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Effects of Different Deficit Irrigation Strategies on Yield, Fruit Quality and Some Parameters: 'Braeburn' Apple Cultivar

Cenk KÜÇÜKYUMUK*, Emel KAÇAL, Halit YILDIZ

*Fruit Research Station, 32500, Eğirdir, Isparta, Turkey; cenkkucukyumuk@hotmail.com (*corresponding author); emelvural101@hotmail.com; halityildiz@hotmail.com*

Abstract

This study was conducted to determine the effects of deficit irrigation applied in different periods to dwarf rootstock apple trees (cv. 'Braeburn')on vegetative development, yield, fruit quality and marketable yield for three years (2010-2012). There were six different treatments (none deficit irrigation, T_1; continuous deficit irrigation, T_2; deficit irrigation between the 40th and 70th days after full bloom, DAFB, T_3; deficit irrigation between the 70th and 100th DAFB, T_4; deficit irrigation between the 100th and 130th DAFB, T_5; deficit irrigation between the 130th and 160th DAFB, T_6). It was determined that short-term (30 days) deficit irrigation treatments during growing season resulted in decrease for vegetative development and yield. The apples that have both the highest marketable yield and the highest red colour density were obtained from T_3 in deficit irrigation treatments. T_3 treatments saved irrigation water according to T_1 treatment in study years (12.4%, 14.4% and 15.2 respectively). For more efficient use of water resources in case of limited irrigation water, T_3 treatment was found to be recommendable for apple growers because it not only saves water but also affects yield and fruit quality least.

Key words: M9 rootstock, marketable yield, vegetative development, water saving

Introduction

The major part (approximately 70%) of water both in Turkey and in the world is used in agricultural production. However, as the ratio of water use increases due to rapidly increasing population and developing industry, water amounts used in agriculture decreases (Önder *et al.*, 2005). For this reason, researches conducted on new irrigation techniques that not only save water but also negatively affect yield and fruit quality less (deficit irrigation, periodic deficit irrigation, partial root zone drying etc.) become more of an issue.

The primary objective of all irrigation studies is to maximize yield and fruit quality in fruit growing. It is possible to decrease competition between fruit growth and shoot growth and thus to increase fruit size and quality with right timing in irrigation (Dennis, 1996). In recent studies, it has been found that deficit irrigation applied to apple in different periods affects yield and fruit quality differently (Mpelasoka *et al.*, 2001; O'Connell and Goodwin, 2007; Zaliha and Singh 2009a,b). In case of apple, there are numerous studies, which have been conducted on the effectiveness of deficit irrigation applications compared to none deficit irrigation applications. However, they usually cover a single year period; no long-term research results exist (Girona *et al.*, 2010; Behboudian *et al.*, 2011). Deficit irrigation strategies are recommended for saving irrigation water without a considerable reduction in yield for fruit trees (Chalmers *et al.*, 1981). However, this approach needs complete and exact information about the responses of trees to water stress in different phenological stages so as to determine the periods when fruit trees are less sensitive to stress. It is necessary for fruit growing to determine and know the application period of deficit irrigation (Fereres and Goldhamer, 1990).

Apple is one of the most important fruits produced in Turkey. Apple production in Turkey is estimated as 3.1% of the world production. Isparta is a very important apple growing region of Turkey with a production accounting for nearly 26% of the country's total (Anonymous, 2012). This study aimed at determining the deficit irrigation period, which saves most irrigation water and has the least negative effects on yield and marketable yield. In addition, it intended to increase red colour density as an important criterion in marketing for 'Braeburn' apple cultivar.

Materials and methods

Study area and plant material

This study was conducted at Fruit Research Station (37°49'18.24''N, 30°52'22.90''E , Eğirdir, Isparta-Turkey) for 3 years (2010 and 2012). Apple trees were planted in 2000 (3.5 m x 1.5 m spacing) and 'Braeburn' apple cultivar grafted on M9 rootstock was used in this study. Some physical and chemical characteristics of the study area soil are given in Tab. 1.

