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Effect of Periodic Deficit Irrigation at Different Fruit Growth Stages on Yield and Fruit Quality of "Anna" Apple Trees.

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ABSTRACT

This study was carried out during two successive growing seasons 2016 and 2017 at a private farm located at El-Nubaria, Beheira governorate, Egypt to study the effect of irrigation deficit at different growth stages on some vegetative growth parameters, yield and fruit quality of "Anna" apple trees. The obtained data showed that, the highest mean values for studied vegetative growth parameters such as shoot length, shoot diameter, leaf area and specific leaf weight , yield (kg/tree – ton/fed.), fruit set percentage and some fruit characters (fruit weight, fruit size, fruit length, fruit diameter and fruit shape) were recorded under control treatment (conventional irrigation). Meanwhile, vegetative growth parameters recorded the lowest values under T_6 treatment, while the lowest values of fruit set percentage and yield were recorded under T_5. Fruit weight, fruit size, fruit length and fruit diameter recorded the least values with T_7 treatment. Concerning, productivity of irrigation water (PIW), whereas the highest values were obtained by T_6 treatment, T_5 treatment gave the lowest values. Fruit firmness, TSS and anthocyanin content in fruit peel of "Anna" apple were significantly affected by irrigation treatments, where, T_7 treatment recorded the highest values for measured fruit firmness and TSS, while T_6 treatment recorded the highest values for anthocyanin. The lowest values for measured fruit firmness, TSS and anthocyanin content were found under control condition (standard irrigation). Hence, we can recommend apple growers to apply T_3 treatment(12.972 m^3/tree/year = 4540.2 m^3/fed./year) to save 25%of irrigation water, as well as, to obtain about the same fruit set and yield of control trees.

Keywords: *"Anna" apple, deficit irrigation, yield, fruit quality, different growth stages.*

INTRODUCTION

"Anna" apple (*Malus domestica, Borkh)* has low chilling requirements. It needs about 300 – 350 hrs blew 7.2ºC to break their bud dormancy, spreading in many tropic and sub-tropic areas including Egypt . In Egypt, the cultivated area of "Anna" apple cultivar is increasing very rapidly in the reclaimed land, especially during the last few years. In order to obtain an abundance of production and high fruit quality of deciduous fruit trees, suitable irrigation water must be available, however in many areas in the world; water resources may be not enough to optimize irrigation and to achieve the maximum yield for the highest reverting. These problems could exacerbated in the future due to this reasons; i) water resources are becoming more limited all over the world and they will not have been sufficient to meet the increasing demands by 2025 (Postel, 1998), ii) reducing irrigation water due to increasing competition with urban and industrial users and economic and social pressures (Fereres and Evans, 2006), and iii) worldwide, irrigation consumes at least 85% of all water used (Jury and Vaux, 2007). Therefore agricultural irrigation will face water scarcity in the near future, so it is very important to understand the effects of water shortage in deciduous fruit trees with the use of techniques that reduce the drought effects. Regulated irrigation deficit is an important technique of saving water and developed to improve control of vegetative growth in high-density orchards to achieve the optimize productivity and high fruit quality. Regulated irrigation deficit is usually applied during the period of slow fruit growth when shoot growth is rapid. Thus, it is beneficial for reducing excessive vegetative growth and nutrient loss through leaching as well as the provision of irrigation water (Chalmers *et al.,* 1981). However, this technique requires accurate information about the response of deciduous fruit trees to water stress, which depends mainly on growth stages of trees, as will, to determine the periods when fruit trees are less sensitive to stress. So, it is very important for growers know the application periods of irrigation deficit (Fereres and Goldhamer, 1990). Many studies such as, Mitchell and Chalmers (1982) and Mitchell *et al*. (1989) found that, water use efficiency, expressed as yield per unit irrigation, increased under regulated irrigation deficit in peach and pears. In this respect, Goldhamer (1999) using regulated irrigation deficit technique on olive, and found, this way save water about 25% without yield decline. Also, many studies have shown that mild water stress applied during the period of slow fruit growth controlled excessive vegetative growth, while maintaining or even increasing yields (Mitchell *et al.*, 1989 on European pear, Ebel *et al.,* 1995 on apple, El-morshedy and Haggag, 1997 and Lopez *et al.,* 2008$_a$ on peach and Cheng *et al.*, 2012 on Asian pear).

The purpose of this research is to study the effect of periodic deficit of irrigation water at different fruit growth stages of "Anna" apple on vegetative growth, fruit set, yield and fruit quality; and to clear the effect of regulated irrigation deficit system on productivity of irrigation water (PIW, kg/m^3) .

MATERIALS AND METHODS

This experiment was carried out during the two successive seasons 2016 and 2017 on eight-year-old "Anna" apple trees (*Malus domestica, Borkh*) budded on Malus rootstock, planted at 3×4 meters apart (350 trees/fed.) on a sandy loam soil under drip irrigation system in a private orchard located at El-Nubaria, Beheira governorate, Egypt. Physical and chemical

characteristics of experimental soil was presented in Tables (1&2). The amounts of irrigation water as liters per tree for each treatment in both seasons are shown in Table (3).

The complete randomized block design was used, as each treatment was represented by three replicates. Twenty one trees were selected in this study and divided randomly into seven groups; each group was subjected to one of the following irrigation treatments:

T_1 (Control): conventional irrigation, like practice by the local farmers in the studied region.

T_2:Irrigation with 75% of control starting from flowering to 40 days after full bloom (stage I)

T_3: Irrigation with 75% of control from 40 to 80 days after full bloom (stage II) .

T_4:Irrigation with 75% of control from 80 days after full bloom until harvesting (stage III).

T_5:Irrigation with 50% of control starting from flowering to 40 days after full bloom (stage I)

T_6: Irrigation with 50% of control from 40 to 80 days after full bloom (stage II).

T_7: Irrigation with 50% of control from 80 days after full bloom until harvesting (stage III).

The investigated irrigation levels (75 & 50%) were basily calculated upon the conventional supply of irrigation water (control-100% level) during each of the three phonological growth stages (Table 3).

Table 1. The mean values of some chemical characteristics of experiment soil:

Soil depth (cm)	pH	EC (ds/m)	OM (%)	$CaCO_3$ (%)	Soluble cations (Meq/L)				Soluble anions (Meq/L)		
					Na^+	Ca^{+2}	Mg^{+2}	K^+	HCO_3^-	Cl^-	SO_4^{--}
0-30	8.14	1.54	0.26	3.85	10.44	2.70	2.30	0.10	2.25	10.17	2.62
30-60	8.10	1.35	0.23	5.69	9.43	2.16	1.82	0.09	1.63	9.98	1.39
Mean		1.45	0.24	4.77	9.93	1.93	2.06	0.09	1.94	10.07	2.00

EC: was measured in the extract of soil paste at 25 C^0, pH: was measured in 1:2.5 (soil water suspension), $SO_4^{--}$was calculated by difference between cations and anions

Table 2. The mean values of some soil physical characteristics and water constants:

Soil depth (cm)	Particle size distribution				Soil moisture characteristics			Bulk density (kg/m^3)
	Sand (%)	Silt (%)	Clay (%)	Soil texture	FC (%)	PWP (%)	AW (%)	
0-30	69.91	18.07	12.02		11.8	6.4	5.4	1.36
30-60	67.89	18.63	13.48	Sandy loam	12.8	7.0	5.8	1.34
Mean	68.90	18.35	12.75		12.3	6.7	5.6	1.35

FC: Field capacity, WP: Wilting point, AW: Available water

Table 3. Combination of irrigation treatments applied during three fruit growth stages of "Anna" apples over two seasons .

fruit Growth stages	Irrigation treatments						
	T_1	T_2	T_3	T_4	T_5	T_6	T_7
I	100	75	100	100	50	100	100
II	100	100	75	100	100	50	100
III	100	100	100	75	100	100	50
Total (m^3|tree|year)	13.572	13.182	12.972	12.762	12.792	12.372	11.952
Seasonal water applied(m^3/fed.)	4750.2	4613.7	4540.2	4466.7	4477.2	4330.2	4183.2

Stage (I) starting from flowering to 40 days after full bloom (AFB), stage (II) from 40 to 80 days after full bloom (AFB), stage (III) from 80 days after full bloom (AFB) until harvest time.

The effect of the previous treatments was studied by evaluating their influence on the following parameters:

1- Productivity of irrigation water (PIW, kg/m^3).

Productivity of irrigation water (PIW) was calculated by the following equation according to (Ali *et al*., 2007).

$$PIW=Y/Wa$$

Where:

PIW: Productivity of irrigation water (kg fruits /m^3 of water), Y: fruit yield (kg/fed.) and Wa: Water applied to the field (m^3).

2- Vegetative parameters:

At the end of each growing season, the selected shoots were used for the following measurements: the average shoot length cm, shoot diameter cm, leaf area cm^2 and specific leaf weight (leaf dry weight/cm^2)

3- Fruit set and yield:

Four main branches at different directions of each tree were chosen and tagged in the beginning of March of the two experimental seasons, the number of flowers was recorded and those set fruitlets on the selected branches were counted then fruit set % calculated according to the following equation:

$$\text{Fruit set percentage} = \frac{\text{Number of developing fruitlets}}{\text{Total number of flowers}} \times 100$$

Yield per tree (kg/tree) and the yield per fed in ton were estimated at harvesting time (3rd week of June).

4- Fruit quality:

At harvest, ten fruits were randomly taken from each replicate for determination of both physical and chemical characteristics: :

A- Fruit physical characteristics:

Fruit weight (g), fruit size (cm^3), fruit dimensions (fruit length and diameter in, mm) and fruit shape index (fruit length /fruit diameter ratio) were measured. Fruit firmness (I b/$inch^2$) which was measured by using fruit pressure tester. Adjusted firmness determined with the equation of Bartram

(1986) : adjusted firmness = firmness + [0.054 (apple weight) – 11.557].

B- Fruit chemical characteristics:

Total soluble solids (TSS) were determined using a hand refracto-meter, percentage of titratable acidity in fruit juice (%) was determined according to AOAC (1995), and anthocynins were determined as mg/100g fresh weight of peel according to the method described by Rabino *et al.,* (1977).

5- Soil physical and chemical properties:

The studied physical properties and soil water constants were determined according to the method described by Klute, 1986. The studied chemical properties, were determined according to the method described by Jackson, (1973).

6- Statistical analysis:

The results were statistically evaluated by analysis of variance. Comparisons of means were done at $p \leq 0.05$ with the Duncan Multiple Range test**.**

RESULTS AND DISCUSSION

A. Vegetative growth parameters:.

The effects of periodic deficit of irrigation water at different fruit growth stages of " Anna" apple on some vegetative growth parameters are presented in Table (4). The obtained data showed that, the vegetative parameters such as shoot length, shoot diameter, leaf area and specific leaf weight were significantly affected in the two growing seasons by the studied treatments. The highest shoot length, shoot diameter, leaf area as well as specific leaf weight values were belonged to the control treatment (T_1), which irrigated by water at 100% level in all fruit growth stages followed by trees irrigated with 75% of control starting from 80 days after full bloom until harvesting – stage III (T_4 treatment). While T_6 treatment (irrigation with 50% of control starting from 40 to 80 days after full bloom –stage II) achieved the lowest values in this respect. Generally, the effects of periodic irrigation deficit on vegetative growth were dependent on the time and the water shortage rate, therefore it was observed that deficit irrigation treatments in a second period (Stage II) such as T_6 (irrigation with 50% of control starting from 40 to 80 days after full bloom) had more negative effects on vegetative growth compared to irrigation with 75% of control and two other periods (Stage I and Stag III). The reason may be that stage II include both rapid shoot growth and spring root growth, accordingly, water deficit in this stage has a negative impact on vegetative growth (Boland *et al.,* 2002). The effects of regulated irrigation deficit on vegetative growth were studied by many researchers such as, El-morshedy and Haggag (1997) and Cheng *et al.,* (2012), they reported that, the vegetative growth is influenced by the time and rate of water shortage.

Table 4. Effect of irrigation deficit at different fruit growth stages on some vegetative growth parameters of "Anna" apple trees in 2016 & 2017 seasons.

Treatments	Shoot length (cm)		Shoot diameter (cm)		Leaf area (cm^2)		Specific leaf weight (mg/cm^2)	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1 (control)	38.1a	39.3a	1.36a	1.48a	28.9a	29.9a	8.83a	9.07a
T_2	36.7b	37.7b	1.34b	1.46b	28.3c	29.3b	7.61d	8.34c
T_3	35.7c	37.3c	1.32c	1.46b	28.2c	29.2b	7.35e	7.84d
T_4	37.9a	39.2a	1.36a	1.49a	28.8a	29.7a	8.67b	8.76ab
T_5	32.0d	35.4d	1.04d	1.32c	24.3d	26.1d	6.80f	7.93d
T_6	30.9e	34.4e	0.96e	1.24d	23.3e	25.4e	6.37g	7.15e
T_7	37.5a	39.0a	1.32c	1.48a	28.5b	28.8c	8.56c	8.59bc

T_1 (control): irrigated 100% at all fruit stages.
T_2, T_3 and T_4: irrigated 75% at fruit growth stages I, II and III respectively.
T_5, T_6 and T_7: irrigated 50% at fruit growth stages I, II and III respectively.
Fruit growth stages: stage I: flowering – 40 days, stage II: 40 – 80 days and stage III: 80 days – harvest time.

B. Fruit set and yield:

It is evident from (Table 5), that fruit set percentage was significantly decreased by reducing irrigation rate especially in stage I (T_5 treatment: irrigation with 50% of control starting from flowering to 40 days after full bloom -stage I) which recorded the lowest percentage of fruit set as compared to the other treatments while, the T_2 treatment (irrigation with 75% of control starting from flowering to 40 days after full bloom) came after the control. These results are in conformity with the finding of George and Nissen (2002) and Mikhael and Mady (2007) who indicated that, fruit set percentage decreases with increasing severity of drought. In addition, fruit set occurs in the stage I and therefore water shortage in this stage has a negative effect on fruit set percentage.

As for the influence of irrigation shortage at different fruit growth stages on yield of "Anna" apple trees, Table (5) explained, mostly periodic deficit of irrigation water significantly decreased fruit yield in the two growing seasons. T_5 treatment (trees irrigated with 50% of control starting from flowering to 40 days after full bloom –stage I) gave the least yield as compared to other treatments in both seasons. The yield obtained from T_3 treatment (trees irrigated with 75% of control from 40 to 80 days after full bloom –stage II) was found to be at par with that obtained from control in the two growing seasons, so the trees irrigated with 75% of control achieved the least effect from those irrigated with 50% in the three stages. These results may be probably due to the different growth rates of apples during the three development stages. Stage I (cell division): the number of cells of the fruit is determined

and irrigation is critical at this stage, accordingly, soil moisture must be readily available. Stage II: involves both rapid shoot growth and spring root growth, the fruit development is slow. Stage III (cell enlargement): in this stage the size of the fruit increases rapidly, shoots and roots growth is slow and bud formation for the following season' begins, irrigation is critical at this stage and soil moisture should be readily available (Boland *et al.,* 2002 and Atay, 2007). Accordingly, the influence of reduction of irrigation at the period from 40 to 80 days after full bloom (stage II) was less negatively on yield and fruit quality than the other two periods (stage I and stage III) (Küçükyumuk *et al.*, 2013). In addition, the impact of water shortage on fruit set in stage I- had a negative effect on the yield.

C. Productivity of irrigation water (PIW):

Regarding productivity of irrigation water (PIW), the values studied here and above mentioned parameters which were affected by periodic deficit of irrigation water (Table 5). The highest values were recorded under T_6 treatment(Irrigation with 50% of control from 40 to 80 days after full bloom –stage II) which were 2.316 and 2.368 (kg/m3) in 2016 & 2017 seasons, respectively. Meanwhile, the lowest values were obtained by T_5 treatment (Irrigation with 50% of control starting from flowering to 40 days after full bloom - stage I) which were 1.878 and 1.807 (kg/m3) in the 2016 and 2017 seasons, respectively. Generally, the values of productivity of irrigation water (PIW) can be descended in order T_6> T_3> T_4>control> T_7> T_2> T_5 in the first season and T_6> T_3> T_4> T_7 > control > T_2> T_5 in the second one, this means that, under deficit irrigation conditions in the stage II(40 to 80 days after full bloom), the values of PIW increased comparing with conventional irrigation (control 100%), meanwhile, irrigation deficit conditions at stage I recorded the lowest values. Increasing productivity of irrigation water under water stress, especially, in stage II may be due to the slowing of fruit growth and decreasing the amount of water consumptive use in this stage (Küçükyumuk *et al.,* 2013). Many studies such as Chalmers *et al.*, 1981; Marsal and Girona, 1997 and Cheng *et al.,* 2012 reported that regulated irrigation deficit technique is only applied during periods in which the fruit growth is less sensitive to water shortage is an important water-saving technique and increasing productivity of irrigation water.

Table 5. Effect of irrigation deficit at different fruit growth stages on fruit set, yield and productivity of irrigation water (PIW) of "Anna" apple trees in 2016 & 2017 seasons.

Treat-	Fruit set (%)		Yield/tree (kgm)		Yield/fed. (ton)		PIW (kg/m^3)	
ments	2016	2017	2016	2017	2016	2017	2016	2017
T_1	17.04a	17.68a	29.87a	30.76a	10.454a	10.767a	2.203b	2.266b
T_2	16.43d	16.96a	27.48c	28.20d	9.620c	9.873d	2.083c	2.139c
T_3	17.00bc	17.36a	29.27ab	30.16ab	10.244ab	10.557ab	2.256ab	2.325ab
T_4	17.02ab	17.66a	28.45bc	29.36bc	9.957bc	10.277bc	2.229b	2.301b
T_5	15.57e	15.08b	24.03e	23.12f	8.413e	8.090f	1.878d	1.807d
T_6	16.98c	17.08a	28.66b	29.30c	10.030b	10.253c	2.316a	2.368a
T_7	17.00bc	17.65a	25.93d	27.39e	9.073d	9.587e	2.170b	2.292b

T_1 (control): irrigated 100% at all fruit stages.
T_2, T_3 and T_4: irrigated 75% at fruit growth stages I, II and III respectively.
T_5, T_6 and T_7: irrigated 50% at fruit growth stages I, II and III respectively.
Fruit growth stages: stage I: flowering – 40 days, stage II: 40 – 80 days and stage III: 80 days – harvest time

D- Fruit characteristics:

Data in Table (6) showed that, all irrigation deficit treatments had a significant effect on fruit characters in terms of fruit weight, size, length and diameter of "Anna" apple as compared to control treatment in both seasons. Decreasing mentioned fruit measurements were different based on the level and the time of irrigation water. While the highest values were obtained with control, T_7 (irrigation with 50% of control from 80 days after full bloom until harvesting- stage III) had the lowest values. Irrigation with 50% and 75% of control in different stages had different effects on studied fruit measurements. Under the periodic irrigation deficit treatments, the highest values were observed in T_3 treatment (irrigation with 75% of control from 40 to 80 days after full bloom stage II), while the lowest values were observed in T_7 (irrigation with 50% of control from 80 days after full bloom until harvesting- stage III) and T_5 (irrigation with 50% of control starting from flowering to 40 days after full bloom- stage I). May be this is due to the more soil moisture affects the amount of water absorbed by roots, which reflects on apple fruit characters.

