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The Influence of Deficit Irrigation on Growth and Productivity of Manzanillo Olive Cultivar in Desert Land

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Abstract: The present study was carried out during the two successive seasons of 2006 -2007 and 2007-2008 in a private orchard located at Cairo – Alexandria desert road 50th Km., to study the effect of deficit irrigation at specific phonological stages on vegetative growth, flowering, yield, quality of olive fruit and physiological status of ‘Manzanillo’ olive trees under drip irrigation system. Results showed that vegetative growth parameters (shoot length, leaves density and leaf area), yield, fruit weight and physiological measurements (percentage of opening stomata, leaf water potential and transpiration rate) responded negatively to the regime water treatments. Trees irrigated with 100% Etc. through along season (control) recorded the highest values, followed in descending order by those irrigated with 66% Etc. in all stages of experiment either harvest: inflorescence emergence or inflorescence emergence: pit hardening or pit hardening: harvest stages which produced an intermediate values. On the contrary, trees irrigated with 33% Etc. in stage of the experiment pit hardening: harvest were the lowest in this respect in both seasons. As for the flowering parameters (No. of total flowers/ inflorescence, sex ratio and length of inflorescence), in addition fruit set, it was found that trees irrigated with 100% Etc. through along season (control) recorded the highest values, following by 66% Etc. and 33% Etc. at pit hardening: harvest stage, followed in a descending order by those irrigated with 66% Etc. and 33% Etc. at harvest: inflorescence emergence stage which produced an intermediate values, while, trees irrigated with 66% Etc. and 33% Etc. at inflorescence emergence: pit hardening stage were the lowest in this respect in both seasons. Whereas the yield and fruit weight the data showed that the trees irrigated with 33% at inflorescence emergence: pit hardening recorded the lowest values while the trees irrigated with 33% at pit hardening: harvest recorded the lowest values of fruit weight. Thus it can decrease the irrigation water quantities to 66%Etc. at the stage from harvest to inflorescence emergence. While at the stage of inflorescence emergence: pit hardening and from pit hardening: harvest not allow decreasing the irrigation water quantities.

Key words: Olive · Manzanillo cultivar · Deficit irrigation · Growth · Flowering · Yield

INTRODUCTION

Olive (*Olea europaea L., Oleaceae*) has probably been cultivated longer than any other trees species. It was domesticated around 3000 to 4000 BC in the eastern Mediterranean then spread widely in northern Africa, the Iberian Peninsula and the rest of southern Europe by civilizations that successively occupied the region. Today, olive remains one of the most important crops in the region and holds enormous economical and agricultural importance [1].

The olive industry has emerged as an important industry in Egypt; it is widely distributed and grown successfully under the prevailing condition, where olive trees can tolerate different types of stresses, as drought and salinity, which the other crops cannot withstand. The planted area of olive reached about 163 thousands Feddans in Egypt according to the statistics of the Ministry of Agriculture, 2010.

Despite the fact that water is beneficial for olive cultivation, we must keep in mind that water scarcity is a global problem that concerns everybody, especially the Mediterranean region [2]. Most of olive growers apply water inefficiently, with lower or higher than required quantities [3]. Water is the most important environmental constrain determining plant growth and fruit yield of olive trees. Although olive trees are resilient to water-limited conditions of Mediterranean-type agro ecosystems, crop

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yields may respond positively to any additional water up to a limit. A field experiment on olive trees was carried out with the aim to present guidelines for efficient management of irrigation scheduling, based on the relationship between plant water status and the optimum fruit yield [4-6]. Under conditions of scarce water supply and drought, deficit irrigation at selected phonological phases can lead to greater economic gains than maximizing yields per unit of water for a given crop. However, this approach requires precise knowledge of crop response to water stress at certain phonological stages as drought tolerance varies considerably by genotype and growth stage [5]. A few regulated deficit irrigation trials with olive varieties have been conducted [7-15]. Regulated deficit irrigation (RDI) is an irrigation strategy to manipulate yield, quality and vegetative growth with water stress at specific phonological stages. Regulated deficit irrigation has been used in some fruit crops to improve water use efficiency, control vegetative growth and maintain or improve fruit quality. A few regulated deficit irrigation trials with oil olive varieties have been conducted in Europe [15]. There are several mechanisms that allow olive trees to withstand for long periods of drought, high temperature and high irradiance regimes. Stomata close slowly as water deficit increases so that photosynthetic rate can be maintained over a wide range of leaf water potential. The stomatal response to vapors pressure deficit is attenuated in highly-stressed plants [16].

The optimization of irrigation management practices require more researches to be done on olive trees responses to water stress through regulated deficit irrigation and efficient irrigation management programs.

Thus, the aim of this work is to study the effect of deficit irrigation at specific phonological stages on vegetative growth, flowering, yield and physiological status of ‘Manzanillo’ olive trees under drip irrigation system.

MATERIALS AND METHODS

The present study was carried out during two successive seasons of 2006-2007 and 2007-2008 in a private orchard located at Cairo – Alexandria desert road, at the 50th km., to study the effect of the deficit irrigation at specific phonological stages on vegetative growth, flowering, yield and physiological status of ‘Manzanillo’ olive trees under drip irrigation system. The irrigation water that obtained from a well water quality is shown in Table 1. Physical and analyses of the experimental soil are presented in Tables 2 and 3.

The chosen trees were ten years old, grown in a sandy soil, spaced at 6 X 6 meters apart, irrigated by the drip system. The tested trees were selected nearly uniform in vigor’s growth, free from pathological and physiological disorders and received the same cultural practices except for the purpose of our study. The trees were annually fertilized with Farm fertilization program

Table 1: Water analysis.

			Cations (meq\L)				Anions(meq\L)			
E.C.w. mmhos	TSS ppm.	(pH)	Mg^{++}	Ca^{++}	K^{+}	Na^{+}	$SO_4^{=}$	Cl^{-}	HCO_3^{-}	$CO_3^{=}$
0.84	537.6	7.4	2	4	0.2	2.1	0.2	6.1	2	few

Table 2: Physical soil analysis

Depth cm.	Clay%	Fine sand%	Sand%	Silt%	Calcium Carbonate%	Organic matter%
0-30	10.47	18.34	5038	5.23	15.4	0.18
30-60	10.45	19.5	48.1	6.8	14.9	0.25
60-90	10.43	21.7	46.99	7.4	13.2	0.28

Table 3: Chemical soil analysis

	Anions (meq\L)				(Cations) (meq\L)			
Depth cm.	$SO_4^{=}$	Cl^{-}	HCO_3^{-}	$CO_3^{=}$	K^{+}	Na^{+}	Mg^{++}	Ca^{++}
0-30	0.18	0.5	0.7	-	0.05	0.7	0.18	0.45
30-60	0.16	0.4	0.62	-	0.05	0.65	0.17	0.42
60-90	0.13	0.35	0.55	-	0.04	0.55	0.15	0.37

Table 4: Theoretical monthly water requirements determined according to Penman's equation

	Nov.	Dec	Jan	Feb	Mar	Apr.	May	Jun	Jul	Aug	Sep	Oct.
Eto Means of 7 years 2000:2006	3.27	2.23	2.10	2.45	3.20	4.52	5.99	7.26	7.32	7.09	5.73	4.43
Kc	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.7	0.6	0.5
ETc mm/day	1.308	0.892	0.84	0.98	1.28	2.26	3.594	5.082	5.124	4.963	3.438	2.215
m^3/f/day	5.49	3.75	3.53	4.12	5.38	9.49	15.1	21.34	21.52	20.84	14.43	9.3
days/month	30	31	31	28	31	30	31	30	31	31	30	31
m^{3}f/ month	164.7	115.63	109.43	115.36	166.78	284.7	468.1	640.2	667.12	646.04	432.9	288.3
Irrigation intervals												
time/month	16	16	16	16	16	16	24	24	24	24	24	24
100% m^3/f/time	10.29	7.23	6.84	7.21	10.42	17.79	19.5	26.68	27.79	26.92	18.04	12.01
100 L/tr./time%	86.21	62.33	58.97	62.15	89.83	153.36	168.1	230	239.57	232.07	155.52	103.53
66% /L / tr./time	56.9	41.14	38.92	41.02	59.28	101.22	110.96	158.12	158.12	159.12	102.64	67.66
33%/L /tr./time	28.45	20.57	19.46	20.51	29.64	50.61	55.48	75.9	79.06	79.56	51.32	33.83

Table 5: The Quantities of water m^3/f /treatment as following

	Treatments	deficit water m^{3}f at specific phonological stage	The rest of water quantities for season (m^3/f)	Total quantities of water through the season (m^3/f./year)
1	All months 100% Etc	---	4099.26	4099.26 m^3
2	1/11/:28/2/ from harvest to Inflorescence emergence 66% Etc.	333.38	---	3925.86 m^3
	1/3 : 31/12 from Inflorescence. emergence to harvest 100%Etc.	---	3592.48	
3	1/3/:30/6/ from Inflorescence. emergence to pit hardening 66% Etc.	1029.45	---	3568.93 m^3
	1/7 : 28/2 from pit hardening to Inflorescence. emergence 100%Etc.	---	2539.53	
4	1/7/:31/12/ from pit hardening to harvest 66% Etc.	1342.68	---	3407.58 m^3
	1/11 : 30/6 from harvest to pit hardening 100%Etc.	---	2064.9	
5	1/11/:28/2/ from harvest to Inflorescence. emergence 33% Etc.	166.68	---	3760.82 m^3
	1/3 : 31/12 from Inflorescence. emergence to harvest 100%Etc.	---	3594.14	
6	1/3/:30/6/ from Inflorescence. emergence to pit hardening 33% Etc.	514.72	---	3054.2 m^3
	1/7 : 28/2 from pit hardening to Inflorescence. emergence 100%Etc.	---	2539.48	
7	1/7/:31/12/ from pit hardening to harvest 33% Etc.	671.34	---	2736.24 m^3
	1/11 : 30/6 from harvest to pit hardening 100%Etc.	---	2064.9	

(Compost and mineral fertilizers) which was added at the second week of November and applied in two parallel ditches of 100×40×30 cm; for length, width and depth, respectively, the ditches surrounded the trees from two directions in the end of the canopy shade.

The amount of compost was 50Kg/tree. The rate of mineral fertilizers was 500 gm nitrogen / trees (ammonium sulfate) +270gm phosphorus/tree (super phosphate 0+ 720gm potassium (potassium sulfate) +0.5Kg /tree as $MgSO_4$ (9.6% Mg) + 0.25 Kg /tree S + 0.25 Kg /tree B.

The crop coefficient recommended by the FAO according to Allen *et al*. [17] is the most widely used approach for determining ETc. It was calculated from the potential evapotranspiration (ETo.) in the area, a coefficient Kc called the crop coefficient. The most widely accepted methods for determining was based on the use either of the evaporation tank or automatic weather stations.

In order to evaluate the volume of water that should be applied to the olive grove each day, the daily reference of evapotranspiration (ETo) should be considered. Eto is multiplied by the crop coefficient (Kc) in order to obtain the daily irrigation requirement of the crop: Crop Evapotranspiration (ETc). Climatic data were obtained from Giza Zone Climatic Station.

ETO was monthly as average for seven years from 2000 to 2006 (Table 4) by the Penman's equation [18]:

$$Eto = C\,[W.Rn) + (1-W) \times F(U) \times (ea - ed)]$$ where:

Eto.: Reference crop evapotranspiration (mm / day).
W = Temperature - related weight factor
Rn: Net radiation in equivalent evaporation in mm / day.
F (U) = Wind — related function
(ea -ed) = Difference between the saturated vapor pressure at air temperature and the mean actual vapor pressure of the air, both in m bar.
C = Adjustment factor to compensate for the effect of day and night weather conditions
Etc = ETo X Kc

Kc is an empiric parameter for different growing conditions and it changes along the seasons.

The present experiment included the following 7 treatments as shown in Table 5.

The experiment was set in a completely randomized block design with seven treatments each contains three replicates and each replicate represented by two olive trees.

The obtained data were handled as the following measurements:

In each season of the study, fifteen shoots (one year old) were randomly chosen at each direction for the vegetative growth measurement for each replicate

Vegetative Growth: At the end of each growing season the following characteristics were measured:

Average Shoot Length (cm): The length of shoots at the end of the growing season were determined.

Leaves Density = Average of leaves number per meter

Leaf Area (cm^2): Leaf samples were taken from the middle part of the shoot from the spring flush (15 shoots / each replicate) and the leaf area in cm was determined by using planimeter (model Cl -203, USA), the leaf area per shoot (cm^2) was directly calculated.

Flowering Parameters and Fruit Set: Average number of flowers / inflorescence according to Fouad *et al*. [19], sex ratio, average inflorescence length (cm) and percentage of fruit set (14 days after full blooming) by using the following equation:

$$\text{Percentage of fruit set} = \frac{\text{No. of fruit set}}{\text{No. of total flowers}} \text{X100}$$

Yield Parameters: Weight of yield per tree (kg) and average of fruit weight (g)

Physiological Measurements of Leaves: Percentage of opening stomata / unit of leaf area.

Leaf water potential (L.W.P) according to Wilson *et al.* [20]; Halma [21] and confirmed by Peynodo and Young [22].

Transpiration rate (ug H_2O $cm^{-2}.S^{-1}$) according to Reda [23].

Leaf Chemical Content: On the first week of August, in both seasons, 50 mature leaves per replicate were collected from the mediate position of the current season' s shoots to determine.

Leaf total nitrogen content (%): According to Pregl [24].

Leaf phosphorus content (%): According to Snell and Snell [25].

Leaf potassium content (%): According to Jackson [26].

Leaf proline content (mg/g): It was colorimetrically estimated on fresh weight basis according to the method of Batels *et al*. [27].

Statistical Analysis: The complete randomized block design was adopted for the experiment. The statistical analysis of the present data was carried out according to Snedecor and Chocran [28]. Averages were compared using the new L.S.D. values at 5% level.

RESULTS AND DISCUSSION

Vegetative Growth Parameters: Data shown in Table 6 reveal that vegetative growth parameters i.e. shoot length, leaves density and leaf area were varied significantly among deficit irrigation treatments.

Shoot Length: Data cleared out that shoot length was responded negatively to deficit irrigation treatments. Trees irrigated with 100% Etc. through along season (control) recorded the highest significant values, (21.43 and 23.23)in both seasons, followed in a descending order by those irrigated with 66% Etc. and trees irrigated with 33% Etc. in the stage of experiment at harvest: inflorescence emergence, in both seasons. On the contrary, trees irrigated with 33% Etc. in the stage of experiment pit hardening: harvest attained the lowest significant values (14.73 and 16.93) in this respect in both seasons. There were no significant differences between all stages of the experiment, except those trees irrigated with 33% Etc. at inflorescence emergence: pit hardening or pit hardening: harvest stages in the first season only.

Average Number of Leaves /100cm. Shoot Length: As for the average number of leaves per 100 cm. shoot length, it could be concluded from the obtained data that trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (177.7 and 183.6) in both seasons, followed in descending order by those irrigated with 66% Etc. and trees irrigated with 33% Etc in the stages of experiment at harvest: inflorescence emergence. On the contrary, trees irrigated with 33% Etc.

Table 6: Effect of water regimes at different physiological stages on vegetative growth parameters of Manzanillo olive cultivar during 2006-2007 and 2007-2008 seasons

Treatments	Average of Shoot length (cm)		Average No. of Leaves /100 cm shoot length		Average of Leaf area/shoot (cm^2)	
	2006/2007	2007/2008	2006/2007	2007/2008	2006/2007	2007/2008
100% through all season (Control) (4099.26 m^3)	21.43a	23.23a	177.7a	183.6a	3.82a	3.91a
66% from harvest to inflorescence emergence (3925.86 m^3)	20.2ab	21.1ab	176.2ab	180.9ab	3.79ab	3.86ab
66% from inflorescence emergence to pit hardening (3568.93m^3)	18.47bc	19.95bc	174.2bc	177.17bc	3.217 b	3.47b
66% from pit hardening to harvest (3406.68 m^3)	17.95c	19.22c	172.8c	176.89cd	3.16 cd	3.09c
33% from harvest to inflorescence emergence (3760.82 m^3)	19.53 bc	20.5bc	175.2ab	179.9b	3.75ab	3.83ab
33% from inflorescence emergence to pit hardening (3054.2 m^3)	16.2d	17.9de	154.9d	161d	2.87c	2.93d
33% from pit hardening to harvest (2736.24 m^3)	14.73e	16.93de	146.6e	154.2e	2.7d	2.603e
New L.S.D. (0.05)	1.74	1.73	2.6	3.7	0.113	0.159

Table 7: Effect of water regimes at different physiological stages on flowering parameters of Manzanillo olive cultivar during 2006-2007 and 2007-2008 seasons

Treatments	No. of total flowers/ inflorescence		Sex ratio (%)		Length of inflorescence (cm)	
	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008
100%Etc,Through all season (Control) (4099.26 m^3)	16.3a	16.9a	68.2a	75.3a	2.89a	2.84a
66% from harvest to inflorescence emergence (3925.86 m^3)	14.52c	14.73c	61.3b	68.8ab	2.67c	2.61c
66% from inflorescence emergence to pit hardening (3568.93m^3)	13.2e	13.32e	41.3c	43.21d	2.18e	2.12 e
66% from pit hardening to harvest (3406.68 m3)	15.72b	15.87b	65.1ab	73.25ab	2.81ab	2.77ab
33 % from harvest to inflorescence emergence (3760.82 m^3)	14.12d	14.25d	60.4 b	67.4b	2.5d	2.4d
33% from inflorescence emergence to pit hardening (3054.2 m^3)	12.15f	12.3 f	32.1d	34.3fg	1.92f	1.89f
33% from pit hardening to harvest (2736.24 m^3)	15.62 b	15.93b	64.2ab	71.1ab	2.75bc	2.67bc
new L.S.D. (0.05)	0.1125	0.187	5.6	7.9	0.114	0.113

at stage of experiment either inflorescence emergence: pit hardening or pit hardening: harvesting recorded lower significant values in this respect during both seasons. There were no significant differences between all stages of the experiment, except those trees irrigated with 33% Etc. at inflorescence emergence: pit hardening or pit hardening: harvest stages in both seasons.

Leaf Area: With respect to leaf area, it is obvious that trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (3.82 and 3.91) in both studied seasons followed in a descending order by those irrigated with 66% Etc. and trees irrigated with 33% Etc. in the stages of experiment at harvest: inflorescence emergence in both seasons. On the contrary, trees irrigated with 33% Etc. at stages of experiment at pit hardening: harvest or inflorescence emergence: pit hardening recorded lower significant values in this respect in both seasons. There were no significant differences between all stages of the experiment except those trees irrigated with 33% Etc. at inflorescence emergence: pit hardening or pit hardening: harvest stages and 66% Etc at pit hardening: harvest stage in second season only.

The results in this respect are in line with those of Alegre *et al*. [10] who showed that leaf water status in the RDI-25% showed a progressive decrease during RDI period compared with the control, since it reduced vegetative growth, fruit growth and fruit yield.

Flowering Parameters: Flowering parameters i.e. No. of total flowers/ inflorescence, sex ratio and length of inflorescence were significantly affected by deficit irrigation treatments according to physiological stage (Table, 7).

No. of Total Flowers/ Inflorescence: Data cleared out that number of total flowers inflorescence showed a significant negative response for the deficit irrigation treatments, trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (16.3and 16.9) in both seasons, followed in a descending order by those irrigated with 66% Etc. and33%Etc. at pit hardening: harvest. On the contrary, trees irrigated with 33% Etc. at inflorescence emergence: pit hardening stage or 66% Etc at the same stage recorded lower significant values in this respect in the both seasons. There were significant differences between all stages of experiment except trees irrigated either with 66% