing season temperatures were typical of long term-means (1952-2007) for Tarsus located in the eastern Mediterranean region of Turkey. Average seasonal rainfall is 616 mm, with 90% of the rain occurring between November and March.

The soil of the experimental site is classified as Arikli silty-clay-loam with relatively high water holding capacity. Available soil water in the upper 0.90 m of the soil depth is 187 mm. Volumetric soil water contents at field capacity and permanent wilting point are 0.469 and 0.262 $m^3 m^{-3}$, respectively. Mean bulk density varies from 1.40 to 1.53 g cm^{-3}.

The experiment consisted of a double row planting in bed spacing of 0.60 m and with row spacing of 0.20 m on the bed. The four-week old "11-B-14" peppers (*Capsicum annuum sp.*) were transplanted in the experimental plots on August 11, 2004. Occurrence of the different phenological growth stages and harvesting time were recorded as number of days after transplanting (DAT) accordingly.

In this study all treatment plots received the same amount of total fertilizer. A compound fertilizer of (15-15-15) was applied at a rate of 50 kg N per hectare prior to planting on August 07, 2004; the rest of N was applied in three split applications to the experimental plots in the form of compound fertilizer (18-18-18) at a rate of 30 kg ha^{-1} on August 25, and 50 kg ha^{-1} on September 12, 50 kg ha^{-1} on October 05, 2004.

Pepper yield was determined by hand harvesting the 6 m sections of the three adjacent center rows in each plot based on the physiological maturity of plants. Quality parameters such as the first and second quality yields, numbers of fruit, fruit weight, length and width and plant height were determined in each harvest period. Harvested peppers were classified in two classes according to the Turkish Standards for peppers (TSE, 1974). The first quality peppers are described as firm, crisp, smooth fairly well shaped in normal mature green color, and free from various injuries.

The experiment was designed in split plots with four replications. In this study, three irrigation intervals based on three different levels of cumulative pan evaporation values (IF_1:20±2 mm, IF_2:40±2 mm and IF_3:60±2 mm), and three irrigation levels (DI_1=0.50, DI_2=0.75 and DI_3=1.00) were considered as treatments. Main plots and subplots were assigned to irrigation frequencies (IF_1, IF_2, and IF_3) and levels (DI_1, DI_2 and DI_3), respectively. Each subplot had dimensions of 8 m long and 5 plant rows wide.

Irrigation water was applied through a drip system in the experiment. Single drip lateral line was laid for each plant row, and inline emitters with discharge rate of 2 L h^{-1} were spaced at 0.20 m intervals on the lateral. The system was operated at 150 kPa throughout the growing season.

Soil water content was measured at 0.3 m increments down to 0.9 m, using a neutron probe (503 DR Hydroprobe, CPN International, Inc., CA., USA) prior to irrigations until harvest. In the top soil layer (0-0.30 m), soil water content was determined gravi-

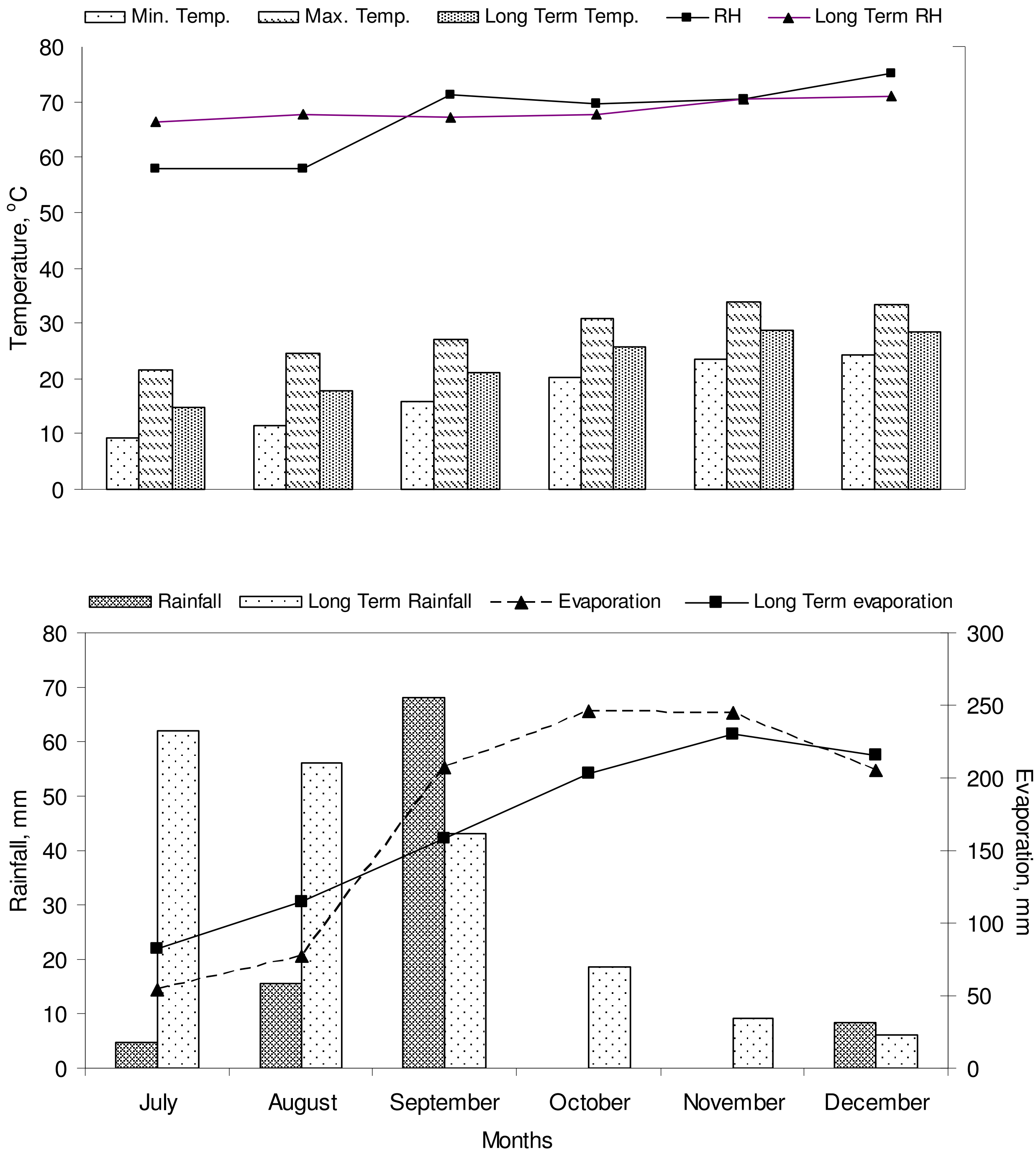

Figure 1. Long-term monthly mean (1955-2004) and 2004 growing season climatic data of the experimental area.

metrically.

Actual crop evapotranspiration (ET) of pepper plants under varying irrigation amounts was calculated with the water balance equation (Equation 1) (Heerman, 1985).

$$ET = I + P \pm \Delta SW - Dp - Rf \quad 1$$

Where, ET, is actual crop evapotranspiration (mm); I, the amount of irrigation water applied (mm); P the precipitation (mm); ΔSW, changes in the soil water content (mm); Dp, the deep percolation (mm); Rf, amount of runoff (mm). Since the amount of irrigation water was controlled, deep percolation and run off were assumed to be negligible. Equation 2 was used to calculate the amount of irrigation water

$$V = P \times A \times Epan \times DI \quad 2$$

Where, V, is the volume of irrigation water (L); P, wetting percentage

Table 1. Yield, irrigation, evapotranspiration, WUE and IWUE data of pepper in different treatments

Irrigation treatment		Seasonal irrigation (mm)	Relative irrigation (%)	Rainfall (mm)	Evapotranspiration (mm)	Relative ET (%)	Pepper yield (kg ha^{-1})*	Relative yield (%)	WUE (kg m^{-3})	IWUE (kg m^{-3})
Irrigation frequency	Irrigation level									
IF$_1$	DI$_1$	355	64.9	85	370	80.0	28730 d	71.6	7.8	8.1
	DI$_2$	451	82.4	85	462	91.1	32720 b	89.4	7.1	7.3
	DI$_3$	547	100.0	85	517	100.0	35920 a	100.0	7.0	6.6
IF$_2$	DI$_1$	352	64.4	85	345	67.1	24100 g	66.7	7.0	6.9
	DI$_2$	447	81.7	85	439	80.4	28890 d	84.9	6.6	6.5
	DI$_3$	542	99.1	85	492	86.8	31190 c	95.2	6.3	5.8
IF$_3$	DI$_1$	351	64.2	85	327	59.5	21390 h	63.2	6.5	6.1
	DI$_2$	447	81.7	85	424	70.8	25440 f	82.0	6.0	5.7
	DI$_3$	542	99.1	85	446	76.3	27400 e	86.3	6.1	5.1

* Duncan grouping at %5 level.

(taken as 100 % for row crops); A, is plot area (m^2); $E_{pan,}$ the amount of cumulative evaporation during an irrigation interval (mm); DI, irrigation levels (0.50, 0.75 and 1.0). Class A Pan is located at the meteorological station next to the experimental plots. A totalizing inflow meter was installed at the control unit to measure total flow distributed to all replications in each treatment.

Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were calculated as pepper yield divided by seasonal crop evapotranspiration (ET) and total seasonal irrigation water applied, respectively (Howell et al., 1990).