Decreased mentioned fruit measurements were different based on the level of deficit irrigation water and periodic irrigation treatments. O'Connel and Goodwin (2007), Zaliha and Singh (2009b) and Küçükyumuk *et al.*, (2013) on apple, they reported that fruit diameter decreased in irrigation deficit applications compared to none irrigation deficit. The same trend was observed on fruit length and fruit weight. However, all irrigation deficit treatments decreased fruit weight, fruit size, fruit length and fruit diameter, it was observed that irrigation with 75% of control from 40 to 80 days after full bloom (T_3 treatment) and control (Conventional irrigation) resulted in fruit weight, fruit size, fruit length and fruit diameter close to each other. As for fruit shape the results showed a significant effect in the first season, whereas the highest value recorded T_7, while the lowest with T_6 treatment.

Table 6. Effect of irrigation deficit at different fruit growth stages on fruit weight, fruit . volume, length, diameter and shape of "Anna" apple trees in 2016 & 2017 seasons.

Treat-ments	Fruit weight (g)		Fruit size (cm^3)		Fruit length (mm)		Fruit diameter (mm)		Fruit shape (L/D)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T_1	152a	157a	172a	175a	79a	80a	67a	63a	1.18de	1.27a
T_2	146b	152bc	160bc	165c	76bc	77bc	63bc	62ab	1.21b	1.24a
T_3	150ab	156a	168a	170b	78ab	78ab	65ab	63a	1.20bc	1.24a
T_4	146b	151c	157c	160d	75c	76bc	63bc	61abc	1.19cd	1.25a
T_5	137c	143d	155c	145f	74c	75c	61c	60bc	1.21b	1.27a
T_6	147b	155ab	166ab	150e	76bc	77bc	65ab	62ab	1.17e	1.24a
T_7	135c	142d	152c	130g	74c	75c	60c	59c	1.23a	1.25a

T_1 (control): irrigated 100% at all fruit stages.
T_2, T_3 and T_4: irrigated 75% at fruit growth stages I, II and III respectively.
T_5, T_6 and T_7: irrigated 50% at fruit growth stages I, II and III respectively.
Fruit growth stages: stage I: flowering – 40 days, stage II: 40 – 80 days and stage III: 80 days – harvest time

E- Fruit physical and chemical characters:

From data in Table (7), it can be noticed that, tested irrigation treatments had a significant effect on fruit firmness in both experimental seasons. The highest fruit firmness values were obtained from trees irrigated with 50% of control from 80 days after full bloom until harvesting - stage III (T_7 treatment), on the other hand, conventional irrigation (control – T_1) had the least values. Irrigation deficit (75% and 50% of control) at different stages had different effects on fruit firmness. Among periodic irrigation deficit treatments, forasmuch T_7 (irrigation at 50% of control from 80 days after full bloom until harvesting time -stage III) had the highest fruit firmness, T_3 treatment (irrigation at 75% of control from 40 to 80 days after full bloom –stage II) gave the lowest values. Similarly, the shortage of irrigation water treatments increased fruit firmness, as previously decided by other authors (Zaliha and Singh, 2009 a; Küçükyumuk *et al.*, 2013). Inverse linear relationships were determined between fruit size and fruit firmness, when fruit size increased fruit firmness decreased, this is due to higher cellular density (Ebel and Proebsting, 1993), so that when adjusted firmness was calculated to remove the effect of size, there were no significant differences in firmness between irrigation treatments.

