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THE IMPACTS OF TRANSITION FROM FLOOD IRRIGATION TO DRIP IRRIGATION METHOD ON PLANT WATER CONSUMPTION AND YIELD IN APPLE GROWING

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Abstract

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This study elucidates the effects of transition from flood irrigation to drip irrigation method on apple trees regarding the water consumption and yield of the plant in 2008 and 2009. Starkrimson Delicious variety grafted onto seedling rootstock was used in the study. The studied apple trees had been irrigated by flood irrigation for many years. During the study, flood irrigation was continued at one part of the orchard, and drip irrigation was applied with different irrigation programs at the remaining parts of the orchard. Irrigation interval was held 20 days for flood irrigation (conventional) method. For drip irrigation, two different irrigation intervals (I_1=4 days, I_2=7 days) and four different pan coefficients (K_{cp1}=0.50, K_{cp2}=0.75, K_{cp3}=1.0, K_{cp4}=1.25) were used in the study. The highest amounts of irrigation water and plant water consumptions were determined for flood irrigation treatment for both years. Expanding the irrigation interval and increasing the pan coefficient led to an increase in plant water consumption during drip irrigation treatments. The highest amount of plant water consumption was determined in I_2K_{cp4} treatment. Statistically, while the yield with flood irrigation treatment was higher than K_{cp1} and K_{cp2} treatment, the yield data of K_{cp3} and K_{cp4} treatments were similar in both years. Irrigation levels (K_{cp}) influenced the yield ($p < 0.01$); however, irrigation intervals and irrigation intervals x irrigation level interaction did not have any impact on the yield. Kcp_3 and Kcp_4 (1.25) represented a more marketable fruit size (extra and class 1) than flood irrigation.

As a result, during the application of drip irrigation for the apple trees, which were previously irrigated, by flood irrigation for many years, the irrigation interval and pan coefficient (K_{cp}) under similar climatic and soil conditions were considered as 4 days and 1.0, respectively.[1]

Key words: apple, yield, drip irrigation, flood irrigation, plant water consumption

Introduction

Global climate change is predicted to have negative effects on both agriculture production and water resources. The people will work more for higher yields per unit of irrigation water due to scarcer and more expensive water resources in the future. Therefore, available water resources should be used more carefully.

Apple production is very important for Turkey and Turkey ranks the 3rd in the world with 2.600.000 tons apple production (Anonymous, 2011). Apple growers have certain problems about growing techniques, especially on irrigation. Basing irrigation on a certain program is critical for plant growth and sustainable water resources. Furthermore, irrigation time of plants and amount of the water applied for each irrigation must be determined accurately **to obtain full efficiency from water** (Barragon and Wu, 2001)**.** Haphazard irrigations prevent plants from obtaining irrigation efficacy, which results in undesired consequences such as high cost, salinity-sodium and low yields (Levin et al., 1973). Growers have started preferring drip irrigation instead of surface irrigation methods (flooding etc.) in recent years, since drip irrigation methods require less water and provide a high yield and crop quality. Besides, it offers other benefits such as ease of use and application, etc.

Apple growers have also adopted drip irrigation instead of surface irrigation methods (flooding etc.) in recent years. How-

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ever, as the growers have continued holding on their certain habits (first irrigation time, irrigation intervals, amounts of applied irrigation water for each irrigation etc.) from their previous irrigation methods (flood irrigation etc.), some problems have occurred on irrigation scheduling, yield and tree growth during the transition period (Küçükyumuk and Ay, 2010).

This study aims to ensure the accommodation and adjustment of apple trees with wide root systems irrigated with flood irrigation method for many years into drip irrigation method after the commencement of drip irrigation, identify the changes in water consumption and yield values of the plants, and analyse their accommodation status and identify the changes in the plants water consumption and yield values, which might occur during this phase.

Material and Methods

Study area and plant material

This study was carried out at Eğirdir Fruit Growing Research Station in 2008 and 2009. The research field has a transitive climate between those of the Mediterranean and Central Anatolia. The highest average temperature is in July (23.8°C), and the lowest in January (1.9°C). Precipitation amounts were respectively 45.0 mm and 70.4 mm in 2008 and 2009. Precipitation is insufficient during the growing period of apple (May-September). Therefore, apple trees require irrigation during their growing period. The soil in the research field is clayey, with a loamy, low-salinity, low and moderate alkalinity structure, which is insufficient in terms of organic substances (Table 1). The results of the analysis of the irrigation water used in the study are given in Table 2. Classification was realized according to the US Salinity Laboratory Graphical System. According to this system, the salinity values of the irrigation water, which are in 250-750 ECx10^6 range, are included in category C_2, and in category S_1 in terms of SAR value (USSL, 1954). Irrigation water was C_2S_1 class, which is suitable for irrigation.