Irrigation treatments

Soil moisture was measured at respectively 30, 60 and 90 cm soil depths with a digital tensiometer (Soilspec digital tensiometer, JGK TECH, Australia) before each irrigation. There were used three tensiometers for each replication (one each at 30, 60 and 90 cm soil depth). Drip irrigation system was used in this study. Emitter flow rate, emitter spacing and main pipe diameters used in the system were calculated according to Yıldırım (2005). The lateral pipes with 16 mm diameter were laid along both sides of each row of trees. Emitter spacing on laterals were 0.50 m with all emitters having a discharge rate of 4 llh^{-1}.

Irrigation interval was considered as 4 days in all treatments. In the study, 6 different treatments were included; i.e., none deficit irrigation (T_1), deficit irrigation during growing season (continuous deficit irrigation) (T_2), deficit irrigation between the 40th and 70th DAFB (T_3), deficit irrigation between the 70th and 100th DAFB (T_4), deficit irrigation between the 100th and 130th DAFB (T_5) and deficit irrigation between the 130th and 160th DAFB (T_6). Plant pan coefficient (K_{cp}) was considered to be 1.0 in T_1 during growing season. However, it was 0.25 during growing season in T_2. The Kcp was used as 0.25 in deficit irrigation periods after full bloom in T_3, T_4, T_5 and T_6. Outside the periods mentioned above, K_{cp} was taken as 1.0 for calculations.

Unlike some other fruit varieties such as pear and peach, phenological stages of apple shoot and fruit development are not clearly separate (Chalmers, 1989). For this reason, 30-day short-term water deficit was applied in this study. Deficit irrigation applications were launched after the 40th and 45th days after full bloom. Cell division phase has a significant effect on fruit size and lasts for 4-5 weeks after full bloom for apple (Felmann, 1996). Due to the fact that fruit cell division is accepted to be completed at the end of these days, deficit irrigation applications were launched following these days.

Calculating of Irrigation Water and Plant Water Consumption

For each treatment, evapotranspiration was calculated according to James (1988):

$$ET = I + R + Cr - Dp - Rf \pm \Delta s$$

where ET is the evapotranspiration (mm), I is 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. R_f was also not taken into account because the total water amount applied through was measured for each irrigation. The precipitation was measured after every raining day with a pluviometer positioned near the Class-A pan. Soil moisture content was measured prior each irrigation and the water amount applied during each irrigation was recorded. During the next irrigation, the soil moisture was measured and the difference was recorded as "plant water consumption" of that treatment. Irrigation quantity in Eq. (1) was calculated for each treatment of drip irrigation according to Ertek and Kanber (2003):

$$I = E_{pan} \times K_{cp} \times P$$

where I is irrigation water (mm), E_{pan} is the cumulative evaporation quantity at 4 days irrigation interval (mm), K_{cp} is the plant-pan coefficient, and P is wetting area. Wetting area was calculated as the ratio of the surface area shaded by trees at noon to the surface area allocated to one tree and found to be 37% (0.37). Evaporation quantity between irrigation intervals was measured everyday with a Class-A pan positioned near the plots. Available moisture at 0-90 cm soil depth was reached to field capacity at the end of full bloom; after that date, programmed irrigation was initiated (Köksal *et al.*, 1999). The first irrigation dates were May 14, May 8 and May 14 respectively while the last irrigation dates were September 27, September 25 and September 23 respectively for 2010, 2011 and 2012.

Measurements of vegetative growth, yield and fruit quality

Vegetative growth: One-year shoots from the main branch were selected for each tree per replications and their lengths (cm) and diameters (mm) measured every January. Shoot length and diameter were determined by digital calliper. Shoot diameters were measured from basal parts of the shoots (Köksal *et al.*, 1999).

Yield and fruit quality: Fruits of five trees selected from each replication were harvested and weighted. Then the yield was determined in terms of kg da^{-1}. Harvesting dates were October 18, 24 and 22 in 2010, 2011 and 2012, respectively. For fruit assessments, samples of 15 fruits in one tree for per replicate were selected. Total 45 fruits per treatment were harvested for quality analyses at the commercial harvest. Physical (fruit diameter, fruit length, fruit weight, flesh firmness, and skin colour) and chemical (TSS; total soluble solids) analyses were conducted on the selected fruits (Tab. 2). Fruit diameter was used as the quality criterion for classification. The fruits were graded on a commercial size grade ranging from 50 to 95 mm. The percentage of fruit in various size categories was determined as extra (>75 mm), class 1 (68-75 mm), class 2 (60-68 mm) and other (<60 mm) (Küçükyumuk *et al.*, 2012).

