14 *Egypt. J. Hort.* **Vol. 40,** No. 2, pp. 205 - 225 (2013)

Irrigation Regimes for Apricot Trees under Different Rates of Soil Moisture Depletion

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THIS EXPERIMENT was conducted at El-Kanater Horticultural Research Station, Kalubeia governorate through two successive seasons of 2010 and 2011 to study the effect of irrigation at 20, 40, 60 and 80% depletion from the available soil moisture on some water relations, some vegetative growth characteristics, yield, fruit quality and N, P, K, Fe, Zn and Mn leaf contents of twelve years old " Canino" cultivar apricot. Trees grown on clay loamy soil and planted at 5 x 5 meters apart. The results revealed that; consumptive use increased by decreasing the available soil moisture depletion (at high soil moisture). The monthly water consumptive was low after dormancy, then increased to reach the maximum during July and August and declined to minimum during October. The value of calculated crop coefficient (Kc) was 0.71.

Moreover, The value of water use efficiency (WUE) was higher with irrigation at 40% depletion of available soil moisture (1.21 and 1.33) compared with (0.98 and 0.97) obtained from irrigation at 80% depletion from available soil moisture during the two growing seasons, respectively. Vegetative growth (shoot length, shoot diameter and leaf area), fruiting parameters (fruit set percentage and yield) and fruit properties (fruit firmness, TSS and TSS/acid ratio) scored the highest significant values with irrigation at 20% and 40% depletion from the available soil moisture. While the leaf content of N, P, K, Fe and Zn significantly decreased when irrigation rate reduced.

Water is becoming scarce in the Mediterranean area where agriculture accounts for the vast majority of consumptive water use. It is therefore necessary to develop and implement regulated deficit irrigation (RDI) techniques in order to optimize water use without affecting crop yield. Although, water stress has a negative effect on most agricultural crops, fruit trees seem to adapt well to deficit irrigation (Costa *et al*., 2007). For example, apricot (*Prunus armeniaca* L.) trees permit the implementation of RDI during stage II of fruit development, which is known to be quite insensitive to water stress (Girona *et al.*, 1997).

On the other hand, the world faces very serious global warming, which will will cause general warming and significant increase in evaporation and crop water requirements. Thus, irrigation efficiency is becoming more important in arid and semi-arid regions due to the limitation of water resources.

Most apricot trees are cultivated in Mediterranean countries, where drought periods are expanded, a fact that makes irrigation water being the most limiting factor for apricot commercial production. So, optimization the efficiency of irrigation in this region by applying the deficit irrigation strategies that permit maximum yield while reducing water application is of great importance. In this sense, regulated deficit irrigation (RDI) may offer an approach to save water in some woody crops by minimizing or eliminating negative impacts on yield and crop revenue (Domingo *et al.,* 1996 and Goldhamer, 1997).

In this respect, Ali (2006) on peach as well as Kandil and El-Feky (2006) on apricot obtained the best growth parameters and yield with 80% F.C (field capacity). Moreover, Cathoun (1975) found that increase tension from zero to 0.33 bar released more than 75% of water in light textured soil but less than 50% in heavy ones. Also, Levin *et al.* (1980) revealed that, root distribution depended upon the volume of wet soil, which related to soil hydraulic conductivity. The crop coefficient (Kc) value has been used for quantifying crop water use (Doorenbos and Pruitt, 1984).

According to Girona *et al*. (1997), timing of water deficits has important effects on productivity of fruit trees. Kandil and El-Feky (2006) reported that water soil potential at 100-200 m bar (12.94 m^3/tree/year) was the best level for "Canino" apricot trees. On the other hand, excessive water may have adverse effects on fruit quality, since it increases vegetative growth, promoting nutritional imbalance and decreasing fruit dry mass. Consequently, it is important to study the effect of regulated deficit irrigation RDI on apricot fruit quality at harvest time.

The purpose of this study is to determine the effect of different irrigation regimes on water consumption, water use efficiency, vegetative growth, fruit set, yield, fruit quality (physical & chemical) and leaf mineral contents of "Canino" apricot trees grown under Qalubeia government.

Materials and Methods

The present investigation was undertaken during the two successive seasons of 2010 and 2011 at the Experimental Farm, El-Kanater Horticultural Research Station, Kalubeia Governorate (Latitude: 30^o. 08N Longitude: 31^o. 15 Elevation: 16.9 m) fruitful trees of "Canino" apricot (*Prunus armeniaca* L.) budded on apricot seedlings rootstock. The selected trees were about twelve years old grown on clay loamy soil and planted at 5 x 5 meters apart. Trees were carefully selected as being healthy and approximately uniform in their vigour, shape and size and received regularly the common horticultural practices in the region.

Analyses of the soil physical properties and the constant of soil moisture content are shown in Table 1. Meteorological data for the Agricultural Research Station is shown in Table 2.

TABLE 1. Physical properties of soil of the experiment .

Parameter		**Value**
Particle size distribution (%):		
Clay	%	30.4
Silt	%	34.5
Fine sand	%	34.1
Coarse sand	%	1.0
Texture class		Clay loam

Water parameters and bulk density

Depth	**Field capacity (FC)**		**Wilting Point (WP)**		**Available water (AW)**		**Bulk density (BD) Mg/m^3**
	% by weight	**Cm**	**% by weight**	**cm**	**% by weight**	**cm**	
0-15	37.9	6.99	18.6	3.43	19.3	3.56	1.23
15-30	35.8	6.39	17.8	3.18	18.0	3.21	1.19
30-45	32.1	6.12	16.1	3.07	16.0	3.05	1.27
45-60	31.7	7.32	15.9	3.67	15.8	3.65	1.54
Total		26.82		13.35		13.47	

The experimental design was a randomized complete blocks with three replicates was used. The investigation was designed to test four irrigation treatments.