Trees were planted in 1988 with 5 m x 4 m spacing. Starkrimson Delicious variety grafted onto seedling rootstock was used in the study. The orchard had been irrigated by flood irrigation method until 2008. As to the fertilizers during the study, ammonium nitrate (33% N), MAP (Monoammonium phosphate, 12-61-0) and potassium nitrate (13-0-46) were used in drip irrigation treatments, while ammonium nitrate, diammonium phosphate (DAP, 18-46-0) and potassium sulphate (50% K) were used in flood irrigation treatment. The fertilizers were applied by fertigation technique in drip irrigation method, and by mixing with soil before the irrigations in flood irrigation method.

Irrigation treatments

One part of the orchard was allocated for flood irrigation treatment, and different irrigation programmes under drip irrigation were applied in the remaining parts. Flood irrigation treatment was considered as a control treatment in order to determine the effects of changing the irrigation method on water consumption and yield. One irrigation interval was employed for flood irrigation treatment, following the common habits of the apple growers in the district (20 days). Drip irrigation treatments of the study included two different irrigation intervals (I_1=4 days, I_2=7 days) and four different pan coefficients (Kcp_1=0.50, Kcp_2= 0.75, Kcp_3=1.00, Kcp_4=1.25).

Irrigation water was supplied from an irrigation canal by a pump. A water meter was used to control the amounts of irrigation water. Irrigation water was transferred to the test plots by a main pipe with 90 mm diameter during drip irriga-

Table 1
Soil characteristics of trial plots

Depth, cm	γ, g cm^{-3}	FC, %	WP, %	Salinity, ECx10^6	pH	Lime, %	St,. %	Organic matter, %	Texture
0-30	1.34	29.1	14.2	234	7.64	7.2	46	1.54	Clay
30-60	1.38	26.5	12.4	190	8.20	8.6	45	1.60	Clay
60-90	1.30	27.9	13.5	175	8.10	5.8	47	1.50	Clay
90-120	1.40	25.8	11.9	170	8.00	6.4	49	1.50	Clay

γ: unit weight of soil; FC: field capacity; WP: wilting point; St: saturation

Table 2
Analysis of irrigation water

Class of irrigation water	μhos cm^{-1}	pH	Kations, mg l^{-1}				Anions, mg l^{-1}				Na, %	SAR
			Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^-	HCO_3^-	Cl^-	$SO_4^=$		
C_2S_1	408	8.3	7	4	44.1	46.2	-	20.2	48.6	32.5	6.9	1.04

tion treatments. The lateral pipes with 16 mm diameter were laid along both sides of each row of trees. Emitter spacing on laterals were 0.75 m with all emitters having a discharge rate of 4 l/h^{-1}. One mini valve was used for controlling the amount of irrigation water for each lateral input. Irrigation water was transferred from the main pipe to the flood irrigation treatment with a 40 mm diameter connector. All plots were irrigated with flood irrigation until the soil water reached field capacity for each irrigation interval at 0-120 cm soil depth.

The percentage cover was calculated as 0.60 (P) for drip irrigation treatments, while it was 1.0 (P) for flood irrigation treatment as the entire soil surface was watered then. Soil moisture was measured at respectively 30, 60, 90 and 120 cm soil depths with a digital tensiometer before each irrigation for both drip and flood irrigation treatments. Because irrigation interval was a long period in flood irrigation treatment, soil water was measured gravimetrically at 30 cm soil depth. Scheduled irrigations were initiated on May 20 and 21 in 2008 and 2009, respectively for drip irrigation treatments –at the time when the soil moisture capacity of the field reached 0-120 cm soil depth. Meanwhile, first irrigation for flood irrigation was initiated on June 27 and 24 in 2008 and 2009, respectively. First irrigation time was determined by taking into consideration the farmers' common practice in the district.

The moisture of soil was measured before each irrigation and the applied irrigation water amount during each irrigation was noted. During the next irrigation, the soil moisture was measured and the difference was recorded as "plant water consumption" of that treatment. Evapotranspiration was calculated according to the following water balance method (Eq. (1)) (James, 1988) for each treatment of drip irrigation.

$$E_t = I_r + R + C_r - D_p - R_f \pm \Delta s, \qquad (1)$$

where E_t is the evapotranspiration (mm), I_r is the amount of irrigation water (mm), R is the rainfall (mm), C_r is the capillary rise (mm), D_p is the water loss by deep percolation (mm), R_f is the surface run-off (mm), and Δs is the change in profile soil water content (mm).

C_r values were considered as zero as there were not any ground water problems in the area. Dp was ignored since the amount of water applied through irrigation was not above the field capacity. R_f was not taken into account either as the total water amount applied through irrigation was measured for each irrigation. The amounts of precipitation were measured after every raining day with a pluviometer positioned near the Class-A pan.

Irrigation quantity in Eq. (1) was calculated for each treatment of drip irrigation according to Eq. (2) (Ertek and Kanber, 2003).

$$I_r = E_{pan} \ x \ K_{cp} \ x \ P, \qquad (2)$$

where I_r is the amount of applied irrigation water (mm), E_{pan} is the cumulative evaporation quantity at each irrigation interval (mm), K_{cp} is the plant-pan coefficient, and P is the wetting area (0.60). **Evaporation quantity between irrigation intervals** were measured everyday with a Class-A pan positioned near the plots. Percentage cover was taken into account for calculating the amount of irrigation water since apple trees with wide canopies were used in the study.

Irrigation water use efficiency (IWUE) and water use efficiency (WUE) were calculated with Eq. (3) and Eq. (4) (Howell et al., 1990; Kanber et al., 1992) for all treatments.

$$IWUE = (E_y / I_r) \ x \ 100, \qquad (3)$$

where IWUE is the irrigation water use efficiency (t ha^{-1} mm), E_y is the marketable yield (t ha^{-1}), and I_r is the quantity of applied irrigation water (mm). In the calculation, total yield was taken for E_y.

$$WUE = (E_y / E_t) \ x \ 100, \qquad (4)$$

where WUE is the water use efficiency, t ha^{-1} mm; E_y is the marketable yield, t ha^{-1}, and E_t is the plant water consumption, mm.

The Equation (5) was used for determining the yield-response factor (K_y) (Doorenbos and Kassam, 1979).

$$Ky = (1 - Y / Y_m) / (1 - E_t / E_{tm}), \qquad (5)$$

where, Y – the real yield (t ha^{-1}), Y_m – the maximum yield (t ha^{-1}), E_{tm} – the maximum plant water consumption (mm), and K_y – the yield-response factor.

Fruits were harvested and weighed from four trees in each plot. Then the yield was determined in terms of kg $tree^{-1}$ and kg da^{-1}. Harvesting dates were September 23 and 26 in 2008 and 2009, respectively.

Grading of furit: For fruit assessments, samples of 15 fruits in one tree for per replicate were selected. Total 45 fruits per treatment (fifteen fruits in one tree) were assessed for quality at the commercial harvest. All fruits picked during commercial harvests were graded. Fruit diameter was used as the prior quality criterion for classification. Fruit was graded on a commercial size grade ranging from 50-95 mm. The percentage of fruit in various size categories extra (>75 mm), class 1 (68-75 mm), class 2 (60-68 mm) and other (<60 mm) was determined.

Experimental design and statistical analysis: The experiment was designed according to completely randomized simple factorial design with tree replications. Each plot consisted of totally eight trees aligned in two rows with 5x4m tree spacing. Four trees in the middle of each plot were used for measurements. There was an extra row of trees, i.e. replications to separate the irrigation treatments from each other between the embankments. Left and right sides of the trees on the separation row received different amounts of irrigation water according to the closest irrigation treatment in order to reduce interruption between the treatments. About flood irrigation, in order to prevent the overflow of water and its impact on other plots, the perimeter of each tree in the plots was surrounded by 40 cm-high earth embankment to cover 5 x 4 m area (between the row and in a row). Thus, separate (individual) basins for each tree were constructed. Trees were irrigated by ponding of water in the basins; separately for each tree. During each irrigation, measured amount of water was applied to equalize the missing moisture of 0-120 cm deep soil to the field capacity. Therefore, the measures to prevent leaking of water into deep were taken. In this way, the impact of the water applied for flood irrigation on other subjects was prevented.

Statistical analysis: The analysis of variance (ANOVA) test for the data was conducted with SPSS software program and differences among treatments were compared by means of Duncan multiple comparison test (SPSS, 2003).

Results

Irrigation water and plant water consumption

Yield, total irrigation water amount and plant water consumption values in 2008 and 2009 are presented in Table 3. Monthly cumulative water consumption of all treatments in 2008 was showed in Figure 1. Totally, 63.8 mm water was applied within drip irrigation treatments during the first irrigation on May 20, 2008 until the soil water reached field capacity at 0-120 cm root zone. Then, scheduled irrigations with 4 and 7 days irrigation intervals from this date were initiated. During the growing season, treatments were irrigated with 4 and 7 days intervals for 31 and 18 times, respectively. First irrigation with flood irrigation was initiated on June 27, 2008. Irrigation water was applied for each irrigation in flood irrigation until the soil water content reached the field capacity at 0-120 cm root zone. Flood irrigation treatment was applied for 5 times during the growing season.