Regression analysis was used to evaluate the water use-yield relationships derived from seasonal crop evapotranspiration and yield data obtained from the experiment. Seasonal values of the yield response factor (ky), which represent the relationship between relative yield reduction [1- (*Ya* /*Ym*)] and relative evapotranspiration deficit [1- (*ETa*/*ETm*)], were determined using the equation given by Doorenbos and Kassam (1986):

$$1-\frac{Ya}{Ym}=ky\left(1-\frac{ETa}{ETm}\right) \quad 3$$

Where, *ETa* and *ETm* are the actual and maximum seasonal crop evapotranspiration values (mm), respectively, and *Ya* and *Ym* are the corresponding actual and maximum yields (kg ha^{-1}).

All data were statistically analyzed by analysis of variance (ANOVA) using the MSTATC program (Michigan State University) and treatment means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980). An economic analysis was performed in order to determine the maximum net income, which was computed by subtracting all the production costs from gross incomes for all treatments. All calculations were done based on a unit area of 1 ha (Dağdelen et al., 2009). Pepper production costs and sale prices were obtained from the Chamber of Farmer Association and Agricultural Provincial Directorate in Mersin. Pepper production costs include land rental, fertilizer, seed, soil cultivation, plant protection and, labor cost for irrigation, harvesting and transportation costs. For the calculation of the total cost of pepper production for one year; the sum of crop production costs, yearly cost of irrigation system, irrigation labor and water cost were taken into account.

RESULTS AND DISCUSSION

The irrigation (I) and crop evapotranspiration (ET) results

The informative data about irrigation treatments are summarized in Table 1. In order for good plant stand, a total of 161 mm of irrigation water was applied equally to all treatment plots in several applications. Soil water deficit in the 0.60 m profile depth was replenished to the field capacity in all treatments on August 16, 2004. The first treatment irrigation was applied on August 11, and irrigations were terminated on November 15, 2004. Total number of treatment irrigations varied from 6 in the lowest frequency (IF$_3$) plots to 19 in the high frequency treatment (IF$_1$). Seasonal amount of irrigation water applied varied from 351 mm to 542 mm depending on the DI levels (Table 1). Irrigation intervals varied from 3-5 days in IF$_1$, 6-10 days in IF$_2$, and 12-13 days in IF$_3$ treatments in the 2004 growing season.

Seasonal crop evapotranspiration used by pepper plants varied from 327 mm in IF$_3$DI$_1$ to 517 mm in IF$_1$DI$_3$ plots in the growing season (Table 1). Water use values increased with increasing irrigation level in each irrigation frequency. Üstün (1993) reported drip-irrigated pepper water use varying from 575 to 663 mm in the recommended treatment (6 day irrigation interval and plant pan coefficient of Kcp=0.50) in Central Anatolia of Turkey. Çelik (1991) evaluated the effect of various irrigation regimes on surface-irrigated pepper yields in the North-central Anatolia, and reported water use of 825 mm and seasonal irrigation water of 654 mm, and recommended irrigating at 40% of available water in the 90 cm profile depth.

Water use efficiency and irrigation water use efficiency

The results revealed that both the the irrigation intervals and irrigation levels significantly affected WUE and IWUE values (Table 1). WUE values ranged from 6.0 kg m^{-3} in IF_3DI_2 to 7.8 kg m^{-3} in the IF_1DI_1. In general, water use efficiency on fresh yield basis increased with more frequent irrigation application and WUE decreased with increasing irrigation levels. IWUE values varied from a minimum of 5.1 kg m^{-3} in IF_3DI_3 to a maximum of 8.1 kg m^{-3} in IF_1DI_1 treatment plots. IWUE values decreased with increasing irrigation interval at the same irrigation level. Dukes et al. (2003) reported higher IWUE values for drip-irrigated pepper ranging from 16.0 to 52.6 kg m^{-3} for marketable yields in Florida, USA. Karam et al. (2009) reported WUE values for fresh pepper yield ranging from 5.9 to 7.8 kg m^{-3} in Lebanon.

Profile soil water content

Profile soil water storage variations during the 2004 growing season for each irrigation frequency are shown in Figure 2a-c, respectively. As shown in these figures, soil water contents in the 0.60 m soil depth were kept fairly constant until 14 days after transplanting (DAT) on which 0.60 m depth was replenished to field capacity in all treatments, then treatment irrigations commenced on 28th of August 2004. This study showed that water management of pepper is extremely important at all stages of plant development due to its influence on stand establishment, fruit set and quality. Soil water contents in the 0.60 m profile decreased gradually from DAT 17 until 90 DAT then started to increase slightly until harvest period in growing seasons. Available soil water in DI_2 and DI_3 treatment plots remained above 50% throughout the growing season except DI_3 level. On the other hand, almost all DI plots in IF_3 treatment, available water fell below 50% after 40 DAT during the growing season and resulted in both lower yield and quality due to water stress occurring prior to flowering. The period at the beginning of the flowering period is most sensitive to water shortage and soil water depletion in the root zone during this period should not exceed 25% percent. Water shortage just prior and during early flowering reduces the number of fruits (Doorenbos and Kassam, 1986). Jones et al. (2000) stated that water deficit during this period would have the greatest negative impact on yield and quality. Optimum soil water content during flowering was at 60% of the available water and that either higher or lower water content resulted in suboptimal fruit yields. Soil water should be maintained between 65 and 80% of field capacity (Jones et al., 2000).

In the high frequency treatment plots (IF_1), soil water contents remained fairly high as compared to lower frequency irrigation treatments. For high yields, an adequate water supply and relatively moist soils are required during the total growing period. Reduction in water supply during the growing period in general has adverse effect on yield and the greatest reduction in yield occurs when there is a continuous water shortage until the time of first picking. Water stress in peppers also causes fruit drop, sun scalding and blossom end rot.

The gradually increasing water stress in the lower frequency irrigation treatments caused significant reductions in fruit yield, whereas higher frequency irrigation with high DI levels created a favourable soil water environment for pepper growth resulting in higher yields.

Growth stages of pepper

The number of days after transplanting comprised the time to transplanting, occurrence of the different growth stages and the harvesting time. The dates of occurrence of the growth stages are given in Figure 2a-c, for the recommended treatment (IF_1DI_3). The total length of the growing season of the pepper in this treatment was 122 days. Our experiment did not reveal any differences between the plants in each treatment until the vegetative stage. However, after this stage, the occurrence of flowering, the first fruit set, and the 50% flowering stages of the pepper were observed at earlier dates in the lower irrigation frequencies (IF_2 and IF_3) than the higher irrigation frequency (IF_1), and furthermore in deficit irrigation treatments (DI_1 and DI_2) as compared to unstressed treatment (DI_3). This was most probably due to the different amounts of irrigation water applied to the different intervals of the treatments. The first harvest was made on DAT 48 and the final picking on DAT 122. The growing period of pepper in North Central Anatolia was very close to this period (125 days) despite the differences in climate and soil type (Çelik, 1991).

Pepper yield

Table 2 presents data on yield and some quality parameters of pepper. A total of 7 harvesting was done starting from September 28th and ended on December 11th, 2004. Both the irrigation frequencies and irrigation levels significantly affected fresh pepper yield and some quality parameters (Table 2). Highest yield averaging,