Experimental design and statistical analysis

This study was designed according to Randomized Blocks Experimental Design with three replications. Plots consisted of two rows with 9 trees each (i.e. 18 trees). One row was left as extra row between two plots. From nine trees in one row in each plot, four trees were not considered (two from the top and two from the end). So, during harvest, 5 trees were taken into account. The analysis of variance (ANOVA) test for the data was conducted with JUMP software program and differences among treatments were compared by means using LSD test.

Results and discussion

Irrigation water and plant water consumption

The lowest irrigation water was applied to T_2 treatment during this study. The lowest plant water consumption was obtained from this treatment. On the other hand, T_1 treatment had the highest values. In other treatments with periodic deficit irrigation, irrigation water applied was lower to the amount of deficit, and plant water consumption was lower (Tab. 3). According to T_1 treatment, periodic deficit irrigation treatments saved irrigation water and these ranged from 12.4 to 19.7% in 2010, from 12.4 to 18.9% in 2011 and from 11.6 to 20.9% in 2012. Some of researchers reported that, periodic deficit irrigation treatments decreased irrigation water and plant water consumption in apple (Mills *et al.*, 1997; Petillo *et al.*, 2009).

Vegetative growth

The effect of the treatments on vegetative development (shoot length and shoot diameter) was highly significantly in the study ($p<0.01$) (Tab. 4). The highest shoot length and shoot diameter values were obtained from T_1 treatment and T_2 had the lowest values. On the other hand, the effects of periodic deficit irrigation were determined to be different depending on the time of deficit. It was observed that, compared to other periodic deficit irrigation treatments (T_5 and T_6), deficit irrigation treatments in an early period such as T_3 and T_4 had more negative effects on vegetative development. As a matter of fact, O'Connel and Goodwin (2007) and Bianco and Francaviglia (2012) reported that deficit irrigation reduced shoot development and consequently vegetative development.

Yield and fruit quality

All deficit irrigation treatments significantly reduced fruit yield in all years ($p<0.01$) (Tab. 5). The lowest yield values were found in T_2 treatment. The reason may be that the effect of 2-year stress conditions became more effective in the 3rd year. The yield obtained from the treatment with deficit irrigation between the 40th and 70th DAFB (T_3) was closest to that obtained from none deficit irrigation treatment during the study (T_1). Decreasing in yield was obtained in T_3, T_4, T_5 and T_6, which included periodic deficit irrigation. Deficit irrigation treatments in different periods had different effects on yield and fruit quality. The reason for this may be that apple have three development stages with different speeds (Stage I: 56 DAFB, fruit development is slow; Stage II: 56-151 DAFB, fruit development is fast; Stage III: 151-180 DAFB fruit development is slow) (Atay, 2007). In order that T_3 treatment was applied in Stage I, deficit irrigation in T_3 treatment affected less negatively on yield and fruit quality (fruit diameter, marketable yield, red colour density etc.). In the same time, this period also meets to the period right after the end of the cell division phase which has an important effect on fruit size in apple (Felmann, 1996). It was reported that the available water amounts in soil plays an active role in root activity (Bergamini *et al.*, 1988). Since different water amounts were applied to treatments, soil water at effective root depth varied and thus water amounts consumed by apple trees differed. The difference proved its effect on yield. This result revealed that deficit water applications had significant effects on the yield of M9 rootstock apple trees even if they were short-term deficit water applications. Also it was determined that knowing the application period of deficit irrigation was fundamental. It was reported that, periodic deficit irrigation applications affected and reduced yield in apple trees (Mpelasoka et al., 2001; Petillo *et al.*, 2009; Girona *et al.*, 2010).