Amounts of irrigation water were similar in both irrigation intervals during drip irrigation treatments. The lowest amounts of irrigation water were applied in K_{cp}=0.50 treat-

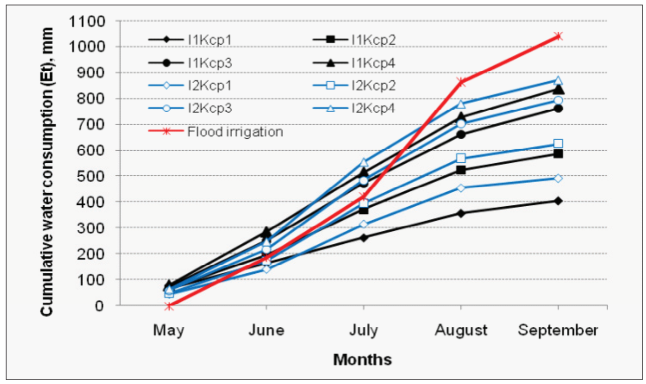

Fig. 1. Monthly cumulative water consumption of all treatments in 2008

Table 3
Yield (kg da^{-1}), irrigation water amount (I_r) and plant water consumption (E_t) in 2008 and 2009

Treatments	2008			2009		
	I_r, mm	E_t, mm	Yield, kg da^{-1}	I_r, mm	E_t, mm	Yield, kg da^{-1}
I_1Kcp_1	349.2	405.6	4633.3 bc*	315.1	437.2	4360.0 bc*
I_1Kcp_2	491.9	588.1	5535.0 abc	445.3	564.2	5278.3 abc
I_1Kcp_3	634.6	761.5	6016.7 ab	575.5	666.5	6098.3 a
I_1Kcp_4	777.2	839.6	6567.3 a	705.8	799.6	5974.2 a
I_2Kcp_1	347.7	491.9	4495.2 c	313.6	495.7	4258.3 c
I_2Kcp_2	489.7	626.2	5413.7 abc	443	608.8	5105.0 abc
I_2Kcp_3	631.6	793.2	5696.7 abc	572.5	723.4	5730.0 ab
I_2Kcp_4	773.6	872	6466.5 a	702.2	849.9	5700.0 ab
Flood irrigation	997.9	1040.9	6765.7 a	917.3	969.3	5821.7 a
Evaporation (mm)	956.3			874.8		
Precipitation (mm)	45			70.4		

* Means followed by the same letter are not significantly different, *$p<0.05$
I_1=4 days, I_2=7 days, Kcp_1=0.50, Kcp_2=0.75, Kcp_3=1.00, Kcp_4=1.25

ments with 4 and 7 days intervals, while the highest amount of irrigation water was applied in K_{cp}=1.25 treatments for both irrigation intervals. Plant water consumption values were different for similar pan coefficients in both irrigation intervals. E_t values in 7 days irrigation intervals were higher than those of 4 days irrigation intervals. The lowest amount of plant water consumption was identified during I_1K_{cp1} (405.6 mm) treatment, while the highest amount of plant water consumption was identified in I_2K_{cp4} treatment (872.0 mm). Amounts of irrigation water and plant water consumption during flood irrigation treatment were identified as 997.9 and 1040.9 mm, respectively. During the growing season, evaporation was 956.3 mm and precipitation was 45.0 mm.

Monthly cumulative water consumption values in 2009 were showed in Figure 2. Totally, 54.6 mm water was applied during all drip irrigation treatments on May 21, 2009 for the soil water to reach the field capacity at 0-120 cm root zone. The scheduled irrigations were initiated after that date. During the growing season, treatments were irrigated with 4 and 7 days irrigation intervals for 31 and 18 times, respectively. First irrigation for flood irrigation treatment was initiated on June 24, 2008 and the plants were irrigated 5 times within this treatment during their growing season. K_{cp}=1.25 and K_{cp}=0.50 treatments represented respectively the highest and lowest amounts of irrigation water for both irrigation intervals of drip irrigation treatments. The highest amount of plant water consumption was identified during I_2K_{cp4} treatment with 849.9 mm, and the lowest value during I_1K_{cp1} treatment with 437.2 mm. Amount of irrigation water and plant water consumption in flood irrigation treatment were identified as 917.3 and 969.3 mm, respectively. Evaporation was 874.8 mm and precipitation was 70.4 mm during the growing season. Because evaporation was higher in 2008 than 2009, amount of irrigation water and plant water consumption in 2008 were also higher than those in 2009.

Figure 3 shows the relations between E_t-I_r values for drip irrigation treatments. Positive linear relations were identified between E_t and I_r with R^2=0.95** and R^2=0.96** in 2008 and 2009, respectively. Soil water was measured on the harvest date following the last irrigation in both years for drip and flood irrigation treatments and the measurements were added to the plant water consumption.