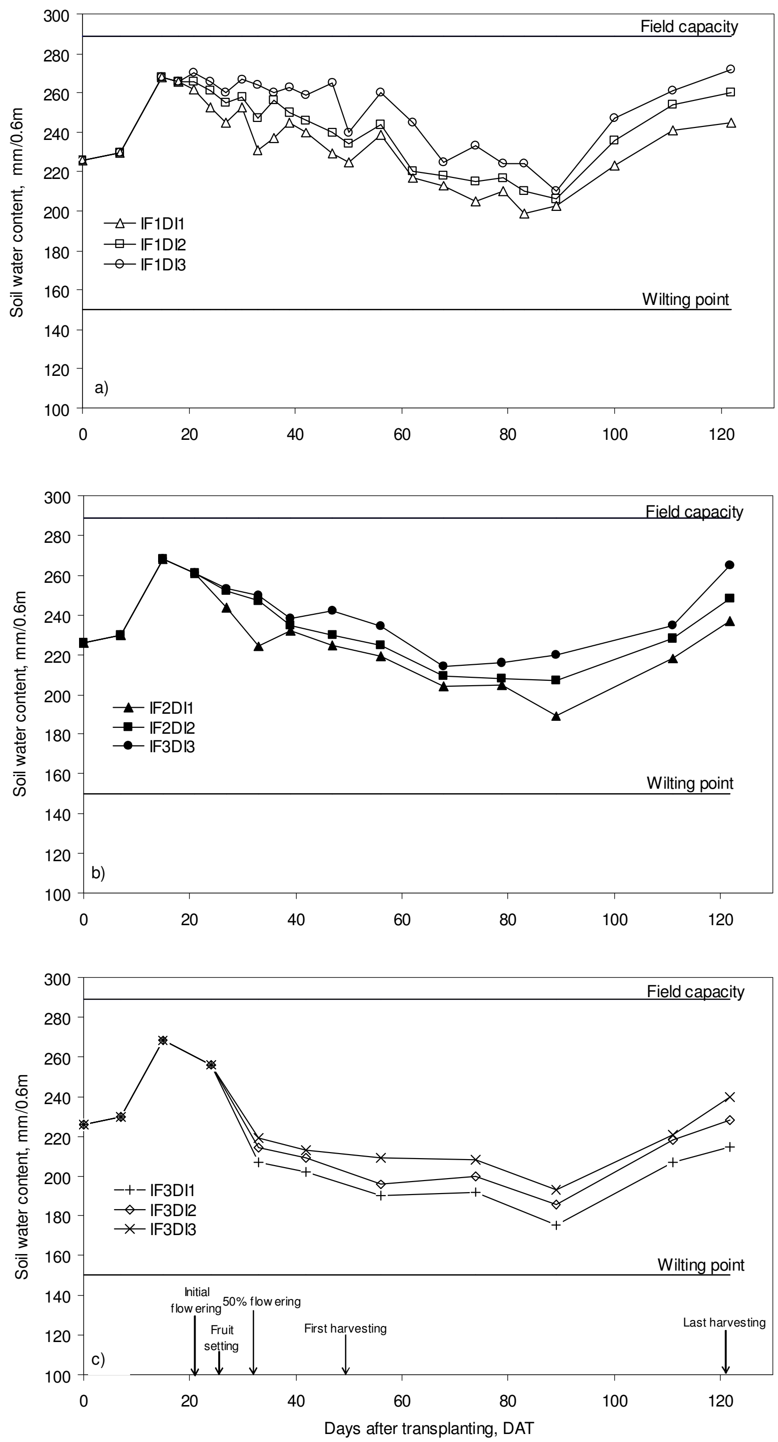

Figure 2. Soil water storage variation with time during the 2004 growing season in all treatments.

35920 kg ha^{-1}, was obtained in IF_1DI_3 treatment, followed by IF_1DI_2 plots with 32720 kg ha^{-1} and minimum yield was obtained from the IF_3DI_1 treatment as 21390 kg ha^{-1}. As the irrigation interval increased (IF_3), pepper yields decreased significantly. The treatment with largest irrigation interval (IF_3) resulted in minimum yields at lower irrigation levels (DI_1, DI_2) along with IF_2DI_1 treatment. Thus, lower irrigation amounts with longer frequency resulted in

Table 2. Total yield and some quality parameters of pepper in different treatments.

Irrigation treatment		Total yield (kg ha^{-1})**	First quality yield (kg ha^{-1})**	Second quality yield (kg ha^{-1})**	Fruit number (1000 ha^{-})**	Mean fruit weight (g)**	Fruit width (mm)**	Fruit length (mm)**	Plant height at harvest (m) *
Irrigation Frequency	Irrigation Level								
IF_1	DI_1	28730 d	20800 d	7930 b-a	1055 bc	27.3a-b	424 e	644 e	0.55 a-c
	DI_2	32720 b	27140 b	5590 b-b	1076 b	30.4a-a	445 b	673 b	0.62 a-b
	DI_3	35920 a	30160 a	5760 b-b	1184 a	30.4a-a	460 a	688 a	0.64 a-a
IF_2	DI_1	24100 g	15600 f	8500 b-a	904 de	26.7a-b	422 e	638 f	0.51 b-c
	DI_2	28890 d	21530 d	7360 b-b	1027 bc	28.2a-a	426 e	652 d	0.55 b-b
	DI_3	31190 c	24320 c	6870 b-b	1075 b	29.0a-a	439 c	666 c	0.59 b-a
IF_3	DI_1	21390 h	11610 g	9790 a-a	899 e	23.8b-b	405 g	612 h	0.48 c-c
	DI_2	25440 f	16780 f	8660 a-b	953 d	26.8b-a	413 f	631 g	0.51 c-b
	DI_3	27400 e	18250 e	9150 a-b	1015 c	27.0b-a	433 d	662 c	0.57 c-a

Letters indicate significant differences at *P<0.05 and **P<0.01. ps. The initial letter marks classification according to the irrigation frequency and the second one according to the irrigation level for the evaluation of second quality yield, fruit weight and plant height at harvest.

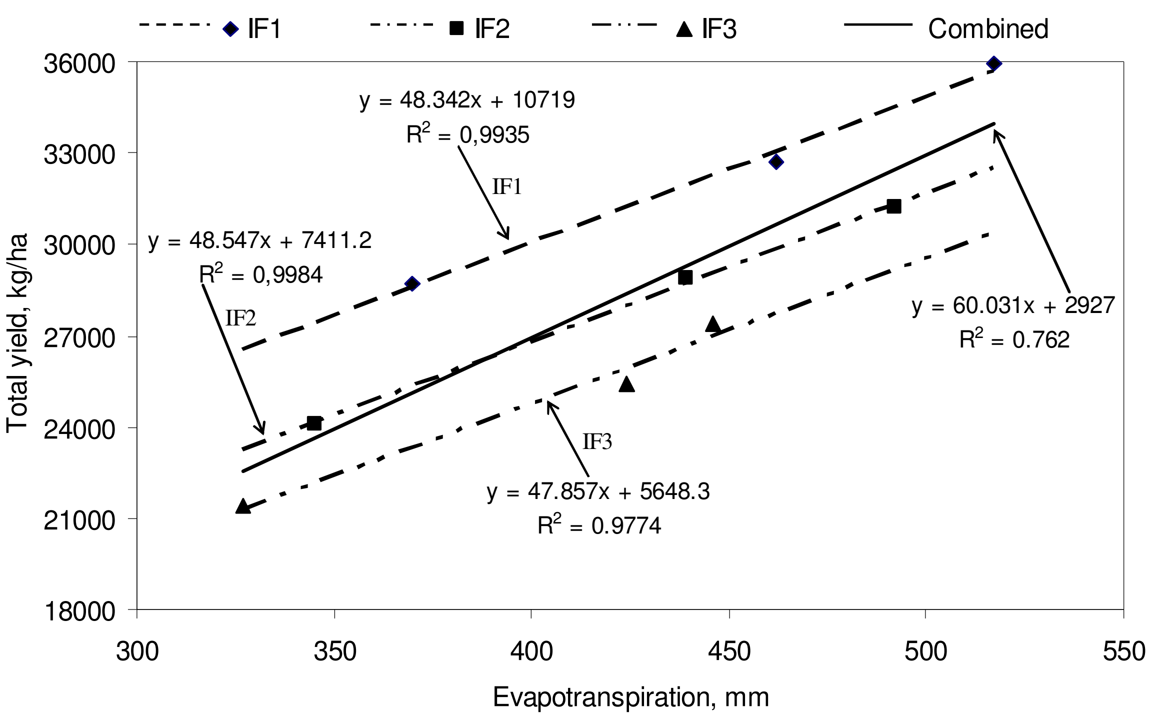

Figure 3. The relationship between seasonal evapotranspiration (ET) and total yield (Y) for three irrigation frequencies.

significantly reduced yields. Duncan grouping of pepper yields from the treatments indicated that yield from the most frequently irrigated treatment (IF_1) with higher irrigation level (DI_3) was in the first group. Thus, an irrigation interval of 9-15 days was found to be unsuitable with lower irrigation levels for drip-irrigated pepper in the region. Üstün (1993) reported a similar finding for drip-irrigated pepper yield varying from 20654 to 26556 kg ha^{-1} in Central Anatolia region of Turkey.

Evapotranspiration yield relationships

Linear relationships were determined between seasonal water use (ET) and yield of pepper in experimental year (Figure 3). Regression equations fit for seasonal water use (ET) versus yields showed that the same increase in ET would induce a different improvement on pepper yields for different irrigation intervals.

The yield response factor (ky), which is the slope of

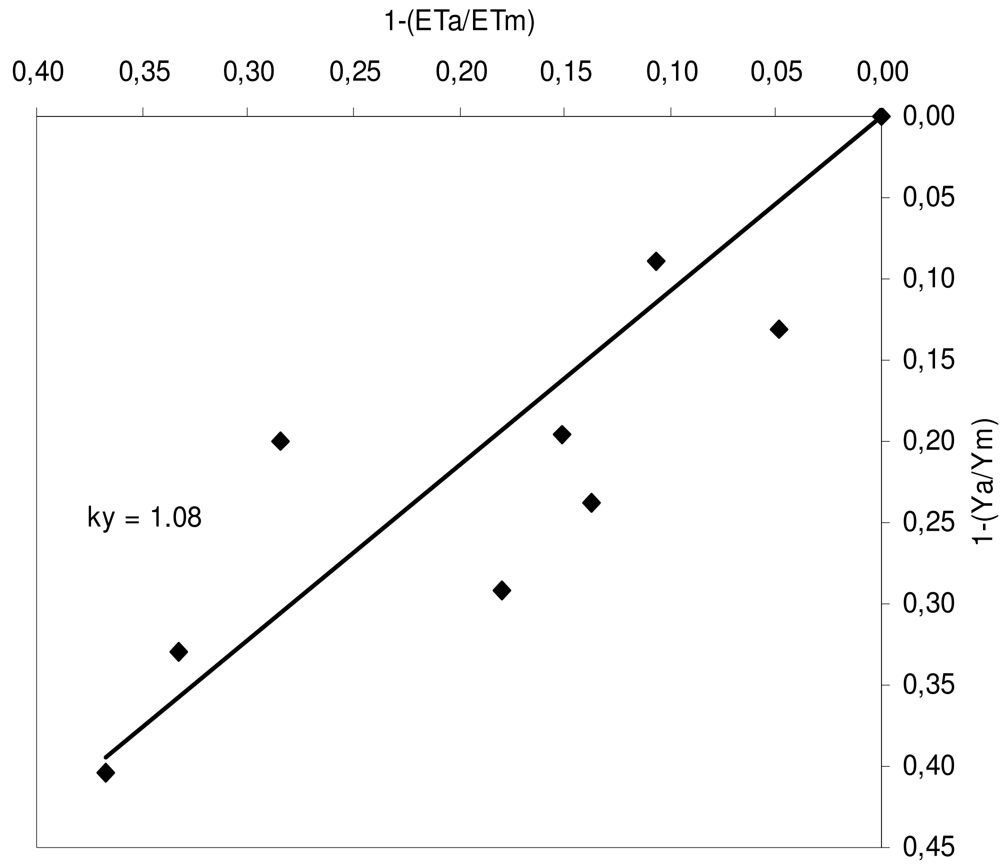

Figure 4. Relationships between relative yield reduction and relative evapotranspiration deficit for pepper (ky).

the relative ET deficit versus relative yield reduction relation, for pepper was found to be 1.08 whole growing season (Figure 4). Doorenbos and Kassam (1986) reported the yield response factor for pepper as 1.1 for whole growing season. Dağdelen et al. (2004) estimated ky factor as 1.14 in the Aegean region of Turkey. These values are similar to our findings.

Fresh fruit quality parameters

First and second quality yields

Some pepper yield quality data in relation to different treatments are presented in Table 2. The results revealed that IF_1DI_3 treatment resulted in significantly higher first quality peppers. Lower first quality yields were obtained from the largest irrigation interval (IF_3) at lower irrigation levels along with IF_3DI_1 treatment. The results indicated that water stress reduced significantly first quality pepper yield. Therefore, higher frequency (IF_1) and higher irrigation level (DI_3) are required to improve the first quality yield. Treatments with lower irrigation level (DI_1) at each irrigation interval generally resulted in highest second quality yields. The higher pepper marketable yield recorded under mild stress conditions, has been previously reported by several authors (Chartzoulakis et al., 1997; Dalla Costa and Gianquinto 2002; Karam et al., 2009).

Fruit number, weight and size

IF_1DI_3 treatment resulted in highest fruit number in the study and followed by IF_1DI_2 and IF_2DI_3 as shown in Table 2. More frequent irrigation with higher irrigation level resulted in significantly higher fruit number. Deficit irrigation with longer irrigation interval resulted in lower fruit number. Increase in fruit number is the most important factor in yield increase. Morever, a uniform supply of soil water throughout the growing season is needed to prevent poor fruit size and shape and to increase yield. Highest mean fruit weight was obtained with DI_3 irrigation level in each irrigation interval (Table 2). Fruit weight is closely associated with a lack of soil water in the root zone; when soil water deficit in the root zone increases, there is a loss in turgidity, and a reduction in growth and fruit weight. Similar results were obtained by Smittle et al. (1994) in pepper grown at water stress.

The effects of the treatments on fruit width were similar to those for the fruit weight revealing the reduction of the fruit width by water stress. The highest mean fruit width (Table 2) was obtained in each irrigation interval of the DI_3 irrigation level. Highest mean fruit length was obtained from the IF_1DI_3 treatment. The results indicated that the higher the irrigation level (DI_3), the higher is the fruit length.

Plant Height

The plant height values in different treatments at harvest time varied from 0.48 to 0.64 m. The DI_3 irrigation level was responsible for the highest plant height in each irrigation interval. The decreasing amounts (lower DI) of irrigation water caused a significant decrease in plant height. Irrigation intervals also signiificantly affected the plant height values and longer the interval the shorter is the plant height.

Economical evaluation

Economical analysis was done by using the results of this study based on investment, operation and production costs, and the results are presented in Table 3. Net income values increased from DI_1 treatment to DI_3 treatment each irrigation frequency and IF_1DI_3 was found to be the most profitable. According to economical evaluation, the maximum net income was obtained as US$ 12514 ha^{-1} for the IF_1DI_3 treatment (most frequently irrigated treatment with full irrigation level). Moderate deficit irrigation treatment DI_2 resulted in a net income of US$ 7133 ha^{-1}, and US$ 4442 ha^{-1}, in IF_2 and IF_3 irrigation frequencies, respectively. Lower irrigation level (DI_1) resulted in the lowest net income each irrigation frequency. IF_3DI_1 treatment generated a net income of US$1382 ha^{-1}. It was noted that there was a significant difference in terms of net income between the treatments. As water supply increased, net income was also raised all irrigation frequencies. On the other hand, IF_1DI_1 treatment resulted in significantly more income compared to the other treatments (Table 3).

The total production costs of IF_1DI_3 treatment include the following components with the associated percentage of the total cost in parentheses: Crop production (90.0 %), irrigation system (32.2 %), labor (0.21%) and water (3.52 %). Similar relationship was obtained by Dağdelen et al. (2009) for cotton under drip irrigation condition. In regions where access to the irrigation water is costly or water supply is less than demanded, IF_1DI_2 treatment is found to be reasonable. In this study, 17.6 % saving in irrigation water (IF_1DI_2) resulted in 8.9 % loss in yield, but resulted in 19.2 % reduction in the net income (Table 3). Above all this, the net income of the IF_1DI_3 treatment is found to be reasonable in areas with no water shortage.

Conclusions

Our results significantly demonstrated that the effects of the amount of the irrigation water and frequency as well as water use are the prime factors in obtaining higher yields of field grown pepper under Mediterranean climatic conditions. Irrigation intervals and levels had significant effects on the yield and quality of pepper at a $P<0.01$ level. The maximum yield (35920 kg ha^{-1}) of the 2004 growing season was obtained from the IF_1DI_3 treatment with the highest water use. Moreover the IF_1DI_3 treatment yielded better quality fruit compared to the other treatments, due to the positive effects of the higher frequency (3 to 6 days) and higher DI (DI=1.0) on quality parameters.