Irrigation treatments were as follows:

- Irrigation when 20 % of available soil moisture is depleted (I_1).
- Irrigation when 40 % of available soil moisture is depleted (I_2).
- Irrigation when 60 % of available soil moisture is depleted (I_3).
- Irrigation when 80 % of available soil moisture is depleted (I_4)

Irrigation started after trees received the winter irrigation on March *i.e.*, starting from bud swelling stage. Irrigation was done when moisture reached the relevant level (5 days after irrigation) to determine available soil water retained in the soil in each treatment.

Soil moisture was determined grave metrically on oven dry basis of soil samples taken to a depth of 15 cm up to 60 cm. Water consumption was computed as the differences of soil moisture content in soil samples taken prior to 48 hour after irrigation.

TABLE 2. Meteorological data in 2010 and 2011 seasons .

Season	2010							2011						
Month	**T.max**	**T.min.**	**W.S**	**R.H.**	**S.S**	**S.R**	**R.F**	**T.max**	**T.min.**	**W.S**	**R.H.**	**S.S**	**S.R**	**R.F**
Feb.	25.0	11.5	1.5	57.7	11.0	354	6.1	22.9	11.3	1.3	56.7	11.0	354	0.7
Mar.	27.1	13.9	1.9	60.0	11.8	441	0.0	24.8	11.9	1.8	57.3	11.8	441	0.4
Apr.	29.6	16.0	1.8	52.3	12.8	419	0.0	28.4	18.5	1.4	51.0	12.8	519	0.4
May	33.9	19.2	1.7	49.0	13.5	585	0.0	32.8	18.7	1.7	50.3	13.5	585	0.1
Jun.	37.0	22.7	1.6	51.3	13.9	627	0.0	35.2	21.7	2.0	54.7	13.9	627	0.0
Jul.	36.3	23.9	1.8	67.0	13.8	613	0.0	37.3	23.5	1.9	58.7	13.8	613	0.0
Aug.	38.3	25.3	1.8	60.7	13.1	577	0.0	3.5	23.9	1.6	61.5	13.2	577	0.0
Sep.	35.8	23.5	2.1	59.0	12.2	512	0.0	35.5	22.7	0.9	58.0	12.2	512	0.0
Oct.	33.8	21.5	1.9	59.0	11.3	417	0.0	33.0	20.3	1.0	59.3	11.3	417	0.0

Where: T.max. , T.min.: maximum and minimum temperatures °C; W.S : wind speed (m/ sec); R.H.: relative humidity (%); S.S: actual sun shine (hour); S.R: solar radiation (cal/ cm^2/ day). RF: rainfall (mm / month).

[Data were obtained from the agrometeorological Unit at SWERI, ARC]

The quantity of irrigation water applied to each "Canino" apricot tree (litters) and per feddan (m^3) in the different irrigation treatments during each growing season was calculated.

Calculation of water consumptive use (CU)

Water consumptive use or actual evapotranspiration (ETc) values were calculated for each irrigation using the following formula (Israelsen and Hansen, 1962).

$$\mathbf{WCU} = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} \times \mathbf{Bd} \times \mathbf{D}$$

Where:

WCU = seasonal water consumptive use (cm),

Θ_2 = soil moisture content after irrigation (on mass basis, **%),**

Θ_1 = soil moisture content before irrigation (on mass basis, %),

Bd = soil bulk density (g/cm^3),

D = depth of soil layer (15cm each), and

i = number of soil layer.

Calculation of crop coefficient and evapotranspiration

Reference evapotranspiration (ETo)

Reference evapotranspiration (ETo) was calculated using the meteorological data using three formulae as cited by Doorenbos and Pruitt, (1977) and Allen *et al.*, (1998) as follows:

Doorenbos - Pruitt equation

The equation adapted the radiation formula of Makkink (1957) to predict potential evapotranspiration as follows:

ETp: bw Rs/L- 0.3

Where: ETp: Daily potential evapotranspiration (mm/day).

b: Adjustment factor based on wind and mean relative humidity.

W : Weighting factor based on temperature and elevation above sea level.

Rs: Daily total incoming solar radiation for the period of consideration ($cal/cm^2/day$).

L: Latent heat of vaporization of water ($cal/ cm^2/ day$)

Factors (b) and (w) could be obtained from the tables cited by (Doorenbos and Pruitt 1977).

Penman- Monteith equation

For estimating potential evapotranspiration of Penman Monteith, it was applied by using CROP WAT model (Smith 1991) as follows :

$$ETo = \frac{0.408\,\Delta(Rn - G) + \gamma\,[900/(T + 273]\,U_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,U_2)}$$

ETo: reference evapotranspiration, mm/day

Rn: net radiation (MJm-2d-1)

G: soil heat flux (MJm-2d-1)

Δ: slope vapor pressure and temperature curve (kPa°C-1)

γ : psychrometric constant (kPa °C-1).

U2:= wind speed at 2 m height (ms-1).

es-ea: vapor pressure deficit (kPa).

T : mean daily air temperature at 2 m height (°C).

Pan evaporation equation

ETo: K_{pan} x E_{pan}

Where:

ETo: reference evapotranspiraton (mm /day).

K_{pan}: Pan Coefficient

E_{pan}: Pan evaporation in mm/day from an unscreened class A type.

Crop coefficient (Kc) and assessment of ET

Three different equations were used to assess the extent of closeness of each estimate with the actual values obtained by direct measurement (values shown by the I_2 treatment which is the medium treatment). These equations are (1) the Penman - Monteith equation using the CROPWAT model and (2) the Doorenobs and Pruitt (1977) and equation (3) the Pan Evaporation equation

Crop Coefficient (Kc)

The recommended values of Kc, according to Doorenbos and Kasam (1986) were used to estimate the ETo for the conditions of the area where the experiment was done. The formula is as follows:

Kc = Etc / ETo

Where: Kc : Crop coefficient.

ETc : The measured (actual) evapotranspition of a considered period (mm/day)

Eto : reference evapotranspiration (mm/day) referring to the same period, calculated as average value of three formulae.