The results of fruit diameter, fruit length and fruit weight are in (Tab. 6). The fruit diameter measurements were statistically significant ($p<0.01$) among the treatments for three years. While the highest values were obtained in $T_{1,}$ T_2 had the lowest values. Deficit irrigation treatments in different periods had different effects on fruit diameter. Among the treatments with periodic deficit irrigation, the highest value was obtained from T_3 while the lowest values were observed in T_4. T_1 had the highest fruit length and fruit weight values, whereas the lowest values were determined in T_2. The more soil water affects the amount of water received by roots. It affects both apple tree yield and fruit quality (fruit diameter, length, weight, etc.). It was determined that deficit irrigation caused decreasing for fruit diameter values. Decreasing for fruit diameter in T_2 treatment was different based on periodic deficit irrigation treatments. The fruits of T_2 treatment had a smaller fruit diameter. The fact that fruit diameter values were correlated with plant water consumption at a significance level of 1% ($p<0.01$) supports these results (Fig. 1). O'Connel and Goodwin (2007) and Zaliha and Singh (2009b) reported that, compared to the applications without any water deficit, fruit diameter decreased in deficit irrigation applications. Bergamini *et al.* (1990) reported for Golden Delicious apple cultivar that fruit diameter increased as the irrigation water amount increased. Similar effects were observed on fruit length and fruit weight. In addition, Talluto *et al.* (2008) and Girona *et al.* (2010) informed that deficit irrigation resulted in a decrease in fruit weight. It was detected that the effects of T_2 treatment were different from that of the deficit irrigation applied in different periods. However, all deficit irrigation treatments were determined to cause a decreasing for fruit diameter, fruit length and fruit weight. It was observed that in T_1 and T_3, the results of fruit diameter, fruit length and fruit weight were close to one another.

Fruit growth (diameter, length, weight) was determined to be closely associated with the amounts of plant

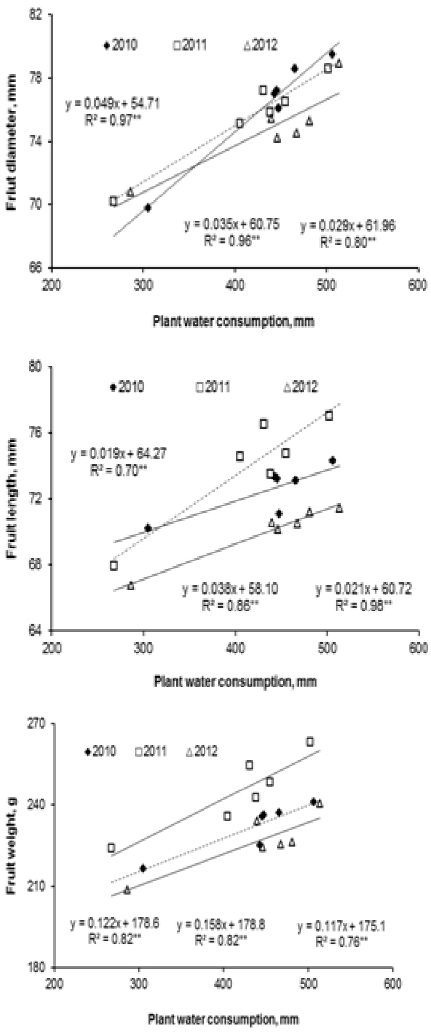

Fig. 1. ET-fruit diameter, ET-fruit length and ET-fruit weight relationship

water consumption. Fig. 1 shows the relationships between plant water consumption and fruit diameter, fruit length and fruit weight (at a significance level of 1%). It was determined that positive linear relationships between plant water consumption and these parameters.

During the experiment, the treatments were determined to have significant effects on fruit flesh firmness values ($p<0.01$) (Tab. 7). The highest values were obtained from T_2. On the other hand, none deficit irrigation (T_1) had the lowest results. Deficit irrigation applied in different periods had different effects on fruit flesh firmness. Among periodic deficit irrigation treatments, T_4 had the highest flesh firmness values. Similarly, the deficit irrigation treatments increased fruit flesh firmness, as previously reported by other authors (Mpelasoka *et al*., 2001; Zaliha and Singh, 2009a). According to the TSS results, differences at a significance level of 1% were found among the treatments. The highest TSS value was obtained from T_2 whereas the lowest TSS value was determined in T_1 (Tab. 7). It was found that fruit flesh firmness and TSS values were close in T_1 and T_3. Different deficit irrigation strategies caused to an increasing for TSS values. Mpelasoka *et al*. (2001) and Leib *et al*. (2006) reported that deficit irrigation applications in apple increased TSS values. In addition, Zaliha and Singh (2009a) indicated that TSS increased in short-term continuous deficit irrigation compared to none deficit irrigation but decreased in continuous deficit irrigation applied shortly before harvest. These results demonstrated that different water deficit application periods led to different TSS values.