Yield data

Yield data are presented in Table 3. Fruits were harvested on September 23 and 26 in 2008 and 2009, respectively. The highest yield among all treatments was obtained from flood irrigation treatment in 2008 (6765.7 kg da^{-1}). The highest and lowest yields in drip irrigation treatments were identified as I_1Kcp_4 (6567.3 kg da^{-1}) and I_2Kcp_1 (4495.2 kg da^{-1}), respectively. I_1Kcp_3 provided the highest yield (6098.3 kg da^{-1}) in 2009, whereas the lowest yield was obtained from Kcp_1 treatments with 4258.3 kg da^{-1} (I_2Kcp_1) and 4360.0 kg da^{-1} (I_1Kcp_1). Yield of flood irrigation treatment in 2009 was more than that of 7-days treatments with 5821.7 kg da^{-1}.

Water-yield relations

Table 3 provides the irrigation water, plant water consumption and yield data of the study. Figure 4 shows the relations between yield, I_r and E_t for both years in drip irrigation. Positive linear relations were identified between I_r and yield (R^2=0.96**), and between E_t and yield (R^2=0.92**) in 2008. As the amount of irrigation water increased, plant water consumption and yield also increased during both irrigation intervals. Positive polynomic correlations were found between I_r and yield (R^2=0.95**) and between E_t and yield (R^2=0.92**) in 2009 (Figure 5). As the irrigation water increased, the plant water consumption and yield also increased up to Kcp=1.0 level during both irrigation intervals. As the irrigation water and plant water consumption also in-

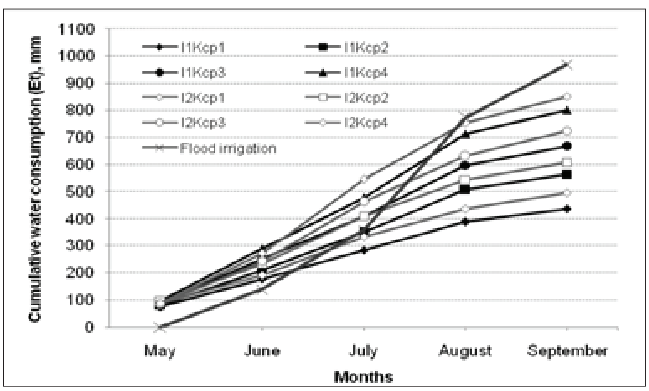

Fig. 2. Monthly cumulative water consumption of all treatments in 2009

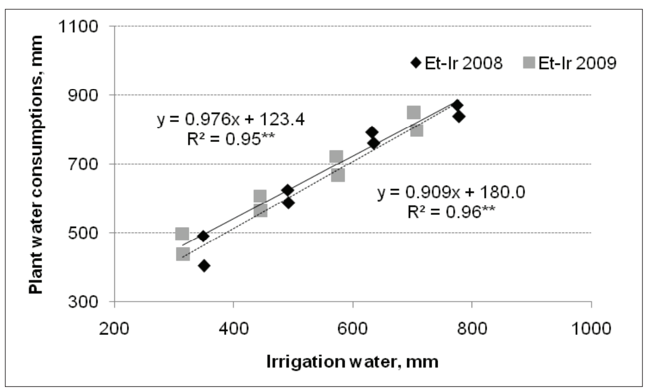

Fig. 3. Relations between E_t-I_r for drip irrigation treatments in 2008 and 2009

creased after that level, a decline in yield (Kcp_4 treatments) was noted beyond this level of irrigation water. Table 4 also presented the correlation equations and coefficients among the I_r, E_t and yield. According to the results of variance analyses in drip irrigation treatments (Table 5), while irrigation levels (Kcp) had positive effects on the yield (*p<0.01*); irrigation intervals and irrigation intervals x irrigation levels interaction had no effects on the yield.

Water use efficiencies

As seen on Table 6, the highest WUE (water use efficiency) was identified in I_1Kcp_1 treatments with 11.42 kg da^{-1} mm^{-1}

Table 4
Correlation equations and coefficients among the I_r, E_t and yield

Yield components	2008	2009
	Irrigation water (Ir)	
Evapotranspiration (E_t)	y = 0.976x + 123.4 R^2 = 0.95**	y = 0.909x + 180.0 R^2 = 0.96**
Yield, kg/da	y = 4.389x + 3136. R^2 = 0.96**	y = -0.014x² + 18.49x - 139.3 R^2 = 0.95**
	Evapotranspiration (E_t)	
Yield, kg/da	y = 4.155x + 2798 R^2 = 0.92**	y = -0.011x² + 17.61x - 983.6 R^2 = 0.92**

** p < 0.01

Table 5
Variance analysis of the yield in 2008 and 2009 in drip irrigation treatments

Variation sources	Yield-2008				Yield-2009		
	DF	SS	F	P	SS	F	P
Main effects							
I_r	1	173570	0.297	0.59 *ns*	315677.3	0.5851	0.4570 *ns*
K_{CP}	3	11970883	68.286	0.0046**	9950807	61,474	0.0069**
Repeat	2	1458194	12.477	0.3172 *ns*	189272.4	0.1754	0.8409 *ns*
Interaction							
I_r x K_{cp}	3	45999	0.0262	0.9940 *ns*	61148.7	0.0378	0.9897 *ns*
Error	14	8180944			7553932		
Total	23	21829589					

DF: degree of freedom; SS: sum of squares; P: level of significance; ** p < 0.01; ns: no significant

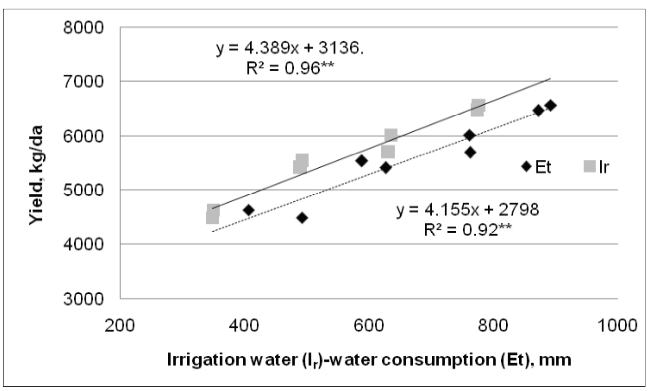

Fig. 4. Relations between yield, I_r and E_t for drip irrigation treatments in 2008

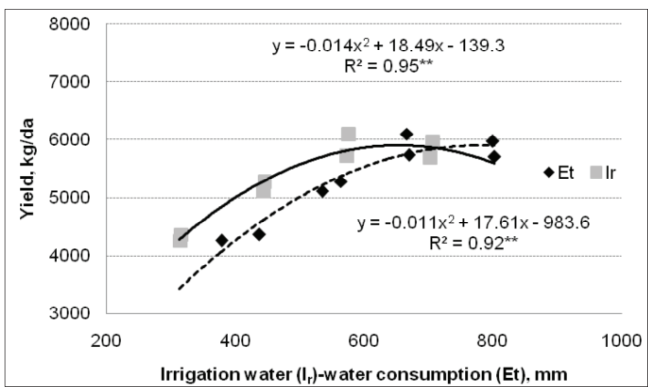

Fig. 5. Relations between yield, I_r and E_t for drip irrigation treatments in 2009

Table 6
Water use efficiency (WUE) and irrigation water use efficiency (IWUE)

Treatments	2008		2009	
	WUE, kg da^{-1} mm^{-1}	IWUE, kg da^{-1} mm^{-1}	WUE, kg da^{-1} mm^{-1}	IWUE, kg da^{-1} mm^{-1}
I_1Kcp_1	11.42	13.27	9.97	13.84
I_1Kcp_2	9.41	11.25	9.36	11.85
I_1Kcp_3	7.9	9.48	9.15	10.6
I_1Kcp_4	7.82	8.45	7.47	8.46
I_2Kcp_1	9.14	12.93	8.59	13.58
I_2Kcp_2	8.65	11.06	8.39	11.52
I_2Kcp_3	7.18	9.02	7.92	10
I_2Kcp_4	7.42	8.36	6.71	8.12
Flood irrigation	6.5	6.77	6	6.34

I_1=4 days, I_2=7 days, Kcp_1=0.50, Kcp_2=0.75, Kcp_3=1.00, Kcp_4=1.25

in 2008. The lowest WUE was obtained from I_2Kcp_3 treatments with 7.18 kg da^{-1} mm^{-1}. Flood irrigation had the lowest WUE among all treatments (6.50 kg da^{-1} mm^{-1}). I_1Kcp_1 and I_2Kcp_4treatments proved the highest and lowest IWUE (irrigation water use efficiency) with 13.27 and 8.36 kg da^{-1} mm^{-1} in drip irrigation, respectively. The lowest IWUE was determined with flood irrigation (6.77 kg da^{-1} mm^{-1}).

Compared to I_1Kcp_1 treatment, which had the highest WUE (9.97 kg da^{-1} mm^{-1}) in drip irrigation, the lowest WUE was determined in I_2Kcp_4 treatment with 6.71 kg da^{-1} mm^{-1} in 2009. Flood irrigation had a lower WUE (6.00 kg da^{-1} mm^{-1}) than drip irrigation treatments according to the findings of the study. With respect to IWUE, the highest IWUE was measured in I_1Kcp_1 treatment with 13.84 kg da^{-1} mm^{-1} in drip irrigation. I_2Kcp_4 treatment had the lowest IWUE 8.12 kg da^{-1} mm^{-1}. Meanwhile, flood irrigation treatment represented the lowest IWUE with 6.34 kg da^{-1} mm^{-1} in all treatments according to the findings.