Water use efficiency (WUE)

Water use efficiency (WUE) is used to describe the relationship between production and the amount of water used. It was determined according to the following equation (Vites 1965):

$$W.U.E = \frac{\text{Fruits yield (kg)/fed}}{\text{Seasonal ET (m}^{3/}\text{ water consumed)/fed}}$$

Vegetative growth measurements

Four main branches, in different directions of each replicate were labeled. All current shoots developed on those branches on Aug. were used for measuring vegetative growth parameters as follows: a) Shoot length (cm), b) Shoot diameter (cm), c) Leaf area (cm^2) using Li-core 3100 area meter. Leaves were dried and weighed to get d) Leaf dry weight (g.).

Fruiting parameters

Fruit set (%) and yield

$$\text{Fruit set (\%)} = \frac{\text{Number of developed fruitlets}}{\text{Total number of flowers at full bloom}} \times 100$$

Yield

At harvest time, yield of each tree was recorded as kg per tree during the two seasons of study.

Samples of twenty fruits from each replicate under treatment at harvest were randomly collected and the following characters were determined as follows:

Fruit quality

Physical fruit properties

Fruit weight (g), fruit size (cm^3), length (cm), diameter (cm) and firmness. Firmness was determined by Magness and Taylor (1925), pressure tester using 7/18 inch plunger two reading were taken on the fresh of each fruit.

Chemical fruit properties

- Total soluble solids (%) in fruit juice was determined by using hand refractometer.
- b-Titratation table acidity (%) was measured according to (A.O.A.C. 1990) and Vogel (1968).
- Total soluble solids/acidity ratio was calculated.
- Total sugars were calculated color-metrically according to Malik and Singh (1980).

Leaf analysis

Leaf nutrient composition

Twenty mature mid-shoot leaves at mid August of both seasons were collected randomly, and then washed with tap water followed by distilled water and oven dried at 70 °C to constant weight and prepared for the determination of leaf mineral content.

Nitrogen was estimated using micro-Kjeldahl method described by Pregl (1945). Phosphorus was determined with a colorimetric method as described by Snell and Snell (1967). Potassium was determined by using the Atomic Absorption Spectrophotometer. Iron, zinc and manganese were determined by Atomic Absorption Spectrophotometer according to Jackson and Ulrich (1959) and Chapman and Pratt (1961). Generally, all macro-elements were expressed as percent, while micro-elements were expressed as (ppm) on dry weight basis.

Leaf total chlorophyll content

Leaf total chlorophyll values were determined by using portable Minolta chlorophyll Meter (Model SPAD-501). Leaf samples collected in mid-June and the reading was taken at the middle of leaf blade according to Murquard and Timpton (1987).

The experimental design was a randomized complete block design and all data obtained throughout the course of this study were statistically analyzed by the analysis of variance as described by Snedecor and Cochran (1990). Differences between treatments were compared by Duncan's (1955) multiple range tests.

Results and Discussion

Water use

The consumptive use of water (CU) measured actually during the season (considered as actual evapotranspiration, *i.e.* actual ET) as affected by the different treatments and the calculated crop coefficient with comparison of actual and calculated ET are presented and discussed bellow, as well as water use efficiency WUE.

Water consumptive use

Seasonal Rates (m^3)

Seasonal rates of water consumptive use (CU) by trees under different soil moisture stress treatments are presented in Fig. 1. The values of water use show that the short irrigation intervals (*i.e.* the wet I_1 regime) followed by the I_2 then dry regime I_3 gave the lowest. ETa values in 2010 were 4746, 4363.8,3691.8 and 3359.2 m^3 for I_1, I_2, I_3 and I_4, respectively. The same respective values in 2011 were 4846.8, 4460.4, 4032 and 3493.1 m^3. The values showed that seasonal water uses by trees are higher in the second than in the first season. Such results are mainly due to the differences in weather factors such as the increasing in air temperatures.

Increased CU with increasing soil moisture content is a direct consequence of increased irrigation water input in addition to the higher evaporation rate from wet soil surface. Abd Alla *et al*. (1990) found that, the highest CU occurred when irrigation was done upon reaching moisture of 70 to 80 % of the field capacity. Ibrahim (1981) concluded that the increase in evapotranspiration by maintaining soil moisture at a high level is attributed to excess available water in the root zone. Unger and Steward (1983) pointed out that, soil water evaporation occurs in three stages. In the first, water loss is rapid and steady, and depends on the net effects of water transmission to the surface and on environmental conditions. In the second stage, the loss rate decreases rapidly as the soil water supply is depleted, and soil factors control the rate of water movement to the surface and above ground. In the third stage, evaporation is extremely slow and is controlled by absorptive factors at the liquid-solid interface. Doorenbos and Pruitt (1984) concluded that, after irrigation the soil water content decreases primarily by evapotranspiration.

