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Effect of Irrigation Levels on Growth and Productivity of Pecan Trees

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Abstract: This study was achieved over two consecutive seasons of 2019 and 2020 on 8 years old pecan trees cv. Burkett cultivated at 4 X 5 m apart and grown in a sandy soil under drip irrigation system in private orchard at Behera governorate, Egypt. This experiment was designed to study the impact of different irrigation levels (75, 100 and 125% ETc) on growth and yield of pecan trees. The highest irrigation level 125% ETc enhanced vegetative growth, flowering, fruit set, yield, nut kernel percentage and leaf (N, P and K) content (%). While irrigation level at 100% ETc gave a moderate vegetative growth and yield and highest water utilization efficiency. Irrigation level 75% ETc decreased vegetative growth, nut weight, yield and leaf (N, P and K) content (%). The best treatment was irrigation at 100% ETc such gave satisfactory growth, yield and saving water.

Key words: Pecan · Irrigation levels · Vegetative growth · Flowering · Yield

INTRODUCTION

The pecan tree (*Carya illinoensis* [Wangenh.] K. Koch) is the only nut crop native to northern Mexico and the southern United States that has significant commercial importance. It need chilling requirement (less than 200 hours of chilling (2-8°C)) that must be received during winter to get optimal growth in spring [1]. Pecans have a much lower chilling requirement than other deciduous fruit crops [2, 3]. This makes them perfect to be grown in the warm regions compared to other deciduous crops such as pome and stone fruit. Pecan can endure a wide range average temperature during summer can reach up to 27°C, with extreme values of 41 to 46°C. While, in winter, the optimum average temperature goes between -1 and 10°C with extreme lows of -18 to -29°C [4]. Most of pecan orchards in Egypt irrigated by flooding, which losses a big amount of water. Under drip irrigation system Behnia [5] and Chopade *et al*. [6] found that yield was increased by 30- 40% and saved water up to 50 -66% compared to flooding irrigation. Pecan production has affects by water more than does any other environmental factor. Adequate water supply is critical for optimal fruit production, particulary in arid and semi arid region that rainfall is low and erratic. This is particulary true for pecans that is need a large amount of water for adequate production compared to other crops. Although the water use efficiency may be low but the monetary value of pecans is high and the economic return for every unit of water added is high compared with other crops [7]. With water stress during the season reducing leaf and shoot growth, nut size, yield and quality of the nuts and return crop [8, 9]. Sufficient soil moisture is necessary to stimulate vigorous growth from bud break till shell hardening and during the nut filling stage for optimizing kernel percentage in order to maximize yield, quality and economic return [10]. Many researchers prove how water depletion has negatively impact on fruit growth rate and harvested yields in several fruit crops peach, apple and kiwifruit respectively [11-13]. This effect is may be due to decrease stomatal conductance and the consequent lower in canopy carbon assimilation. However, soil water content may also impact on the water and carbohydrates translocation to the fruit. Indeed, water depletion decreases both leaf and stem water potentials during the day and may thus reduce water potential gradient from stem-to-fruit, with consequent negative effects on fruit growth rate [14]. The objective of our study was to determine relatively the actual water need for irrigation pecan orchards under drip irrigation system that gave satisfactory growth and yield.

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MATERIALS AND METHODS

Field Experiment: this study was achieved over two consecutive seasons of 2019 and 2020 on 8 years pecan trees cv. Burkett. Trees were cultivated in a sandy soil at 4 x 5 m apart under drip irrigation system in private orchard at Cairo-Alex. desert road (about 90 km from Cairo), Behera governorate, Egypt. Trees were received the normal cultural practices according to the recommendation of Horticultural Research Institute, Ministry of Agriculture, Egypt. The study involved fifteen healthy productive trees. The experiment included three treatments each treatment was replicated three times with one tree for each replicate. Soil physical, chemical properties, soil water parameter and bulk density of experimental site were analyzed according to Page *et al*. [15]; Kulte [16] and Stackman [17] as shown in Tables (1and 2). Meteorological data for the Agricultural Research Station are shown in Table (3).

Hydro Physical Characters: As shown in Table (1) the values of field capacity varied from 10.5% (2.76 cm water /15 cm soil depth) to 13.1 % (3.05 cm water /15 cm soil depth) and decreased with increasing soil depth. Permanent wilting point values ranged from 3.2% (0. 84 cm/15 cm soil depth) to 4.4% (1.02 cm/15cm soil depth) and also, decreased with increasing soil depth. Total available soil moisture content values in the soil profile (0 - 60 cm) were 7.18 cm water/ 60 cm. Values the of bulk density were 1.55, 1.57, 1.64 and 1.75 (gm/cm^3) for the soil depths from 0 – 15, 15 – 30, 30 – 45, cm and 45 – 60 cm, respectively.

Irrigation Treatments: Three amounts of applied irrigation water based by Penman- Monteith equation were tested in this experiment. The irrigation treatments were as follow:

- Irrigation with amount of water equals 75 % of potential evapotranspiration (ETcrop).
- Irrigation with amount of water equals 100 % of potential evapotranspiration (ETcrop).
- Irrigation with amount of water equals 125 % of potential evapotranspiration (ETcrop).

Drip Irrigation System: The drip irrigation system used in the farm includes an irrigation pump (50 hp) connected to sand and screen filters and a fertilizer injector tank. The conveying pipeline system consists of a main line that is made of PVC pipe of 76.2mm diameter connected to sub-main line of 50.8mm and manifold of 38.1mm. The drip lateral lines of 16mm diameter are connected to the manifold line. Each plant line is served by two lateral lines about 0.60m apart (i.e., 0.30m from each side of the tree stems). Lateral lines equipped with build-in emitters of 4.0 l/h discharge were spaced 0.3m apart on the lateral line. There were 12 emitters per tree. The irrigation levels were applied by installing a flow-meter and a valve to control the applied water quantity for drip irrigation technique. The flow-meter was connected with proper fittings to distribute water for the different irrigation levels. Each irrigation level treatment has one flow-meter to record the applied. Water for irrigation methods and irrigation scheme as follows: December, January, one time/2 weeks; November, February: one time/week; March, April, September: three times/week, October: two times/week and May, June, July and August: six times/week.

Amount of Applied Irrigation Water (AIW): Reference evapotranspiration (ETo): ET_o values were calculated based on local meteorological data of the experimental site (Table 4) and according to the Penman-Monteith equation [18]. Calculations were performed using the CROPWAT model [19].

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where:

ET_o : Reference evapotranspiration (mm day^{-1}),
R_n : Net radiation at the crop surface (MJ m^{-2} day^{-1}),
G : Soil heat flux density (MJ m^{-2} day^{-1}),
T : Mean daily air temperature at 2 m height (°C),
u_2 : Wind speed at 2 m height (ms^{-1}),
e_s : Saturation vapor pressure (kPa),
e_a : Actual vapor pressure (kP)
e_s-e_a : Vapor pressure deficit (kPa)
Δ : Slope of the vapor pressure-temperature curve (kPa °C^{-1}),
γ : Psychrometric constant (kPa °C^{-1}).

Pecan Trees Evapotranspiration Estimated ETc Formulae by (ET o and Kc Crop): The ETc values were calculated according to the following equation given by FAO [20]:

Table 1: Physical and chemical analysis of the orchard experimental soil

Physical properties of soil				Chemical properties of soil				
Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC dSm^{-1}	Organic matter %		$CaCO_3$ %
83	10	7	Loamy Sand	8.17	1.11	0.35		1.7
Cations and anions in soil paste extract ($meql^{-1}$)								
Na	K	Ca	Mg	Cl	HCO_3	CO_3	SO_4	Moisture
4.3	1.0	3.2	3.2	6.4	1.9	0.0	3.4	26

Table 2: Field capacity, wilting point, available water and bulk density of soil at various depths

	Field capacity (F.C.) %		Wilting point (WP) %		Available water (AW) %		
Depths	w/w %	cm	w/w %	cm	w/w %	cm	Bulk density (BD) g/cm^3
0-15	13.1	3.05	4.4	1.02	8.1	1.88	1.55
15-30	12.5	2.94	4.2	0.99	8	1.88	1.57
30-45	11.6	2.85	4	0.98	6.6	1.62	1.64
45-60	10.5	2.76	3.2	0.84	6.8	1.79	1.75
		11.60		3.84		7.18	

Table 3: Meteorological data in 2019 and 2020 seasons

	2019					
Month	T.max.	T.min.	WS	RH	SS	R. F
January	17.6	6.8	3.1	54.7	10.3	2.7
February	19.8	7.9	2.6	57.0	11.0	5.6
March	22.6	8.7	3.0	54.9	11.9	9.3
April	27.1	11.8	3.1	46.1	12.8	2.9
May	35.3	17.0	3.2	32.5	13.4	0.1
June	36.5	20.7	3.1	43.5	13.9	0.0
July	37.5	21.7	3.2	44.3	13.8	0.0
August	37.4	21.0	3.1	46.2	13.0	0.0
September	34.3	20.1	3.1	52.2	12.2	0.0
October	31.5	18.4	2.8	55.7	11.4	19.8
November	27.3	14.4	2.3	56.3	10.6	0.0
December	20.5	9.9	3.1	65.5	10.1	21.8
	2020					
January	17.4	7.4	3.1	68.2	10.5	22.1
February	19.6	8.0	2.6	67.0	11.0	34.5
March	23.5	9.4	3.1	59.0	11.9	55.3
April	26.1	11.7	2.7	55.8	12.7	73.8
May	31.8	15.2	3.2	48.9	13.4	0.0
June	34.7	18.2	3.2	43.7	13.9	0.3
July	37.1	20.5	3.2	46.0	13.8	0.0
August	37.6	21.4	3.1	48.0	13.1	0.0
September	37.1	21.3	3.1	50.7	12.2	0.0
October	32.5	18.8	2.7	55.6	11.4	0.8
November	23.8	14.0	2.5	64.9	10.5	23.6
December	21.8	10.6	2.3	63.5	7.3	1.0

T. max, T. min = maximum and minimum temperatures °C. - WS = wind speed (m/sec). RH = relative humidity (%). - SS = actual sunshine duration (h/day) - RF = rainfall (mm / month)

ETc = ETo X Kc

where:

ETc : Crop evapotranspiration (mm day^{-1})

ET_o : Potential evapotranspiration (mm/day) values obtained by Penman-Monteith equation.

Kc : Crop coefficient: Current Kc values published for pecan trees by Shalamu *et al.* [21].

Amount of Applied Irrigation Water (AIW): The amount of applied water was measured by a flow meter and was calculated according to the following equation [22]:

$$AIW = \frac{S_p \ XS_l \ ET_c \ \ XKr \ XI \, \text{int}\, erval}{Ea} + LR$$

where:

AIW = Applied irrigation water depth (liters/day).

Sp = Distance between plants in the same line (m).

S_l = Distance between lines (m).

ETc = Crop evapotranspiration (mm day^{-1})

K_r = Reduction factor that depends on ground cover. It equals 0.7 for mature trees [23].

E_a = Irrigation efficiency it equals 90 %

$I_{interval}$ = Irrigation intervals (days) = 1 day for the experimental site.

LR = Leaching requirements [20] = $\frac{EC_w}{2MaxEC_e}$

where: EC_w = electrical conductivity of the irrigation water (1.2 dS/m).

Max EC_e = maximum tolerable electrical conductivity of the soil saturation extract for pecan trees (5 dS/m).

Table 4: Penman-Monteith formula in 2019 and 2020 seasons

	Penman-Monteith (ETo)				
	2019 season			2020 season	
Month	Kc	mm/day	mm/month	mm/day	mm/month
January	0.20	2.9	89.9	2.46	76.3
February	0.30	3.28	91.8	2.95	82.6
March	0.35	4.51	139.8	4.47	138.6
April	0.40	5.97	179.1	5.4	162.0
May	0.6	8.46	262.3	7.3	226.3
June	0.75	8.62	258.6	7.78	233.4
July	0.9	8.97	278.1	8.6	266.6
August	0.80	8.29	257.0	8.22	254.8
September	0.65	6.87	206.1	7.37	221.1
October	0.30	5.28	163.7	5.42	168.0
November	0.25	3.76	112.8	3.23	96.9
December	0.20	2.76	85.6	2.84	88.0
Seasonal (mm)			2125		2015

Soil Analysis: Particle size distribution was conducted using the pipette method according to Klute [16]. Soil moisture constants were determined using the pressure membrane apparatus [17]. Soil pH, electric conductivity (EC) and cationic and anionic compositions of the saturation extract of the soil were determined according to the standard methods described by Page *et al.* [15]. The following characters were studied.

Morphological Parameters: Twenty twigs of each tree (5/each direction) in both seasons were selected at random and tagged to determine and measuring affects irrigation level on:

Vegetative Growth: Dormant and opened buds percentage, length of new shoots (cm), average leaflet length and width and leaf length.

Flowering Characteristics and Fruit Set Percentage: Number of staminate (male) and pistillate (female) inflorescences were counted at April.

Fruit set (%): was calculated by the following equation:
Fruit set (%) = No. of fruitlets x 100/No. of pistillate flowers.

Yield and Nut Characteristics: Pecan nuts were harvested through the 1st week of October when the outer inedible hull has split and can be removed easily. After harvest and hull were removed, nuts were dried under room temperature (20-30°C) for 3-4 weeks to determine: yield (kg/tree), nut weight (g), nut length (cm), nut width (cm) and kernel and shell percentage.

Water Utilization Efficiency (WU_tE): Water utilization efficiency values were calculated according to Jensen [24] as follows:

$$WUtE = \frac{Fruit\ Yield\ (kg\ /\ fed)}{Applied\ Irrigation\ Water\ (m^3\ /\ fed)}$$

Leaf Chemical Analysis: Leaves were sampled from middle of shoots of average length and well exposed to light, taken in July of both seasons [25] then dried by oven at 70°C for 48 hours (until a constant weight) then grounded and used in preparing the wet digested solution (1:4 perchloric acid: sulphuric acid) as described by Piper [26] which analyzed for total macro elements. Total nitrogen (%) was determined by the modified micro-keyldahl method [27]. Phosphorus (%) was estimated coloremetically (ammonium molybdate) according to the official methods of analysis [28]. Potassium (%) was determined by using flame photometer [29].

Experimental Design and Statistical Analysis: Experiments conducted in this study followed the randomized complete blocks design. The obtained data were tabulated and statistically analyzed according to Snedecor and Cochran [30]. Differences between means were compared by Duncan's multiple range test at 5% level of probability according to Duncan [31].

RESULTS AND DISCUSSIONS

Water Relations:

The Estimated Evapotranspiration ETcrop: Crop water use of mature pecan trees (ETcrop) is determined by multiplying the reference ETo by the pecan crop coefficient (Kc). The ETcrop was calculated from climate data for both seasons to estimate the water requirement for pecan trees by Penman-Monteith equation. Data in Figure (3) illustrate the results of the ETcrop calculations for experiment site. Maximum daily evapotranspiration range from 6.2 mm, 7.9 and 6.6 mm and all the maximum values occurred at June and July and August, respectively. While the lowest ETcrop value occurs in March and April were 1.58 and 1.56 and 2.69 and 2.43 mm/day in both seasons, respectively. The results showed that the calculations pecan ETcrop ranged from 48.7 mm to 245.1 mm for the growing season of March to October which is the similar growing season as in previous studies [32-34].

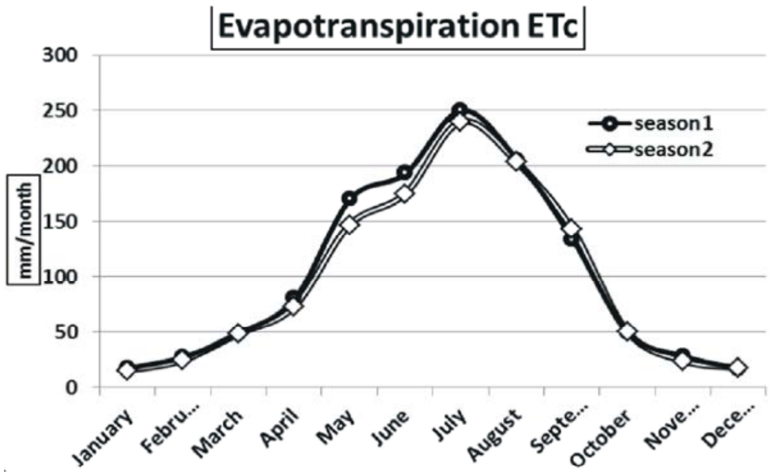

Fig. 1: The estimated Evapotranspiration (Etc) during two growing seasons 2019 and 2020 for experiment site

Table 5: Effect of irrigation treatments on the amounts of applied irrigation water for the 2019 and 2020 growing seasons

	75% Etc		100 % Etc		125% ETc	
Month	L/tree /day	m^3/fed./month	L/tree/day	m^3/fed./month	L/ tree/day	m^3/fed./month
			2019			
Jan.	8.1	52.9	10.8	70.5	13.5	88.1
Feb.	13.8	81.0	18.4	108.0	23.0	135.0
Mar.	22.1	143.9	29.5	191.8	36.8	239.8
Apr.	37.6	236.9	50.1	315.9	62.7	394.9
May	77.0	501.2	102.6	668.2	128.3	835.3
Jun.	90.5	570.2	120.7	760.3	150.9	950.4
Jul.	113.0	735.8	150.7	981.0	188.4	1226.3
Aug.	92.8	604.4	123.8	805.9	154.7	1007.4
Sep.	62.5	393.9	83.4	525.1	104.2	656.4
Oct.	22.2	144.4	29.6	192.5	37.0	240.6
Nov.	13.2	82.9	17.5	110.5	21.9	138.2
Dec.	7.7	50.3	10.3	67.1	12.9	83.8
Total m^3/fed.		3598		4797		5996
			2020			
Jan.	6.9	44.8	9.2	59.8	11.5	74.7
Feb.	12.4	72.9	16.5	97.1	20.7	121.4
Mar.	21.9	142.6	29.2	190.1	36.5	237.6
Apr.	34.0	214.3	45.4	285.8	56.7	357.2
May	66.4	432.5	88.6	576.6	110.7	720.8
Jun.	81.7	514.6	108.9	686.2	136.2	857.7
Jul.	108.4	705.4	144.5	940.6	180.6	1175.7
Aug.	92.1	599.3	122.8	799.1	153.4	998.9
Sep.	67.1	422.5	89.4	563.4	111.8	704.2
Oct.	22.8	148.2	30.4	197.6	37.9	247.0
Nov.	11.3	71.2	15.1	95.0	18.8	118.7
Dec.	8.0	51.8	10.6	69.0	13.3	86.3
Total m^3/fed.		3420		4560		5700

Applied Irrigation Water (AIW): The effect of tested irrigation treatments on applied irrigation water expressed as liters/tree/day, m^3/fed/month and m^3/fed/year for the 2019 and 2020 growing seasons is presented in Table 5. Results showed that amounts of applied irrigation water were 3598, 4797 and 5996 m^3/fed./year in first season and 3420, 4560 and 5700 m^3/fed./year in second season for the 75 % ETc, 100 % ETc and 125 % ETc irrigation treatments, respectively. The obtained amounts equal 1156, 1542 and 1927 mm/fed/year of 1 March to 1 October for the same respective treatments for the growing season. These results agreed with those of Liu and Sheng, [34] who showed the annual pecan ET value is in range of 1000 to 1460 mm for mature trees. Miyamoto [32] estimated a mature pecan orchard's consumptive use as 1310 mm for the growing season of April 1 through October 15 study involved orchards that were 8 to 35 years old. The values showed that seasonal water applied by pecan trees is higher in the first season than in the second one. Such results are mainly due to differences in climatic 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. Doorenbos and Pruitt [35] concluded that, after irrigation the soil water content decreases primarily by evapotranspiration.

Monthly Applied Irrigation Water: Concerning monthly applied irrigation water for pecan trees in Fig. (2) showed that water consumptive use 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 Fig. 2 and then it increased gradually as the green cover increased with increases in air temperature and solar radiation. The highest water consumptive use by pecan trees occurred during June, July and August reflecting: with expansion of the leaf system, growth of fruit on a volume basis and high solar radiation and air temperature. The June, July and August values for averaged 723.3, 960.8 and 802.5 m^3/month/fed. under 100% ETcrop (means of the 2 seasons), respectively. All irrigation treatments went in the same direction. These results agreed with those of Shalamu *et al*. [21] who found that the monthly ET reached its maximum value in August at the rates of 188 mm/month (605 m^3/fed./month), 220 mm/month (708 m^3/fed./month) and 201 mm/month (648 m^3/fed./month) in June for both seasons. Sammis *et al*. [33] found that the maximum monthly ET values are all occurred either July or/and August in all years in all studies.

Daily Applied Irrigation Water (L/Tree/Day): Improved irrigation water management requires accurate scheduling of irrigations which in turn requires an accurate calculation of daily crop evapotranspiration. Results in Fig.3 show that daily water consumptive use values began to raise during March then gradually increased to reach its maximum during July. Maximum daily evapotranspiration by pecan trees during June, July and August 114.8 L/tree/day 147.6 L/tree/day and 123.3 L/tree/day under 100 % ETcrop (means of the 2 seasons), respectively. This might be due to the increase of vegetative growth rate and the raise of temperature during summer season. Afterwards, the daily applied irrigation water values, gradually decreased. Such pattern was attained by pecan trees. In this concern, during the end of October to the first of March the trees growth rate slowed down. Minimum daily evapotranspiration by pecan trees during November, December, January and February 12.25, 7.85, 7.50 and 13.10 L/tree/day under 100 % ETcrop (means of the 2 seasons), respectively. All irrigation treatments went in the same direction.

Vegetative Growth: Vegetative growth is regarded as the most important plant trait leading to carbohydrate production and subsequent plant growth. Like any other plant component and process, vegetative growth is sensitive to any form of stress as in water deficit. Vegetative parameters were affected by irrigation treatments as shown in Tables (6 & 7). Table (6) displayed obviously that, the dormant buds proved to be significantly lowest by irrigation level at 125%, while decreasing irrigation rate to 100% and 75% of water requirement achieved a significant high dormant buds percentage. The opposite trend was found with burst buds percentage that increasing with increasing irrigation levels from 75% ETc to 125% ETc in both seasons. In addition, shoot length increased from (10.27, 9.50 cm) to (15.40, 17.59 cm) by increasing water irrigation from 75% ETc to 125% ETc in both 2019 and 2020 seasons respectively. Furthermore, data presented in Table (7) showed that, the highest significant in leaflet length and width and leaf length were recorded with irrigation at 125% ETc followed significantly by 100% ETc then 75% ETc irrigation levels in both seasons of study. These findings went parallel with those obtained by Li *et al*. [36] on peach, Romero *et al*. [37] on almond, El-Seginy [38] on apricot, Yadollahi *et al*. [39] on Walnut, Abd-Ella [40], Egea *et al*. [41] on almond and peach, Elsouda [42] and Ali *et al*. [43] on pomegranate and Faghih *et al*. [44] on apple. These results may be due to decrease in the photosynthetic rate, stomatal conductance and cytokinin transport from root to shoots and increase leaf abscisic acid content under water stress condition. Therefore, leaf expansion and shoot growth were declined [45, 46].

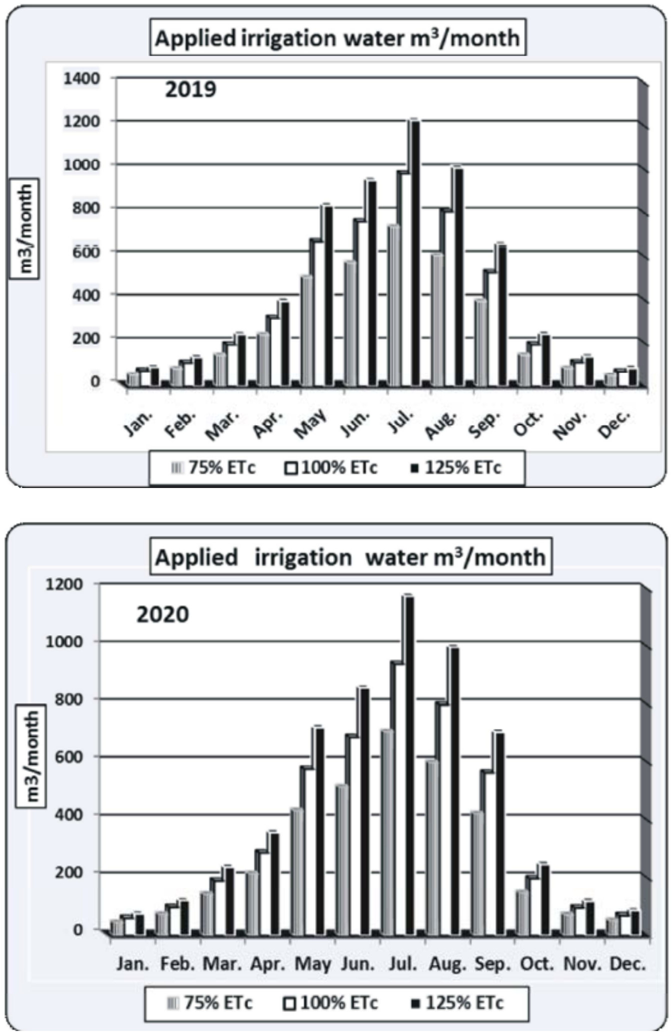

Fig. 2: Effect of irrigation treatments on applied irrigation water m^3/month of pecan trees

Table 6: Effect of irrigation levels on dormant and opened buds percentage and length of new shoots of pecan cv. Burkett in 2019 and 2020 seasons

	Dormant bud (%)		Burst bud (%)		Shoot length (cm)	
Irrigation levels	2019	2020	2019	2020	2019	2020
75 % ETc	57.93 A	58.8 A	42.07 C	41.20 C	10.27 C	9.50 C
100 % ETc	52.38 B	50.49 B	47.62 B	49.51B	13.07 B	14.86 B
125 % ETc	47.52 C	44.47 C	52.48 A	55.53 A	15.40 A	17.59 A

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Table 7: Effect of irrigation levels on leaflet length and width and leaf length of pecan cv. Burkett in 2019 and 2020 seasons

	Leaflet length (cm)		Leaflet width (cm)		Leaf Length (cm)	
Irrigation levels	2019	2020	2019	2020	2019	2020
75 % ETc	5.38 C	6.06 C	1.81 C	1.67 C	13.20 C	12.54 C
100 % ETc	8.22 B	9.67 B	1.98 B	2.20 B	18.47 B	18.90 B
125 % ETc	10.72 A	11.05 A	2.30 A	2.52 A	22.18 A	23.50 A

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

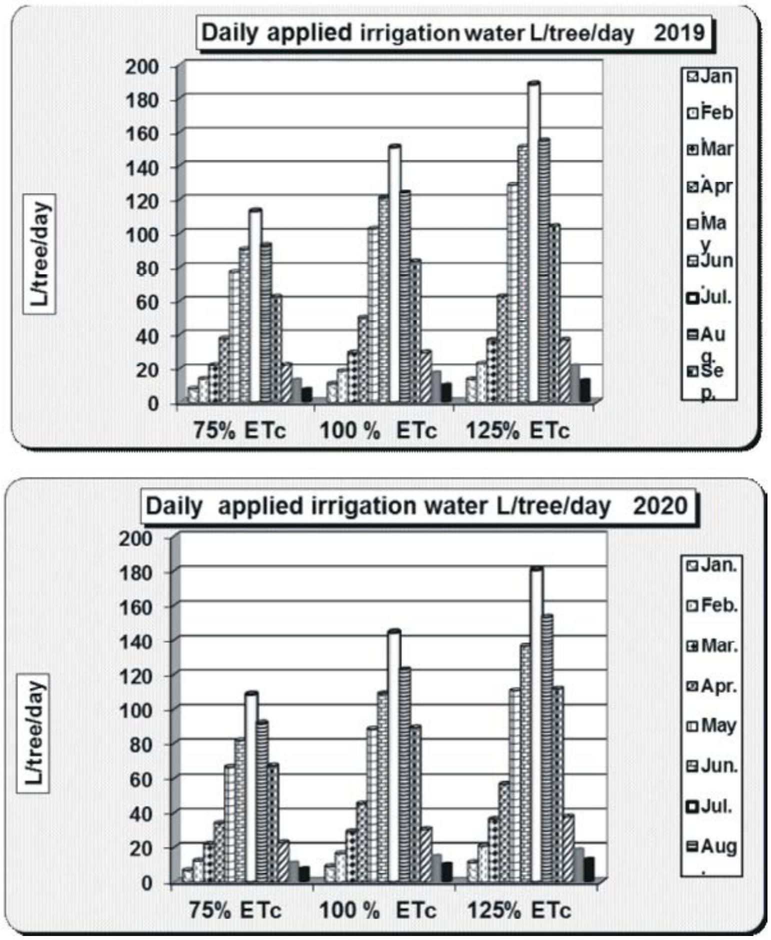

Fig. 2: Effect of irrigation treatments on daily applied irrigation water L/tree/day of pecan trees

Flowering Characteristics and Fruit Set Percentage: Irrigation levels significantly affected the number of staminate and pistillate inflorescences per twig. Declining applications of irrigation water led to reductions in the number of staminate and pistillate inflorescences. The treatment 75% ETc exhibited the highest reductions among all treatments, the data in Table (8) indicating that, with this irrigation treatment, declining yields can be expected, although the most water was saved in this treatment. The pattern of decreasing number of flowers concurrent with decreasing amount of irrigation applied were similar in the following year. Generally, there is a significant increase in the fruit set percentage associated with increasing rate of irrigation during the two seasons Table (8). Also appeared that, reducing irrigation levels significantly decreased fruit set. Where by raising irrigation levels from 75% ETc to 125% ETc, fruit set increased significantly from 69.96, 70.73% to 77.28, 79.82 in both seasons respectively. In this connection, Ruiz-Sanchez *et al.* [47] on apricot and Hussein [48] on pear indicated that, flowers number gradually reduced parallel to reduction in irrigation rate. Also, Chauhan *et al.* [49] on apple, Cheng *et al.* [50] on pear and Mellisho *et al.* [51] and Ali *et al.* [43] on pomegranate mentioned that, highest application of irrigation had the highest significant fruit set percentage.

Nut Weight, Yield and Water Use Efficiency: Nut weight and yield (kg/tree) were significantly affected by different irrigation levels (Table 9). The irrigation treatment (125% ETc) displayed significantly highest nut weight (9.34- 9.57g) and yield (7.56 - 8.26 kg/tree) throughout the two seasons respectively comparison to the other treatments. These results were in harmony with those recorded by Garrot *et al*. [8] on pecan, Goldhamer *et al*. [52] on almond, Elsouda [42], Mellisho *et al.* [51] and Ali *et al*. [43] on pomegranate and Yun *et al*. [53] on apple. They mentioned that, tree productivity was significantly declined by increasing irrigation deficit of different fruit species.

Table 8: Effect of irrigation levels on number of staminate (male) and pistillate (female) inflorescences and fruit set (%) of pecan cv. Burkett in 2019 and 2020 seasons

	Number of staminate inflorescences		Number of pistillate inflorescences		Fruit set (%)	
Irrigation levels	2019	2020	2019	2020	2019	2020
75 % ETc	5.33 C	6.40 C	1.20 C	1.05 C	69.96 C	70.73 C
100 % ETc	6.71 B	7.92 B	1.84 B	2.60 B	75.64 B	77.91 B
125 % ETc	8.24 A	9.54 A	2.43 A	3.12 A	77.28 A	79.82 A

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Table 9: Effect of irrigation levels on fruit weight, yield and water utilization efficiency of pecan cv. Burkett in 2019 and 2020 seasons

	Nut weight (g)		Yield (kg/tree)		Water utilization efficiency (kg/m^3 water)	
Irrigation levels	2019	2020	2019	2020	2019	2020
75 % ETc	7.66 C	7.21 C	5.22 C	4.49 C	0.29 AB	0.24 C
100 % ETc	8.82 B	9.12 B	6.90 B	7.82 B	0.30 A	0.34 A
125 % ETc	9.34 A	9.57 A	7.56 A	8.26 A	0.28 B	0.31 D

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Table 10: Effect of irrigation levels on nut length and width, kernel and shell percentage of pecan cv. Burkett in 2019 and 2020 seasons

	Nut length (cm)		Nut width (cm)		Nut kernel (%)		Nut shell (%)	
Irrigation levels	2019	2020	2019	2020	2019	2020	2019	2020
75 % ETc	4.20 B	3.80 B	1.94 B	1.83 B	55.34 C	54.80 C	44.66 A	45.20 A
100 % ETc	4.52 A	4.75 A	2.15 A	2.13 A	59.39 B	61.57 B	40.61 B	38.43 B
125 % ETc	4.66 A	4.83 A	2.20 A	2.35 A	61.82 A	62.74 A	38.18 C	37.26 C

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Water utilization efficiency, is used to show the fruit yield production (kg) per unit of water. It appears from Table (9) that this trait was markedly profitable under the medium soil moisture level (100 % ETc), as it registered 0.302 and 0.360 Kg. fruit yield /m^3 water of irrigation in the first and second seasons, respectively. Whereas the high amount of irrigation water treatment produced the least value 0.268 and 0.312 Kg. fruit yield /m^3 irrigation water in both seasons, respectively. Values of water utilization efficiency were higher by 13.7 and 14.1% under 100 % ETc comparable with irrigation at 75 % ETc and 125 % ETc, respectively. This means that pecan trees favors medium watering and high production prefers medium soil moisture than lower and high watering. These results are in agreement with those reported by Zeng *et al.* [54] found that with the lower amount of irrigation water applied, the higher irrigation water use efficiency obtained. Ritchie [55] 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. Roth *et al.* [56] 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.

Nut Dimension, Kernel and Shell Percentage: The lowest significant nut length and diameter were noticed by the least irrigation treatment (Table 10). Meanwhile, the biggest significant nut length and diameter were produced from both irrigation treatments (100- 125% ETc). The increase in nut length and diameter with the increase in the amount of added water to trees is generally due to the increase in cell enlargement of fruit tissues. nut kernel percentage increased significantly from (55.34, 54.80 %) to (61.82, 62.74 %) by increased water amount from 75% ETc to 125% ETc. The opposite trend was observed with fruit shell percentage. These results are in line with those obtained by Abd El-Moteleb [57] and Ali *et al.* [58] on apple and Kandil and El-Feky [59] on apricot Elsouda [42] on pomegranate they declared that, as irrigation level increased both fruit length and diameter significantly increased.

Leaf Nutrient Content: With increasing amount of irrigation water applied the leaf N, P and K content gradually increased (Table 11). The lowest significant leaf N and K content was observed by the least irrigation treatment. Differences between the 100% ETc and 125% ETc were less pronounced and not significant in both seasons. No significant different was illustrated between treatments leaf P content in both seasons. These results

Table 11: Effect of irrigation levels on nitrogen, Phosphorus and potassium leaf content of pecan cv. Burkett in 2019 and 2020 seasons

	N (%)		P (%)		K (%)	
Irrigation levels	2019	2020	2019	2020	2019	2020
75 % ETc	1.46 B	1.61 B	0.18 A	0.16 A	1.30 B	1.37 B
100 % ETc	1.75 A	2.15 A	0.22 A	0.18 A	1.41 A	1.53 A
125 % ETc	1.82 A	2.31 A	0.25 A	0.22 A	1.45 A	1.62 A

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

may be led to the conclusion that nutrient uptake was retarded under water stress condition, where essential decrease in transpiration rates and damaged active transport and membrane permeability and resulting in a reduced root absorbing power of plant. So depletion of soil moisture level caused a reduction in leaf mineral content [60]. It is necessary to say that, under drought stress conditions nitrogen Phosphorus and potassium uptake and use efficiency of these elements will be, reduced and such declining led to low yield as mentioned by many researchers [61, 62]. These results are confirmed with the results obtained by Boland *et al.* [63] and Chauhan *et al.* [49] on apple, Ramteke *et al*. [64], Babu and Prakash [65] on grapes and ElSouda [42] and Hamdy *et al* [66] on pomegranate they mentioned that mineral content in leaves was declined by decreasing irrigation rate.

CONCLUSION

It could be concluded that, applying water irrigation at 100% ETc in pecan orchard gave satisfactory growth, yield and saving water.

REFERENCES

1. Thompson, T.E. and L.J. Grauke, 1991. Pecans and Hickories. Chapter 18, pp: 839-904. In: Genetic resources of Temperate Fruit and Nut Crops 2. Pages: 974. Int. Soc. Hort. Sci. Wageningen, the Netherlands.
2. Wood, B.W., 1993. Hydrogen cyanamide advances pecan budbreak and harvesting. J. of the American Society for Horticultural Science, 118: 690-693.
3. Kuden, A.B., Ö. Tuzcu, S. Bayazit, B. Yildirim and B. Imrak 2013. Studies on the chilling requirements of pecan nut (Carya illionensis Koch) cultivars. African Journal of Agricultural Research, 8: 3159-3165.
4. Peterson, J.K., 1990. Carya illinoensis (Wangenh.) K. Koch pecan. p.205-210. In: R. Burns and B. Honkala (eds.), Silvics of North America. Washington, D.C., USDA. Forest Service. V.2, (Agricultura Handbook no. 654). http://www.na.fs.fed.us/sfo/pubs/ilvics_manual/volume_2/carya/.
5. Behnia, A., 1999. Comparison of different irrigation methods for pomegranate orchards in Iran. Irrigation under conditions of water scarcity. Vol 1C. 17th ICID International Congress on Irrigation and Drainage, Granada, Spain, 13 - 17 September, pp: 207-217.
6. Chopade, S.O., S.D. Gorantiwar, P.S. Pampattiwar and V.S. Supe, 2001. Response of pomegranate to drip, bubbler and surface irrigation methods. Advances in Horticulture and Forestry. Scientific Publishers India Jodhpur, 8: 53-59.
7. Sharma, P.K. and S. Dwivedi, 2018. Economic analysis of pecan nut production: An Application of Input Oriented DEA Model. Economic Affairs, 63(1): 223-228.
8. Garrot, D.J., M.W. Kilby, D.D. Fangmeier, S.H. Husman and A.E. Ralowicz, 1993. Production, growth and nut quality in pecan under water stress based on the crop water stress index. J. Am. Hortic. Sci., 118: 694-698.
9. Herrera, E., 2001. Growth and development of pecan nuts. College of agriculture and home economics, New Mexico State University, Guide H-618 (Feb. 2000).
10. Wells, L., 2016. Pecan water requirements and irrigation scheduling. Published by the University of Georgia in cooperation with Fort Valley State University. UGA cooperative extension, Circular 1106, pp: 1-6.
11. Berman, M.E. and T.M. DeJong, 1996. Water stress and crop load effects on fruit fresh and dry weights in peach. Tree Physiol., 16: 859-864.
12. Naor, A., I. Klein, I. Doron, Y. Gal, Z. Ben-David and B. Bravdo, 1997. The effect of irrigation and crop load on stem water potential and apple fruit size. J. Hort. Sci. Biotech., 72: 765-771.
13. Miller, S.A., G.S. Smith, H.L. Boldingh and A. Johansson, 1998. Effects of water stress on fruit quality attributes of kiwifruit. Ann. Bot., 81: 73-81.
14. Naor, A., I. Klein, H. Hupert, Y. Grinblat, M. Perez and A. Kaufman, 1999. Water stress and crop level interactions in relation to nectarine yield, fruit size distribution and water potentials. J. Amer. Soc. Hort. Sci., 124: 189-193.

15. Page, A.L., R.H. Miller and D.R. Keeny, 1982. Methods of soil analysis Part 2 Chemical and Biological Properties. Amer. Soc. Agron. Inc. Mascson, Wisconsin USA.
16. Klute, A., 1986. Methods of Soil Analysis, part 1. Physical and mineralogical method. American Society of Agronomy. Madison. Wisconsin.
17. Stackman, W.P., 1966. Determination of pore size by the air bubbling pressure method proceeding unesce Symp on Water in the Unsaturated Zone, pp: 366-372.
18. FAO, 1998. Crop evapotranspiration: Guidelines for computing crop water requirements. In FAO Irrigation and Drainage Paper, 56. By Richard, A., Luis, P., Dirk, R. and Martin, S., Eds.; Food and Agricultural Organization: Rome, Italy.
19. FAO, 1992. CROPWAT: A computer program for irrigation planning and management. In FAO Irrigation and Drainage Paper, 46. By Martin, S., Ed.; Food and Agricultural Organization: Rome, Italy.
20. FAO, 1977. Guidelines for predicting crop water requirements. In Irrigation and Drainage Paper, 24. By Doorenbos, J. and Pruitt, W.O., Eds.; Food and Agricultural Organization: Rome, Italy.
21. Shalamu A., Z. Sheng, A. Michelsen, O. Rodriguez, J. King, 2016. Evapotranspiration and Crop Coefficient for Pecan Trees in El Paso, Texas. Conference: Irrigation Show & Education Conference At: Las Vegas, United States. 5-9 /12/ 2016. https://www.researchgate.net/publication/311571352
22. FAO, 1984. Food and Agriculture Organization of the United Nations Rome.
23. FAO, 1979. Yield response to water, Irrigation and Drainage Paper, 33. By Doorenbos, J. and Kassam, A. H., Rome.
24. Jensen, M.E., 1983. Design and operation of farm irrigation systems. Amer. Soc. Agric. Eng. Michigan, USA, pp: 827.
25. Chandler, W.H., 1957. Deciduous orchards. Third edition, Thoroughly Berised with 128 Illustrations LEA and Febiger, Philadelphia, pp: 164.
26. Piper, C.S., 1950. Soil and Plant Analysis. Inter. Sci. Publ., New York, pp: 368.
27. Naguib, M.L., 1969. Colourimetric determination of nitrogen components of plant tissues. Bull. Fac. Agric. Sci. Cairo Univ., 453: 1-5.
28. Murphy, J. and J.P. Riely, 1962. A modified single dilution method for determination of phosphate in natural water. Ann. Chemi. Acta., 27: 31-36.
29. Brown, J.D. and D. Lilleland, 1946. Rapid determination of potassium and sodium in plant material and soil extract by flame photometer. Proc. Amer. Soc. Hort. Sci., 48: 341-346.
30. Snedecor, G.W. and W.G. Cochran, 1980. Statistical methods. Oxford and J. B. H. Bub com. 7th Edition.
31 Duncan, D.B., 1955. Multiple range and multiple F test. Biometrics, 11: 1-24.
32. Miyamoto, S., 1983. Consumptive water use of irrigated pecan J. Amer. Soc. Hort. Sci., 108(5): 676-681.
33. Sammis T.W., J.G. Mexal and D. Miller, 2004. Evapotranspiration of flood-irrigated pecans, Agricultural Water Management, 69: 179-190.
34. Liu, Y. and Z. Sheng, 2013. Soil moisture status in an irrigated pecan field, J. Irrigation and Drainage Engineering, 139(1): 26-40.
35. Doorenbos, J. and W.O. Pruitt, 1984. Guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper No. 24, (revised) FAO, Rome, Italy.
36. Li, G.Y., X.F. Huang and X.W. Wang, 2000. Water use of drip irrigated peach tree under full irrigation and regulated deficit irrigation. 6th International Micro Irrigation Congress Micro, Cape Town, South Africa, 22-27 October pp: 1-6.
37. Romero P., P. Botia and F. Garcia, 2004. Effects of regulated deficit irrigation under subsurface drip irrigation conditions on vegetative development and yield of mature almond trees. Plant and Soil, 260: 169-181
38. El-Seginy, A.M., 2006. Response of Canino apricot trees to different irrigation and potassium treatments. Alex. Sci. Exchange J., 27(1): 64-75.
39. Yadollahi, B.K., R. Amiri, N. Lotfi and K. Vahdati, 2010. Morphological and physiological responses to water stress for seedlings of different walnut genotypes, Acta Hortic., 861: 253-262.
40. Abd-Ella, E.K.A., 2011. Effect of soil conditioner and irrigation levels on growth and productivity of pomegranate trees in new region. Alex. Sci. Exchange J., 32: 550-577.
41. Egea, G., P.A. Nortes, R. Domingo, A. Baille and A. Perez-Pastor, 2013. Almond agronomic response to long-term deficit irrigation applied since orchard establishment. Irrig. Sci., 31(3): 445-454.
42. Elsouda, A.S., 2011. Effect of irrigation levels, humic acid and amino acids on growth and fruiting of pomegranate trees. Ph.D. Thesis, Fac. Agric. Hort. Dept., Cairo Univ., Egypt, pp: 192.
43. Ali, A.A.M., S.A. Nomier, A.S.A. Hassan and M.A. Hassan, 2015. Effect of different irrigation levels and some soil conditioner treatments on growth and productivity of pomegranate trees cv. Manfalouty. Zagazig J. Agric. Res., 42(5): 983-998.

44. Faghih, S., Z. Zamani, R. Fatahi and A. Liaghat 2019. Effects of deficit irrigation and kaolin application on vegetative growth and fruit traits of two early ripening apple cultivars. Bio. Res., 52(43): 1-12.
45. Atkinson, C.J., A.D. Webster, S.P. Vaughan, L. Toylor and G. Kingswell, 2000. Interaction between root restriction, irrigation and rootstock treatments on Queen Cox apple trees: Effect of soil and plant water relation. J. Hort. Sci. Biotech., 75(4): 376-382.
46. Mpelasoka, B.S., M.H. Behboudian and T.M. Mills, 2001. Water relation, photosynthesis, growth, yield and fruit size of Braeburn apple: Responses to deficit irrigation and to crop load. J. Hort. Sci. Biotech., 70: 150-156.
47. Ruiz-Sanchez, M.C., J. Egea, R. Galego and A. Torrecillas, 1999. Floral biology of Bulida apricot trees subjected to postharvest drought stress. Ann. Appl. Bio., 135(2): 523-528.
48. Hussein, S.M.M., 2004. Effect of Different Irrigation Levels on the Le-Cont Pear Trees. Ph.D. Thesis, Fac. Agric. Hort. Dept., Cairo Univ., Egypt, pp: 175.
49. Chauhan, P.S., A. Sud, L.K. Sharma and M.S. Mankotia, 2005. Studies on the effect of micro-irrigation levels on growth, yield, fruit quality and nutrient assimilation of delicious apple. Acta Hort., 696: 193-196.
50. Cheng, F., S. Li and Z. Meng, 2003. Study on the effect of regulated deficit irrigation on the vegetative growth, cropping and fruit quality of Yali pear variety. J. Fruit Sci., 20(1): 22-26.
51. Mellisho, C.D., I. Egea, A. Galindo, P. Rodríguez, J. Rodríguez, W. Conejero, F. Romojaro and A. Torrecillas, 2012. Pomegranate fruit response to different deficit irrigation conditions. Agric. Water Manag. J., 114: 30-36.
52. Goldhamer, D.A., M. Viveros and M. Salinas, 2006. Regulated deficit irrigation in almonds: effects of variations in applied water and stress timing on yield and yield components. Irrig. Sci., 24: 101-114.
53. Yun Z., F. Liang, L. Yibo , Z. Jian and D. Zhiguang, 2019. Response of fruit yield, fruit quality and water use efficiency to water deficits for apple trees under surge-root irrigation in the Loess Plateau of China. Agricultural Water Management, 222: 221-230.
54. Zeng, C.Z., L.Z. Bie and Z.B. Yuan, 2009. Determination of optimum irrigation water amount for drip-irrigated muskmelon (*Cucumis melo* L.) in plastic greenhouse. Agricultural Water Management, 96: 595-602.
55. Ritchie, J.T., 1974. Atmosphere and the plant balance. Agric. Meteorol., 14: 183-198.
56. Roth, D., K. Kachel, R. Teichardt and G. Schalitz, 1988. Results and recommendation for splinkler irrigation of culinary potatoes. Feldwirtschaft, 29(5), 206-209. Ruggiero, C. (1991): Effect of water regime on apricot [cv. Cufona] in Vesuvian area. Acta Horticulturae, 293: 443-449.
57. Abd El-Moteleb, M.M.M, 1998. Response of apple trees of some irrigation treatments in new reclaimed soils. Ph.D. Thesis, Fac. Agric., Hort. Dept, Ain Shams Univ., Egypt, pp: 94.
58. Ali, M.A., M.M. Mahmoud and A.Y. Salib, 1998. Effect of soil moisture stress on apple trees. Egypt. J. Agric. Res., 76(4): 1565-1583.
59. Kandil, E.A. and U.S. El-Feky, 2006. Effect of soil matric potential on Canino apricot trees in sandy soil under drip irrigation. J. Agric. Sci. Mansoura Univ., 31(9): 5867-5880.
60. Tanguilig, V.C., E.B. Yambao, J.C. O'Toole and S.K. De Datta, 1987. Water stress effects on leaf elongation, leaf water potential, transpiration and nutrient uptake of rice, maize and soybean. Plant and Soil, 103: 155-168.
61. Hoseinlou, S.H., A. Ebadi, M. Ghaffari and M. Mostafaei, 2013. Nitrogen use efficiency under water deficit condition in spring barley. Int. J. Agron. Plant. Prod., 4(S): 3681-3687.
62. Pimratch, S., N. Vorasoot, B. Toomsan, T. Kesmala, A. Patanothai and C.C. Holbrook, 2013. Association of nitrogen fixation to water uses efficiency and yield traits of peanut. Int. J. Plant Prod., 7(2): 225-242.
63. Boland, A.M., P.H. Jerie, P.D. Mitchell, I. Goodwin and D.J. Connor, 2000. Long-term effects of restricted root volume and regulated deficit irrigation on peach: II. Productivity and water use. J. Amer. Soc. Hort. Sci., 125(1): 143-148.
64. Ramteke, S.D., J. Satisha, R.K. Singh and R.G. Somkuwar, 2001. Effect of soil moisture stress on nutrient content, growth and yield of Tas-A-Ganesh grapes grafted on DOG ridge rootstock. Ann. Plant Physiol., 15(1): 67-71.
65. Babu, H.K.N. and G.S. Prakash, 2003. Effect of water stress and rootstock on leaf mineral composition on grape. Indian J. Hort., 60(2): 147-150.
66. Hamdy, A.E., S.M. Khalifa, S.S. Shawer and A.G.A. Mancy, 2016. Effect of water stress on the growth, nutritional and biochemical status of two varieties of pomegranate seedlings. J. Plant Production, Mansoura Univ., 7(12):1321-1329.