Inverse linear relationships ($p<0.01$) were determined between plant water consumption and fruit flesh firmness and between fruit diameter and fruit flesh firmness (Fig. 2). As plant water consumption increased, fruit flesh firmness values decreased. A similar relationship was found between fruit diameter and fruit flesh firmness. While fruit diameter increased fruit flesh firmness decreased.

There were statistically significant differences among fruit skin colour values (Tab. 8). A negative correlation was determined between red colour and fruit skin brightness values (data not shown). Red colour(a) increased

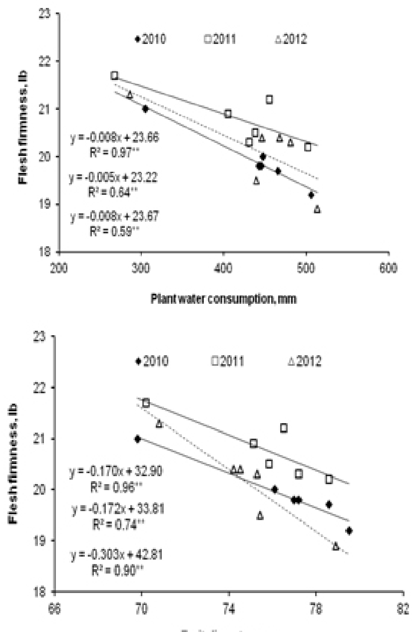

Fig. 2. ET-flesh firmness and fruit diameter-flesh firmness relationship

while the fruit flesh brightness (L*) decreased. The highest L* values were obtained from T_4 whereas the lowest L* values were found in T_2. Continuous deficit irrigation, T_2, had the highest a* (red colour) values. However, the lowest a* values were obtained from T_4. On the other hand, deficit irrigation between the 70th and 100th DAFB led to a decrease in apple red colour. Deficit irrigation that was applied to T_4 caused a decrease the fruit skin red colour whereas T_3 had a positive effect on the red colour. These results can be due to the effects of deficit irrigation on the shoot length values. Actually, the highest red colour values were found both in T_2 and T_3 treatments that was determined as the lowest shoot length values. The results for skin colour in the study were similar to those of Mills *et al*. (1997); Kilili *et al*. (1996); Zaliha and Singh (2009a), which reported that deficit irrigation applications led to the increase of red colour.

Due to the effect of deficit irrigation treatments on fruit diameter, marketable yield differences were observed among treatments (Tab. 9). As one of the important criteria in marketing, marketable yield was negatively affected by deficit irrigation applications. T_1 had the highest marketable yield (extra and class 1) and followed by T_3. There were the lowest extra and class 1 ratio in T_2 treatment. Among the treatments with periodic deficit irrigation, T_3 had the highest marketable yield values. The treatment with the highest Class 2 ratio was determined to be T_2. It was found that T_3 deficit irrigation treatment had the minimum negative effect on marketable yield. Girona *et al*. (2010) reported that, compared to none deficit irrigation, different deficit irrigation applications decreased marketable yield.

Tab. 1. Soil characteristics of trial plots

Depth (cm)	γ (g/cm³)	FC (%)	WP (%)	AWHC (mm)	Salinity (ECx106)	pH	Organic matter (%)	Texture
0-30	1.46	24.2	11.5	55.6	175	8.1	1.80	Clay loam
30-60	1.38	25.1	13.1	49.7	125	7.9	2.70	Clay loam
60-90	1.41	24.3	12.2	51.2	130	8.0	2.75	Clay loam

Tab. 2. Quality parameters and measurements

Parameters	Unit	Measurements
Fruit diameter	mm	digital calliper was used with 0.01 mm resolution
Fruit length	mm	digital calliper was used with 0.01 mm resolution
Fruit weight	g	digital balance (Scaltec, SBA–51) to 0.01 g sensitivity
Fruit flesh firmness	lb	determined on two opposite sides of each fruit, using a hand held penetrometer fitted with a 11 mm diameter probe
Fruit skin colour	L* a*	measured on the two opposite sides of each fruit with a Minolta Chroma meter model CR-400. The data obtained were evaluated CIELAB colour scale
Total soluble solids content	%	LCD Digital bench refractometer