In view of yield and evapotranspiration values obtained from the study, the yield-response factor (Ky) was determined as 0.56 for the first year and 0.54 for the second year (Figure 6).

Fruit size classification

According to fruit size classification, the sum of extra and class 1 fruit ratio increased as the pan coefficient increased, but it decreased after Kcp_3 (1.0) pan coefficient for both irrigation intervals in drip irrigation (Figure 7). The highest extra and class 1 fruit ratios were obtained with Kcp_3=1.0 treatments for both irrigation intervals during the study. The highest ratio of class 2 fruits was noted with flood irrigation treatment in the first year, while Kcp_1 and flood irrigation treatments indicated the lowest values in the second year.

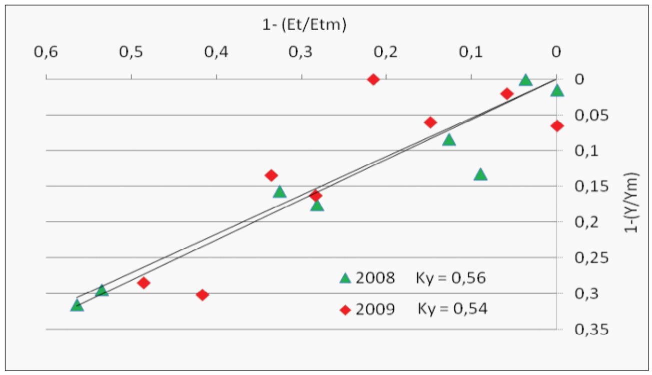

Fig. 6. Yield-response factor values of treatments as per years

Discussion

Due to a higher evaporation in 2008 than 2009, irrigation water amounts were also higher in 2008 than in 2009. Amounts of irrigation water and plant water consumption determined during drip irrigation treatment were less than those of flood irrigation treatment. The results correspond to those of Köksal et al. (1999) and Orta et al. (2001). Nonetheless, an augmentation in plant water consumption values was found along with higher amounts of irrigation water within the drip irrigation treatments for both years. The occurrence of such a result with increasing irrigation water quantity may be associated to the fact that the roots of apple trees consume more of the available soil water at their root zones. Çay et al. (2009) and Uçar et al. (2009) reported an increase in plant water consumption as the amount of irrigation water for apple trees was increased. Results of this study correspond to those of these studies.

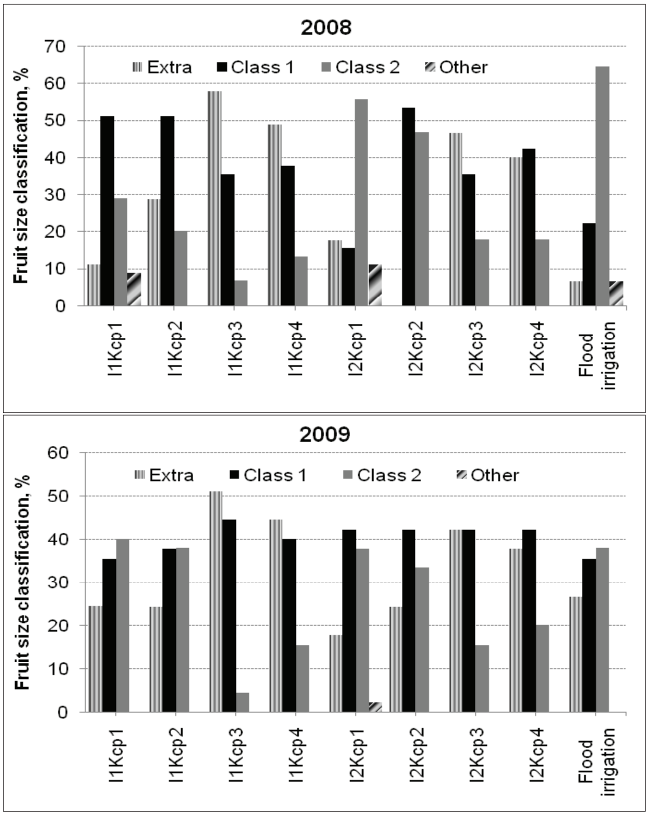

Fig. 7. Fruit size classification in 2008 (a) and 2009 (b)

The treatments in 7-days irrigation interval were applied with more water at once compared to those in 4-days irrigation interval. Therefore, the irrigation water of the treatments in 7-days irrigation interval could penetrate deeper in the soil while the irrigation water of those treatments in 4–days irrigation interval soaked a more superficial soil layer. Considering that the root system of the studied apple trees is wide and deep, and spread on a wider soil layer due to abundant water applied for many years, the plants water consumption appeared higher when water was available on a wider soil layer (during the adjustment period for drip irrigation) Because, when higher amount of water is applied at once (as in 7-days irrigation interval), the trees are able to use this water due to their root systems spread on a wide soil layer. Therefore, higher plant water consumption was identified with the treatments in 7-days irrigation interval.