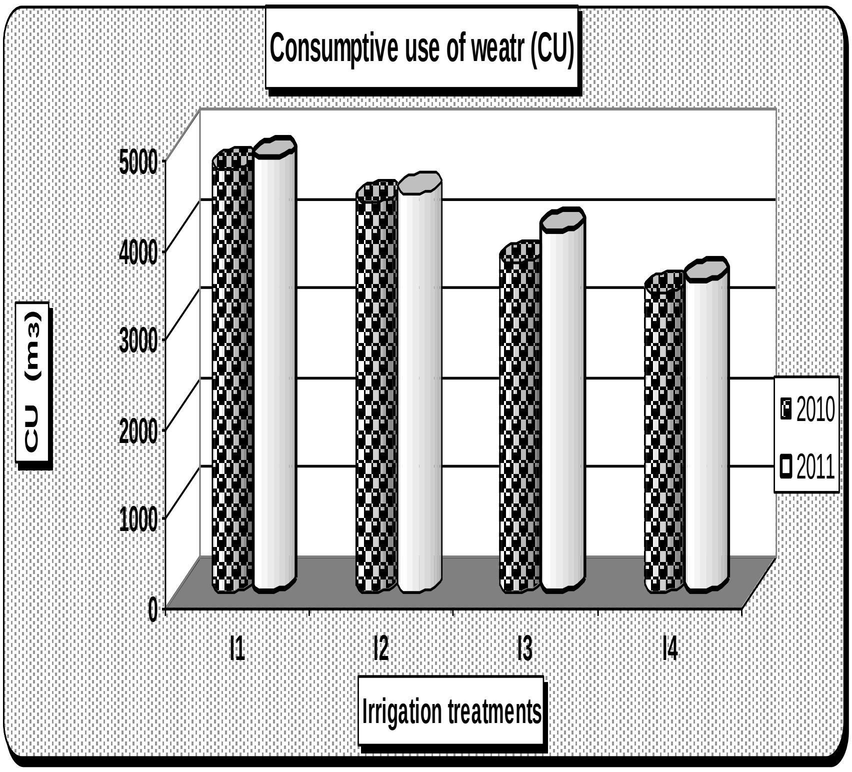

Fig. 1.Effect of irrigation treatments on water consumptive use (CU) mm of apricot trees.

As the soil dries, the rate of water transmitted through the soil is reduced. When the rate of flow falls below the rate needed to meet ET of crop, it will fall below its predicted level. Chang (1971) concluded that the rate of evapotranspiration depends on the evaporate power of air and there was a very close correlation of water consumptive use and climate. The pattern of consumptive use was $I_1 > I_2 > I_3 > I_4$ is a manifestation of greater water availability of soil moisture to plants. High evaporation would occur from a relatively wet rather than a relatively dry soil surface. Higher CU with the wet regime can be attributed to greater availability of soil water to apricot trees in addition to the higher evaporation rate from wet soil surface.

Monthly consumptive use

Monthly CU Fig. 2 was low at the beginning of the growth season (after dormancy). This can be related to less transpiring surface (leaves) during the period of bloom. Potential evapotranspiration was low through this period Table 3, then increased gradually as the green cover increased with increases in air temperature and solar radiation. The highest CU occurred during July reflecting: a) expansion of the leaf system, b) growth of fruit on a volume basis, c) high solar radiation and air temperature. The July values for the treatments averaged 741.3, 694.3, 628.3 and 582.1 m^3 for I_1,I_2, I_3 and I_4 (means of the 2 seasons), respectively.

Thereafter, evapotranspiration rate decline to reach its minimum value during October as the trees were approaching dormant period . Such results can be attributed to high evaporation than transpiration early in the season (blooming period) as plants intercepts little of net radiation. Later, as the green cover expanded, transpiration was greater than evaporation. Thus, the increase in evapotranspiration from the beginning of the growth season till fruit maturity can be explained on the basis of the cover. It can be concluded that soil moisture stress has a direct effect on monthly evapotranspiration of trees as soil moisture stress increased by prolonged irrigation intervals. Smajstrla and Koo (1984) found that irrigation of selected trees was initiated during the growth stages before and after June. They suggested that irrigation is required to keep soil moisture tension between 40 -60 mbar at 30 cm soil depth (*i.e.* 50% available water) and this frequency of water application resulted in the highest yields.

TABLE 3. Monthly water consumptive use Eta (m^3) by apricot trees under different water regime levels.

Irrigation regimes	2010									
	Febr.	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Total**
I_1	242.34	451.08	510.3	612.78	659.4	699.3	584.64	507.78	478.38	4746.0
I_2	236.46	386.82	457.8	559.44	600.6	682.08	572.46	466.2	401.94	4363.8
I_3	232.26	325.92	380.52	486.78	546.42	571.2	517.44	399	232.26	3691.8
I_4	226.8	271.32	338.52	461.58	505.68	533.4	471.24	356.16	194.46	3359.2
	2011									
	Febr.	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Total**
I_1	254.1	460.32	517.02	593.46	693.42	741.3	639.24	504.84	443.1	4846.8
I_2	236.46	395.22	466.2	571.2	613.2	694.26	606.06	464.1	413.7	4460.4
I_3	231.42	371.28	403.62	540.12	604.38	628.32	556.92	422.52	273.42	4032.0
I_4	227.22	329.28	365.82	409.92	545.16	582.12	501.48	330.12	202.02	3493.1

Crop coefficient "Kc"

Factors affecting values of crop coefficient (Kc) are mainly the climatic conditions, crop characteristics, sowing date, rate of crop development and length of growing season. Results of the current study (Table 4) show that the mean value of Kc was 0.71. Monthly values increased with time and was higher in June, July and August (0.65, 0.74 and 0.63), respectively. This demonstrates that such period is the peak of water demand. The crop coefficient decreased again during the late season to reach minimum when plants were reaching dormancy .

Most crops do not require much water during the season as would be needed to meet the potential evapotranspiration, even though adequate soil moisture can be provided (Jensen, 1968). Thus, the term crop coefficient is used to differentiate water requirements of crops. For the determination of crop coefficient, both actual and potential evapotranspiration are measured concurrently.

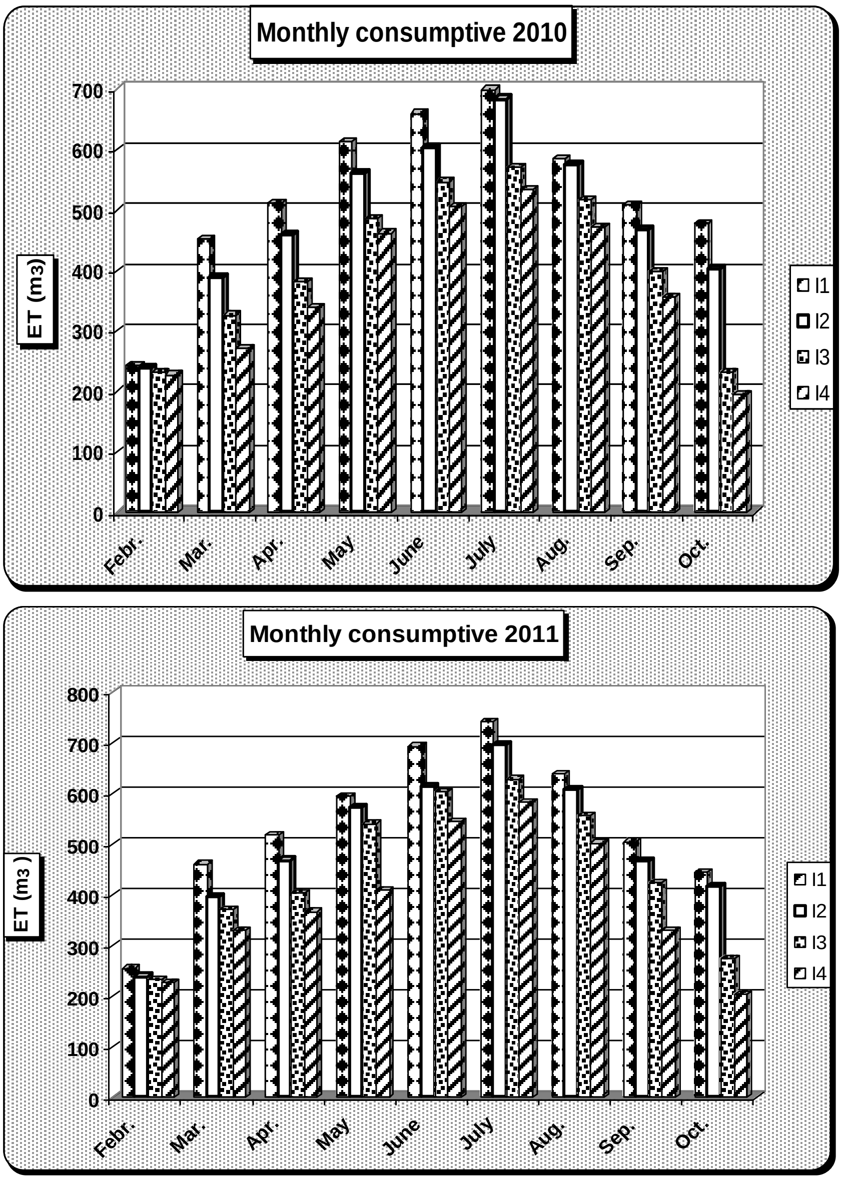

Fig. 2. Monthly water consumptive use Eta (m^3) by apricot trees under different water regime levels.

Comparing actual ETa with calculated ETp

Evapotranspiration (ETp) crop values Table 4 calculated using the three different equations (Penman - Monteith, Doorenbos - Pruitt and Evaporation Pan) were compared with the actual ETa as obtained by actual measurement *i.e.* the consumptive use. In season 2010, seasonal ETp values were 1605, 1353 and 1034 mm for the Penman - Monteith, Doorenbos - Pruitt and Evaporation Pan equations, respectively. In season 2011, seasonal ETp values were 1528, 1327 and 1138 mm for the same respective equations.

Generally, results indicate that there were differences among calculations using the different equations. The Doorenbos - Pruitt equation was the second highest estimate preceded by the Penman - Monteith equation. The evaporation pan showed great differences between the two seasons, which reflects differences in weather conditions particularly temperature and solar radiation temperature. The Penman - Monteith formula gave the highest ETp crop value, while the Evaporation Pan equation gave the lowest one in the two seasons. Comparison with ETa as calculated by actual determination shows that the Evaporation A Pan equation was the nearest to actual ET.

Comparison between the calculated ETp and the actual ETa

Value of ratios of ET (*i.e.* crop ET/ actual ET) are shown in Table 5. Actual ET was obtained from the I_2 irrigation treatment. Ratios of 1.54, 1.30 and 1.0 were recorded in 2010 for Penman-Monteith, Doorenbos-Pruitt, and Evaporation Pan Equations respectively. In 2011 the corresponding ratios were 1.42, 1.23and 1.05 for the same respective formulas. The overall averages for the 2 seasons are 1.48, 1.27 and 1.02 for the same respective equations. The Evaporation Pan formula was the closest compared with the other equations because the ET crop calculated from this formula was slightly differed from the actual ET value. The ET crop calculated due to Doorenbos-Pruitt was the second closest to actual ET after the Evaporation Pan while the value of the Penman-Monteith formulae differed widely from actual ET.

Water use efficiency WUE

Water use efficiency, is used to show the fruit yield production (kg) per unit of water. It appears from Fig. 3 that this trait was markedly profitable under the medium soil moisture stress level (40%), as it registered 1.21 and 1.33 Kg. fruit yield /m^3 water of irrigation in the first and second seasons, respectively. Whereas the wet treatment produced the least value 1.02 and 1.17 Kg. fruit yield /m^3 irrigation water in both seasons, respectively. This means that apricot trees favors medium watering and high production prefers medium soil moisture than lower and high watering. Ritchie (1974) pointed out that, water conservation benefits can be obtained by allowing plants to experience moderate water stress. When roots are subjected to soil moisture stress, extraction of soil water from greater depths would occur therefore, water stored in the profile is used more efficiently. Smajstrla and Koo (1984) found that irrigation of selected trees was initiated during the growth stages before and after June. They suggested that irrigation is required to keep soil moisture tension between 40 -60 mbar at 30 cm soil depth (*i.e.* 50% available water) and this frequency of water application resulted in the highest yields. Roth *et al.* (1988) found that depletion of a small portion of available soil moisture and found that irrigation upon depletion of 40 % of available soil moisture gave the highest water use efficiency.

TABLE 4. Crop coefficient (Kc), ETcrop for Penman Monteith, Doorenbos- Pruitt and Evaporation Pan formulae and actual ET for apricot trees in 2010 and 2011 seasons.