The results indicated that the WUE and IWUE values decreased with the increasing irrigation interval. The higher WUE and IWUE were obtained at the lowest DI level of each irrigation interval. However, the lowest DI levels resulted in lower total yields and lower quality. Thus, the use of less frequent irrigation with low DI levels for drip irrigated pepper production in the region is not recommended.

Significant relationships between the pepper yield and the seasonal water consumption were found for each irrigation frequency in this study. Irrigation intervals resulted in similar seasonal water use in the treatments with the same DI level.

In conclusion, the IF_1DI_3 treatment (3-6 days irrigation interval and (DI=1)) is recommended for drip irrigated pepper grown under field conditions for higher and better quality yield in the Mediterranean belt of Turkey. Moreover, the generative growth parameters beside the vegetative ones were best in the IF_1DI_3 treatment, because of the higher amounts of irrigation water use and plant water consumption positively affecting pepper quality parameters (fruit width, length, number of fruits and fruit weight). The evapotranpiration of the pepper was determined to be lower than the evapotranspiration from the Class A Pan in the early and late growing stages indicating the use of lower DI levels instead of the DI_3 used for water saving. In case of water shortage regarding IWUE and WUE, the recommended water regime can be the IF_1DI_2.

Moreover, generative growth parameters besides vegetative ones were best in the IF_1DI_3, because higher irrigation water amount and plant water consumption positively affected pepper total yield, first quality and yield components such as the fruit weight, fruit width and length as well as plant height at harvest. Therefore, in order to attain higher fruit yield, full irrigation is recommended under the Mediterranean climatic conditions. However, under water scarcity situation, moderate deficit irrigation IF_1DI_2 provides an acceptable strategy for both higher fruit yield. According to the economic evaluation, the net income from the IF_1DI_3 treatment is found to be reasonable in areas with no water shortage. However, under water scarcity conditions, IF_1DI_2 treatment can

Table 3. The summary of the economic analysis of the different irrigation treatments.

Treatment	Irrigation water (mm) (1)	Irrigation water (m^3 ha^{-1}) (2)	Irrigation duration for the irrigation season (h) (3)	Labor cost for irrigation (\$ h^{-1}) (4)	Total cost for irrigation labor (\$) (5) (3x4)	Water price (\$ m^{-3}) (6)	Water cost (\$ ha^{-1}) (7) (2x6)	Crop production costs (\$ ha^{-1}) (8)
IF_1D_1	355	3550	28.4	0.37	10.5	0.1	355.0	13941
IF_1D_2	451	4510	36.1	0.37	13.4	0.1	451.0	13941
IF_1D_3	547	5470	43.8	0.37	16.2	0.1	547.0	13941
IF_2D_1	352	3520	28.2	0.37	10.4	0.1	352.0	13941
IF_2D_2	447	4470	35.8	0.37	13.2	0.1	447.0	13941
IF_2D_3	542	5420	43.4	0.37	16.1	0.1	542.0	13941
IF_3D_1	351	3510	28.1	0.37	10.4	0.1	351.0	13941
IF_3D_2	447	4470	35.8	0.37	13.2	0.1	447.0	13941
IF_3D_3	542	5420	43.4	0.37	16.1	0.1	542.0	13941

Treatment	Irrigation system cost for 1 ha (\$ h^{-1}) (9)	Yearly cost for the irrigation system (\$ ha^{-1}) (10) (9/5 years)	Total cost for 1 year (\$ ha^{-1}) (11) (5+7+8+10)	Yield (kg ha^{-1}) (12)	Pepper sales price (\$ kg^{-1}) (13)	Gross income per ha (\$ ha^{-1} $year^{-1}$) (14) (12x13)	Net income (\$ ha^{-1} $year^{-1}$) (15) (14-11)
IF_1D_1	5000	1000	15306.5	28730	0.78	22409	7103
IF_1D_2	5000	1000	15405.4	32720	0.78	25522	10117
IF_1D_3	5000	1000	15504.2	35920	0.78	28018	12514
IF_2D_1	5000	1000	15303.4	24100	0.78	18798	3495
IF_2D_2	5000	1000	15401.2	28890	0.78	22534	7133
IF_2D_3	5000	1000	15499.1	31190	0.78	24328	8829
IF_3D_1	5000	1000	15302.4	21390	0.78	16684	1382
IF_3D_2	5000	1000	15401.2	25440	0.78	19843	4442
IF_3D_3	5000	1000	15499.1	27400	0.78	21372	5873

generate an acceptable net income in which 17.6 % saving in irrigation water (IF_1DI_2) resulted in 8.9% loss in yield and 19.2% reduction in the net income as compared to full irrigation. The results of the economic analysis under various irrigation strategies provide information to policy makers for formulating improved planning regarding irrigation management practices. The results would be helpful in adopting deficit irrigation in ways that enhance net financial returns.

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