The highest yield was obtained from flood irrigation treatment in 2008. An increase in yield was identified with higher amounts of irrigation water during drip irrigation treatments (Figure 4). The highest yield in drip irrigation treatments was identified in 2009. Flood irrigation treatment provided higher yield than 7 days treatments in drip irrigation. Yield increased with increasing irrigation water up to Kcp_3=1.0 level both irrigation intervals. Besides, a decrease in yield was noted after Kcp_3=1.0 level in both irrigation intervals (Figure 5), which means that transition from flood irrigation to drip irrigation had no negative effects on the yield. Yield in 2009 was lower than that in 2008, which may be due to a lower evaporation in 2009 than that in 2008. Some researchers previously found that different irrigation methods did not result in differences on yield in apple irrigation (Proebsting et al., 1984; Köksal et al., 1999; Orta et al., 2001). According to the results of this study, yield was not affected negatively due to transition from flood irrigation to drip irrigation. Thus, conforming the results of previous studies.

Plant water consumption and yield increased in drip irrigation treatments during the first year (2008) as the amount of irrigation water also increased. This may be because the root system of apple trees, which had been irrigated for many years by flood irrigation, spread to a wide area at soil depths. As the amount of irrigation water increased, plant water consumption and yield also increased in 2009. However, the yield decreased after Kcp_3 level for both irrigation intervals. According to these results, it is possible to conclude that apple trees adjust their root systems during the transition from flood irrigation to drip irrigation after the second year of transition. Safran et al. (1975) also reported that trees which had been irrigated for many years by flood irrigation method and had a widespread root system, adjusted their roots to a very small wetted volume of soil within one season of drip irrigation and no reduction in yield was observed. Furthermore, pan coefficient has been determined as 1.0 for irrigation scheduling in transition from flood irrigation to drip irrigation. Çay et al. (2009) stated that the yield increased together with increasing plant water consumption, and the highest yield was obtained during Kcp=1.0 treatments.

According to these results, yield was identified higher in 4 days irrigation intervals than 7 days irrigation intervals. Considering that drip irrigation is a suitable method for frequent irrigation, 4 days irrigation interval may be recommended to obtain a higher yield in apple production.

Although the highest yield was obtained with flood irrigation; the lowest WUE and IWUE were also obtained with this treatment in both years. As a result, irrigation water and plant water consumption were also higher, which may be considered as an important drawback despite the higher yield. The highest WUE was determined during drip irrigation treatments with low Et and high yield values. Results for IWUE were also similar. Kcp_1 treatments had the highest values among drip irrigation treatments. Although the highest values were obtained from Kcp_1 treatments, yield was less than those in other treatments were. Therefore, choosing these treatments are not suitable for saving irrigation water. IWUE decreased when the irrigation water amount increased. Kanber et al. (1991) reported that the highest WUE was determined in treatments, which had lower irrigation water and higher yield. Furthermore, according to Ky values, it is clear that it will be 0.56 unit for the first year and 0.54 unit for the second year of decrease in yield per unit decrease of water.

Drip irrigation treatments had the highest extra and class 1 fruit ratios during the study. Flood irrigation treatment showed the lowest values. It has been identified that transition from flood irrigation method to drip irrigation increases the fruit size, which is an important marketing criterion for apple growing. Besides, when Kcp_3 (1.0) pan coefficient is used obtaining the highest fruit diameter will be possible. Köksal et al. (1999) also observed increased extra fruit ratio with drip irrigation.

Conclusions

This study identified the differences in the amount of irrigation water, plant water consumption and fruit size classification during transition from flood irrigation method to drip irrigation method for apple trees. Lower irrigation water application could be realized with drip irrigation treatments compared to flood irrigation in both years. As a result, plant water consumption was reduced to less than that of flood irrigation. That is, a substantial water saving was obtained. This result illustrates that growers should be encouraged for transition from flood irrigation to drip irrigation method for saving water. Yield differences could not be determined during the change in irrigation methods, which means that apple growers may obtain a similar yield with lower amount of irrigation water after beginning to use drip irrigation method instead of flood irrigation. In addition, the highest marketable fruit diameter was determined in drip irrigation treatments during transition from flood irrigation to drip irrigation method.

As a result, drip irrigation system should be used for saving irrigation water in fruit growing on account of increasing demands for water resources. Furthermore, when shifting to drip irrigation method for apple trees which had been irrigated with flood irrigation for many years, the best results for saving water, higher yield and higher marketable fruit diameter can be obtained in the Kcp treatment with 1.0 and irrigation interval with 4 days, which is the recommended method for apple growing in Isparta and other regions with similar soil and climatic conditions.

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