As for to the TSS results, a significant differences were found among the treatments. The highest TSS value was obtained from T_7 treatment whereas the lowest TSS value was determined in the control (conventional irrigation). Deficit irrigation especially in stage III (cell enlargement stage) increased TSS values. These results agreed with those mentioned by Mpelasoka *et al*. (2001) and Leib *et al*. (2006) who found that irrigation deficit applications increased total soluble solids (TSS) of apple fruits. In addition, Zaliha and Singh (2009a) reported that, TSS affected by the rate and the time of irrigation water. These results explained that different water deficit application periods led to different TSS values.

According to the acidity, data did not show significant differences between control and most treatments in the first season and with all treatments in the second one.

Regarding to the effect of irrigation deficit at different growth stages on anthocyanin content of "Anna" apple fruits, data presented in Table (7) revealed that a significant effect was remarkable in the two growing seasons. Irrigation deficit applied (75% and 50% from control) at different stages had effects on anthocyanin content compared to the control (conventional irrigation - T_1). The highest anthocyanin content was obtained from irrigation with 50% of control from 40 to 80 days after full bloom – stage II (T_6 treatment), whereas the lowest value belonged to the control. These results can be due to the effects of water shortage on the shoot length, especially in stage II, which allowing more light to penetrate the canopy thus improving the coloring in the fruits accordingly, the highest anthocyanin contents were found in T_6, T_5 and T_3 treatments. Improving the coloring in the apple fruits by regulated deficit irrigation decided by many of researchers such as, Mills *et al*. (1997); Zaliha and Singh (2009a) and Küçükyumuk *et al.*,(2013).

Table 7. Effect of irrigation deficit at different fruit growth stages on physical and chemical characters of "Anna" apple fruits in 2016 & 2017 seasons.

Treat-ments	Fruit firmness ($lb/inch^2$)				TSS (%)		Acidity (%)		Anthocyanin (mg/g F.W.t)	
	Measured		Adjusted							
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T_1	11.61f	11.27c	7.183a	7.110a	12.33d	12.70d	0.54a	0.47ab	20.87b	20.37d
T_2	11.84d	11.52b	7.023a	7.093a	12.40d	12.83c	0.55a	0.51a	21.93b	22.06bc
T_3	11.67e	11.32c	7.133a	7.107a	12.61c	13.03b	0.54a	0.51a	22.09b	22.49b
T_4	11.91c	11.58b	7.154a	7.097a	12.96b	13.05b	0.53a	0.47ab	21.24b	21.33c
T_5	12.35b	12.02a	7.113a	7.053a	12.45cd	13.05b	0.54a	0.51a	23.54a	23.58a
T_6	11.82d	11.35c	7.120a	7.090a	12.88b	13.55a	0.46ab	0.46ab	24.58a	24.38a
T_7	12.47a	12.07a	7.123a	7.070a	13.32a	13.59a	0.41b	0.43b	21.48b	22.36b

T_1 (control): irrigated 100% at all fruit stages.
T_2, T_3 and T_4: irrigated 75% at fruit growth stages I, II and III respectively.
T_5, T_6 and T_7: irrigated 50% at fruit growth stages I, II and III respectively.
Fruit growth stages: stage I: flowering – 40 days, stage II: 40 – 80 days and stage III: 80 days – harvest time

CONCLUSION

According to the above mentioned results, it could be noticed that short-term (40 days) irrigation water deficit during the growth season decreased vegetative growth and yield but saving irrigation water. The water deficit treatments between the 40 to 80 days after full bloom (T_3 & T_6) not only saved irrigation water but also have a least negative impact on yield and fruit quality. The fruits that have good coloring were obtained from irrigation deficit treatments compared to the conventional supply of irrigation water (control). To increase the use efficiency of irrigation water resources, especially in case of limited water, T_3 followed by T_6 treatments may be recommended to apple farmers because it not only saves water by 25 and 50%, but also have a least negative effect on yield and fruit quality.