Month	Kc	Penman Monteith		Doorenbos & Pruitt		Evaporation Pan		Actual ET	
		mm/ day	mm/ month	mm/ day	mm/ month	mm/ day	mm/ month	mm/ day	mm/ month
2010									
February	0.61	3.3	92.4	2.84	79.5	1.74	53.9	2.01	56.3
March	0.68	4.4	136.4	3.78	117.2	2.33	72.2	2.97	92.1
April	0.65	5.6	168.0	4.73	141.9	3.42	102.6	3.63	108.9
May	0.64	6.7	207.7	5.71	177.0	4.55	141.1	4.30	133.3
June	0.65	7.3	219.0	6.39	191.7	4.77	143.1	4.77	143.1
July	0.74	7.1	220.1	6.09	188.8	4.94	153.1	5.24	162.4
August	0.63	7	217.0	5.88	182.3	4.95	153.5	4.40	136.4
September	0.61	6.1	183.0	5.05	151.5	3.92	117.6	3.70	111.0
October	0.59	5.2	161.2	3.97	123.1	3.14	97.34	3.09	95.79
Seasonal (mm)	0.65		1605		1353		1034		1039
2011									
February	0.72	3.07	89.0	2.81	78.7	1.78	55.2	2.08	64.5
March	0.72	4.23	131.1	3.62	112.2	2.33	72.2	3.04	94.2
April	0.69	5.35	160.5	4.56	136.8	3.48	104.4	3.70	111.0
May	0.65	6.74	208.9	5.61	173.9	4.68	145.1	4.39	136.1
June	0.67	7.25	217.5	6.26	187.8	5.54	166.2	4.87	146.1
July	0.71	7.48	231.9	6.21	192.5	5.76	178.6	5.33	165.2
August	0.81	5.74	177.9	5.71	177.0	5.57	172.7	4.65	144.2
September	0.75		160.2		147.3	4.33	129.9	3.98	119.4
October	0.65	5.34	151.3	4.91	120.28	3.68	114.1	3.18	98.6
Seasonal (mm)	0.71	4.88	1528	3.88	1327		1138		1079

TABLE 5. Ratios of ET crop values calculated by different ET formulae to the actual ET of apricot in 2010 and 2011 seasons .

Formulae	2010		2011		Average	
	ET crop	Ratio	ET crop	Ratio	ET crop	Ratio
Penman Monteith	1605	1.54	1528	1.42	1567	1.48
Doorenbos- Pruitt	1353	1.30	1327	1.23	1340	1.27
Evaporation A Pan	1034	1.00	1138	1.05	1086	1.02
Actual ET	1039	…	1079	…	1059	…

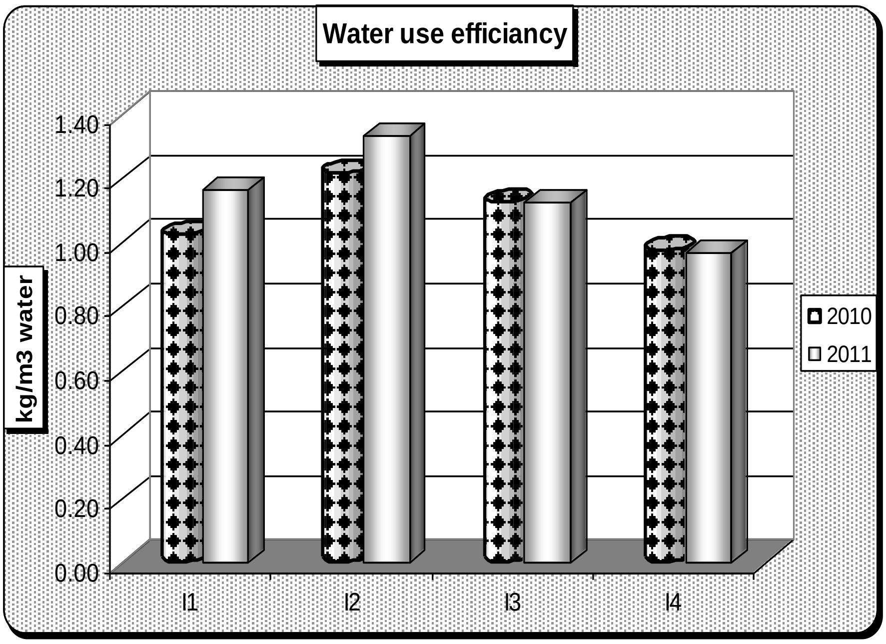

Fig. 3. Water use efficiency (WUE) kg/m^3 by apricot trees under different water regime levels.

Vegetative growth and fruiting parameters

Vegetative growth parameters:

Shoot and leaf growth parameters: The obtained data in Table 6 showed that shoot and leaf parameters of "Canino" apricot trees affected by irrigation rates in 2010 and 2011 seasons. It cleared that shoot length (cm), diameter (cm), leaf area (cm^2) and leaf dry weight (g) recorded the highest significant values at I_1 irrigation rate (20% depletion), while showed gradually decrease with irrigation rate reduction. Data were in harmony at both studied seasons. However, Alkinson *et al.* (2000) reported that drought stress caused an increase in abscissic acid production in the root and transportation to the shoot. The increase in ABA could reduce shoot growth and leaf expansion of "Queen Cox" apple trees. Also, water stress reduces the capacity of the protoplasm to carry on photosynthesis. In addition, this reduction in the trees growth under water stress could be related to lower photosynthetic rates and stomatal conductance (Mpelasoka *et al.*, 2001) which decrease the supply of $Co_{2.}$ These results were in agreement with those obtained by Chalmers *et al.* (1981) who mentioned that the growth of peach trees was inhibited with reduced irrigation than with full irrigation. Furthermore, Abd El-Messeih and El-Gendy (2004a) on "Canino" apricot; Mikhael (2007a) on "Anna" apple; Hussein *et al.* (2008) on apricot and Mikhael *et al.* (2010) on "Dessert Red" peach, reported that shoot and leaf growth were reduced under the low drip or flood irrigation rates.

TABLE 6. Effect of different irrigation levels on shoot length, shoot diameter, leaf area and leaf dry weight of "Canino" apricot trees during two seasons.

Irrigation regimes	Shoot length (cm)	Shoot diameter (cm)	Leaf area (cm^2)	Leaf dry weight (g)
2010				
***I_1**	62.19 A	1.230 A	36.40A	0.450A
I_2	45.65 B	1.000 B	28.19B	0.407B
I_3	33.34 C	0.810 C	27.13C	0.380C
I_4	25.05 D	0.650CD	21.72D	0.316D
2011				
I_1	50.30 A	1.120 A	35.00A	0.544A
I_2	46.13 B	0.950 B	28.84B	0.485B
1_3	36.55 C	0.770 C	25.06C	0.440BC
I_4	27.72 D	0.530 D	20.50D	0.337D

* I_1 Irrigation when 20% available soil moisture is depleted (wet)
I_2 Irrigation when 40% available soil moisture is depleted.
I_3 Irrigation when 60% available soil moisture is depleted.
I_4 Irrigation when 80% available soil moisture is depleted (dry)

Fruit set percentage and yield

Data in Table 7 revealed that the highest fruit set percentage (23.3 and 25.2%) and fruit yield (31.55 and 35.40 kg) were accompanied with 40% water depletion (I_2), while decreased markedly with higher (I_1) or lower (I_3 and I_4) irrigation rates. However, the difference was statistically confirmed except between I_1 and I_2 fruit set in 2011 season. The lowest fruit set percentage was induced by the deficit water irrigation rate (I_4). These results were in harmony with those noticed by Skepper and Vircent (1962) who reported that 4-5 weeks water shortage before blooming resulted in a reduction in fruit setting in deciduous trees. Also, Ali *et al.* (1998) found that maintaining soil moisture at high level (20% depletion) caused a significant decrease in peach fruit setting compared with the other irrigation treatments. At the same time, more water stored in the root zone of apple trees may cause a reduction in fruit setting due to their effect either on aeration or on the growth of roots. Moreover, in this study at low moisture levels (dry), it showed a significant decrease in fruit set %. Also, all previous data were in line with Abd El-Messeih and El-Gendy (2004a) and Mikhael and Mady (2007b). In this respect, George and Nissen (2002) indicated that, as the severity of drought increased, fruit set was reduced. Such results might be due to lower photosynthetic rates under deficit irrigation regime. As for yield (kg fruits/tree), it could be noticed that water deficit had a significant effect on productivity of apricot trees. The maximum fruit yield and yield efficiency Fig. 3 were scored from I_2 followed by I_1. The lowest significant production was induced by the dry soil moisture level in both studied seasons. Ali *et al.* (1998) pointed out that such type of foundations may prove the importance of maintaining soil moisture at an optimum level (40% depletion.) for increasing the retained fruits on apple trees.

TABLE 7. Effect of different irrigation levels on fruit set % and yield (kg/tree) of "Canino" apricot trees during the two experimental seasons.

Irrigation regimes	Fruit set %	Yield (kg/tree)	Firmness (Ib/inch^2)
2010			
I_1	20.81B	28.90B	5.32D
I_2	23.30A	31.55A	5.89CD
I_3	18.62C	24.70C	6.64B
I_4	16.53D	19.53D	7.22A
2011			
I_1	24.50A	33.62B	5.60D
I_2	25.20A	35.40A	6.00C
1_3	19.07B	27.00C	6.58B
I_4	16.66C	20.11D	7.53A

Fruit quality

Physical fruit properties (weight, volume, length and diameter)

Data in Table 8 showed that all the fruit characteristics were significantly affected by water deficit. The highest values were resulted from I1 and I2 followed by I3 (medium). Generally, the lowest values were gained from the severe soil moisture stress. Results were true under both studied seasons. These results were supported by Behboudian *et al.* (1994). Also, Mpelasoka *et al.* (2001) stated that effect of deficit irrigation on reduced average fruit weight and volume could be due to the reduction in fruit cell enlargement by reducing fruit turgor early in the season and decrease cell water content.

TABLE 8. Effect of different irrigation levels on fruit weight (g), fruit volume (cm^3) and fruit length (cm) & diameter (cm^2) of "Canino" apricot trees during the two experimental seasons.

Irrigation regimes	Fruit weight (g.)	Fruit volume (cm^3)	Fruit length (cm)	Fruit diameter (cm)
2010				
I_1	57.86B	50.20A	5.30B	4.82B
I_2	65.01A	47.40B	5.58A	5.08A
I_3	53.40C	41.10C	4. 40C	4.20C
I_4	46.97D	36.20D	3.35C	3.78D
2011				
I_1	67.20A	46.70B	5.04B	4.95A
I_2	52.57B	49.03A	5.36A	4.90A
1_3	48.83C	39.02C	4.57C	4.40B
I_4	43.98D	34.03D	3.95D	4.00C

Fruit firmness

With regard to fruit firmness it could be noticed that reducing irrigation rate caused significant higher of fruit firmness especially at deficit irrigation rate (I4). The lowest significant value of fruit firmness was induced by I1. Data was in harmony during two studied seasons. Higher firmness may be a result to smaller fruit exhibit the effect of water stress at cell enlargement stage. These results were confirmed with Ali *et al.* (1998), Abd El-Messeih & El-Gendy (2004a) and Mikhael & Mady (2007b) who reported that deficit irrigation induced significantly higher firmness.

Chemical fruit properties

Total sugars, total soluble solids, acidity, TSS/acid ratio in fruit juice and leaf total chlorophyll content

As for TSS and total sugars fruit content in Table 9 appeared that, TSS and TSS/acid ratio, in both seasons, significantly decreased with increasing irrigation water intervals, it reached to the maximum value when trees were supposed to irrigation at I_1. Generally, the lowest statistical values of TSS fruit content were recorded at deficit irrigation rate (m^3 /tree/year) due to the reduced net photosynthesis under drought condition. These results were in the same line with Abd El-Messeih and El-Gendy (2004a) on apricot.

Moreover, total sugars recorded the same trend of TSS. It was in harmony with Abd El-Messeih and El-Gendy (2004a). In addition, no definite trend was found with irrigation treatments by Abou Garah *et al.* (2009) on persimmon.

TABLE 9. Effect of different irrigation levels on total sugars (%), TSS (%), acidity (%), TSS/acid ratio in fruit juice leaf chlorophyll content of "Canino" apricot trees during the two experimental seasons.

2010					
Irrigation regimes	**Total sugars %**	**TSS %**	**Acidity %**	**TSS/acid Ratio**	**Chlorophyll (SPAD)**
I_1	58.50A	15.50A	0.690D	22.46A	43.20A
I_2	54.03B	15.20B	0.720C	21.11B	38.80B
I_3	49.70C	14.70C	0.770B	19.09C	34.00C
I_4	45.60D	14.02D	0.840A	16.69D	31.20D
2011					
I_1	56.71A	15.04A	0.750D	20.05A	38.43A
I_2	53.70B	14.81A	0.800C	18.51B	36.62B
1_3	49.63C	14.40B	0.850B	16.94C	32.58C
I_4	46.82D	13.80C	0.910A	15.16D	31.00C

From data in both studied seasons it was obvious that, fruits produced from trees grown under dry conditions were significantly higher in the values of juice acidity. The lowest value was obtained from irrigation level (I_1). Similar results were reported by Perez-Pastor *et al.* (2007) on apricot. On the other hand, Abd El-Messeih and El-Gendy (2004a) stated that acidity decreased with decreasing applied irrigation water.

It was clear from Table 9 that, leaf chlorophyll content at both seasons gradually decreased with decreasing water irrigation rate with significant differences between irrigation levels. These results appeared that a positive impact between soil moisture level and leaf chlorophyll content. This increase in leaf chlorophyll could be related to increase the uptake of N an Mg elements are necessary for chlorophyll synthesis (Mengle and Kirkby, 1982). The same results were supported by Abd El-Messeih and El-Gendy (2004b) and Mikhael *et al.*, (2010) worked on apricot and peach, respectively.

Macro and micro elements leaf contents

Data in Table 10 it mentioned that, reducing irrigation rate caused gradually significant reduction in leaf N, P, K, Fe and Zn content. The same trend was clear in the second season. However, no definite trend was cleared with Mn leaf content. These results may be lead to the conclusion that nutrient uptake was retarded under water stress conditions where the roots failed to absorb and accumulate valuable nutrient elements. Furthermore, depletion of soil moisture level caused a reduction in leaf mineral contents as a result of reduced active rooting as an indirect effect (Abd El-Messeih and El-Gendy, 2004b) on apricot trees.

TABLE 10. Effect of different irrigation levels on some macro and micro nutrients of "Canino" apricot trees during two seasons.

Irrigation regimes	N%	P%	K%	Fe ppm	Zn ppm	Mn ppm
2010						
I_1	2.50A	0.32A	1.50A	122.3A	19.90A	50.20A
I_2	2.20B	0.28B	1.20B	111.1B	17.60B	38.20C
I_3	1.95C	0.23C	1.00C	99.40C	15.00BC	34.00D
I_4	1.80D	0.20CD	0.82D	89.70D	12.10C	43.10B
2011						
I_1	2.35A	0.29A	1.60A	131.2A	21.60A	25.00D
I_2	2.00B	0.26B	1.40B	125.0B	19.70A	46.20B
1_3	1.90B	0.22C	1.32C	119.3C	15.50B	48.60A
I_4	1.52C	0.19D	1.22D	115.1C	11.40C	39.50C

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(*Received* 15/7/2013;
accepted 25/9/2013)

تنظيم رى أشجار المشمش تحت معدلات مختلفة من إستنفاذ الرطوبة الأرضية

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أجريت هذه التجربة بمحطة بحوث البساتين بالقناطر الخيرية بمحافظة القليوبية خلال موسمى 2010 و 2011 لدراسة تأثير الرى عند 20، 40، 60، 80٪ استنزاف من ماء التربة الميسر على بعض العلاقات المائية و بعض صفات النمو الخضرى و المحصول و جودة الثمار و محنوى الأوراق من عناصر النيتروجين والفوسفور والبوتاسيوم و الحديد والزنك و المنجنيز فى اشجار المشمش صنف كانبنو بعمر حوالى 12 عام الأشجار مزروعة فى أرض طينية طميية على مسافة 5×5 أمتار فى نظام مربع ، و أوضحت النتائج :

زياده معدل الإستهلاك المائى مع نقص معدل استنزاف رطوبة التربة (الرطوبة العالية للتربة).

معدل الإستهلاك المائى بدأ منخفض بعد السكون ثم زاد إلى الحد الأقصى خلال شهرى يوليو و أغسطس ثم تناقص لأقل معدل فى أكتوبر وكانت قيمة معامل المحصول 0.71 .

وجد ان كفاءة استخدام المياه (كجم ثمار/م3 مياه) كانت عالية مع الرى عند استنزاف 40 ٪ من الماء الميسر (1.21، 1.33) بالمقارنة مع (0.98 ، 0.97) المتحصل عليها من الري عند استنزاف 80 ٪ من الماء الميسر خلال موسمى النمو على التوالى.

صفات النمو الخضرى (طول وقطر الأفرع ومساحة الورقة) و صفات النمو الثمرى (٪ للعقد والمحصول) ومواصفات الثمار (صلابة الثماروالمواد الصلبة الذائبة الكلية و نسبتها إلى الحموضة) سجلت أعلى قيم معنوية مع الرى عند معدل 20 و 40٪ استنزاف من الماء الميسر. بينما تناقص معنويا محتوى الأوراق من عناصر النيتروجين والفوسفور والبوتاسيوم والحديد والمنجنيز مع تناقص معدل الرى .