Tab. 3. Irrigation water, plant water consumption, evaporation and precipitation values of the study

Treatments	2010		2011		2012	
	I (mm)	ET (mm)	I (mm)	ET (mm)	I (mm)	ET (mm)
T_1	370.5	506.2	361.0	501.9	395.1	513.5
T_2	120.0	305.1	108.4	267.7	119.3	286.2
T_3	324.6	465.4	308.8	431.0	335.0	439.4
T_4	303.1	447.4	292.7	405.2	312.7	446.3
T_5	297.8	442.8	300.6	438.1	320.3	467.4
T_6	322.5	445.5	316.5	455.0	349.3	480.9
Evaporation (mm)	890.1		909.9		984.8	
Precipitation (mm)	80.5		87.2		114.9	

Tab. 4. Shoot length and shoot diameter in 2010, 2011 and 2012

Treatments	Shoot length (cm)			Shoot diameter (mm)		
	2010	2011	2012	2010	2011	2012
T_1	62.78 a**	57.42 a**	54.42 a**	7.83 b**	8.41 a**	7.39 a**
T_2	42.87 d	41.67 c	38.86 c	6.30 c	5.95 c	4.99 c
T_3	48.69 cd	46.16 bc	43.96 bc	7.29 b	7.53 b	6.60 b
T_4	53.69 bc	51.84 ab	48.69 ab	6.36 c	7.55 b	6.68 b
T_5	55.20 bc	52.67 a	50.17 ab	7.48 b	7.86 ab	6.92 ab
T_6	58.40 ab	54.24 a	51.10 a	9.05 a	8.02 ab	7.15 ab

**$P < 0.01$, Values with common letters do not differ significantly.

Tab. 5. Effects of deficit irrigation treatments on yield parameters

Treatments	2010	2011	2012
	Yield (kg da^{-1})		
T_1	5875.1 ^{a**}	6107.2 ^{a**}	7171.1 ^{a**}
T_2	3892.5 ^{d}	3759.0 ^{c}	3216.7 ^{c}
T_3	5518.8 ^{ab}	5406.9 ^{ab}	6377.8 ^{ab}
T_4	5038.5 ^{bc}	4853.6 ^{b}	5795.5 ^{b}
T_5	4675.0 ^{c}	5169.5 ^{b}	5814.4 ^{b}
T_6	5176.2 ^{bc}	5309.7 ^{b}	6209.5 ^{ab}

** $P < 0.01$, Values with common letters do not differ significantly.

Tab. 6. Effects of deficit irrigation treatments on some fruit parameters

Treatments	Fruit diameter (mm)			Fruit length (cm)			Fruit weight (g)		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
T_1	79.50 ^{a**}	78.64 ^{a**}	78.91 ^{a**}	74.31 ^{a*}	77.02 ^{a**}	71.41 ^{a**}	241.1 ^{a*}	263.2 ^{a**}	240.4 ^{a**}
T_2	69.81 ^{d}	70.39 ^{d}	70.80 ^{c}	70.22 ^{c}	67.91 ^{b}	66.72 ^{b}	216.6 ^{b}	223.9 ^{d}	208.8 ^{b}
T_3	78.60 ^{ab}	76.28 ^{b}	75.42 ^{b}	73.31 ^{ab}	76.53 ^{a}	70.53 ^{a}	237.1 ^{a}	254.7 ^{ab}	234.0 ^{a}
T_4	76.11 ^{c}	74.14 ^{c}	74.21 ^{b}	71.10 ^{bc}	74.52 ^{a}	70.15 ^{a}	236.3 ^{a}	235.7 ^{cd}	224.2 ^{ab}
T_5	76.98 ^{bc}	75.53 ^{bc}	74.52 ^{b}	73.12 ^{ab}	73.51 ^{a}	70.51 ^{a}	225.1 ^{ab}	242.6 ^{bcd}	225.4 ^{ab}
T_6	77.20 ^{bc}	74.89 ^{bc}	75.29 ^{b}	73.19 ^{ab}	74.76 ^{a}	71.20 ^{a}	235.6 ^{a}	248.4 ^{abc}	226.3 ^{a}

** $P < 0.01$ * $P < 0.05$, Values with common letters do not differ significantly.

Tab. 7. Effects of deficit irrigation treatments on flesh firmness and soluble solids content

Treatments	Flesh firmness (lb)			Total soluble solids content (%)		
	2010	2011	2012	2010	2011	2012
T1	19.2 ^{b**}	20.2 ^{c**}	18.9 ^{c**}	12.6 ^{b**}	11.72 ^{c**}	11.93 ^{c**}
T2	21.0 ^{a}	21.7 ^{a}	21.3 ^{a}	13.8 ^{a}	12.80 ^{a}	12.93 ^{a}
T3	19.7 ^{b}	20.3 ^{c}	19.5 ^{c}	12.8 ^{b}	11.93 ^{c}	12.59 ^{ab}
T4	20.0 ^{b}	21.2 ^{abc}	20.6 ^{b}	13.0 ^{b}	12.02 ^{bc}	12.36 ^{bc}
T5	19.8 ^{b}	20.5 ^{bc}	20.3 ^{b}	12.9 ^{b}	12.43 ^{ab}	12.45 ^{b}
T6	19.8 ^{b}	20.9 ^{ab}	20.3 ^{b}	13.2 ^{b}	12.20 ^{bc}	12.58 ^{ab}

** $P < 0.01$, Values with common letters do not differ significantly.

Tab. 8. Skin colour per irrigation treatments

Treatments	2010		2011		2012	
	L	a	L	a	L	a
T_1	51.49 ^{abc*}	17.14 ^{abc**}	51.15 ^{ab*}	17.34 ^{abc**}	50.90 ^{ab*}	18.06 ^{abc**}
T_2	48.79 ^{c}	20.44 ^{a}	49.09 ^{b}	20.42 ^{a}	47.61 ^{b}	20.61 ^{a}
T_3	49.56 ^{bc}	19.89 ^{ab}	49.25 ^{b}	19.56 ^{ab}	49.67 ^{ab}	19.93 ^{ab}
T_4	54.14 ^{a}	13.87 ^{c}	52.76 ^{a}	13.86 ^{c}	53.15 ^{a}	14.88 ^{c}
T_5	52.55 ^{ab}	14.38 ^{c}	51.50 ^{ab}	15.98 ^{bc}	52.86 ^{a}	15.39 ^{c}
T_6	52.00 ^{abc}	15.95 ^{bc}	52.50 ^{a}	16.19 ^{bc}	51.21 ^{ab}	16.36 ^{bc}

** $P < 0.01$ * $P < 0.05$, Values with common letters do not differ significantly

Tab. 9. Fruit size classification (%)

Treatments	2010				2011				2012			
	Extra	Class 1	Class 2	Other	Extra	Class 1	Class 2	Other	Extra	Class 1	Class 2	Other
T_1	90.0	10.0	0	0	76.7	23.3	0	0	86.7	13.3	0	0
T_2	16.7	43.3	33.3	6.7	10.0	69.9	20.1	0	20.0	53.3	26.7	0
T_3	83.3	16.7	0	0	66.6	30.0	3.4	0	56.7	43.3	0	0
T_4	50.0	50.0	0	0	40.0	56.6	3.4	0	43.3	53.3	3.4	0
T_5	80.0	16.7	3.3	0	53.3	43.3	3.4	0	53.3	36.7	10.0	0
T_6	70.0	26.7	3.3	0	46.6	46.6	6.8	0	43.3	53.3	3.4	0

Extra (>75 mm), Class 1 (68-75 mm), Class 2 (60-68 mm), Other (<60 mm).

Conclusions

According to the results obtained, it was determined that short-term (30 days) deficit irrigation during growth season resulted in decrease for vegetative development and yield but saving irrigation water. The deficit water treatment between the 40th and 70th DAFB (T_3) not only saved irrigation water but also negatively affected yield and marketable yield least. The apples that have the highest red colour density were obtained from that treatment except T_2. For more efficient use of water resources in case of limited irrigation water, T_3 treatment may be recommended to apple growers because it not only saves water but also negatively affects yield and fruit quality least.

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