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تأثير النقص المائي عند المراحل المختلفة لنمو الثمار على محصول وجودة ثمار أشجار التفاح صنف "آنا"

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أجريت هذه الدراسة خلال موسمي نمو 2016و 2017 وذلك في مزرعة خاصة بناحية النوبارية محافظة البحيرة بهدف دراسة تأثير النقص المائي عند مراحل مختلفة لنمو الثمار على بعض الصفات الخضرية والمحصول وجودة الثمار لأشجار التفاح صنف "آنا" - وكان عمر الأشجار8 سنوات ومسافات الزراعة 3*4 م. كانت الأشجار التي تم اختيارها ذات نمو ثمري وخضري جيد- التصميم الأحصائى المستخدم في الدراسة قطاعات كاملة العشوائية في ثلاث مكررات. وتم اختيار واحد وعشرون شجرة قسمت إلى سبع مجموعات كل مجموعة نفذت عليها واحدة من المعاملات الآتية:1- T_1 : الكنترول ري عادى, وكما يمارس المزارع العادي .2- T_2 : الري عند 75% من الكنترول بداية من التزهير حتى 40 يوم من التزهير الكامل .3- T_3 :الري عند 75% من الكنترول خلال الفترة من 40 حتى 80 يوم من التزهير الكامل.4- T_4 : الري عند 75% من الكنترول خلال الفترة من80 يوم من التزهير الكامل حتى وقت الحصاد .5- T_5 :. الري عند 50% من الكنترول بداية من التزهير حتى 40 يوم من التزهير الكامل.6- T_6 : الري عند 50% من الكنترول خلال الفترة من 40 حتى 80 يوم من التزهير الكامل.7- T_7 : الري عند 50% من الكنترول خلال الفترة من 80 من التزهير الكامل حتى وقت الحصاد . ويمكن تلخيص أهم النتائج كما يلي : *أعلى متوسطات القيم بالنسبة للصفات الخضرية المدروسة (طول الفرع – قطر الفرع – مساحة الورقة – الوزن النوعي للورقة) وكذلك بالنسبة للمحصول (كجم/شجرة – طن/فدان) ونسبة العقد والصفات الثمرية المدروسة (وزن الثمرة – حجم الثمرة - طول الثمرة- قطر الثمرة – شكل الثمرة) سجلت تحت معاملة الكنترول في حين أن اقل القيم بالنسبة للصفات الخضرية المدروسة سجلت تحت معاملة الري T_6 واقل القيم بالنسبة للمحصول ونسبة العقد سجلت تحت المعاملة T_5 وبالنسبة للصفات الثمرية المدروسة (وزن الثمرة- حجم الثمرة- طول الثمرة- قطر الثمرة) سجلت تحت المعاملة T_7 .بالنسبة لإنتاجية وحدة المياه المستهلكة والمضافة سجلت أعلى القيم تحت معاملة الري T_6 ولكن اقل القيم سجلت تحت معاملة الري T_5 . *بالنسبة للصفات الفيزيائية والكيمائية للثمار تأثرت كل من صلابة الثمار المقدرة بجهاز الصلابة وTSS بشكل معنوي والتي زادت تحت ظروف المعاملة T_7 في حين أن محتوى قشرة الثمار من صبغة الانثوسيانين زادت تحت ظروف المعاملة T_6 بينما كانت اقل القيم بالنسبة لصلابة الثمار وTSS ومحتوى قشرة الثمار من الانثوسيانين تحت ظروف معاملة الكنترول. ولم تظهر نتائج تقليل الري حتى 75% خلال الفترة من 40 حتى 80 يوم من التزهير الكامل (T_3) (12.972متر^3/شجرة/سنة = 4540.2متر^3/فدان) من كمية ماء الري المعطاة لأشجار الكنترول (13.572متر^3/شجرة/سنة = 4750.2متر^3/فدان) فروق معنوية مع معاملة الكنترول في عقد الثمار وكمية المحصول وكفاءة استخدام مياه الري لذلك يوصي بها لتوفير كمية ماء الري بنسبة 25% وكانت النتائج المترتبة على ذلك تقليل أعفان الجذور وانتشار الأمراض والحشرات.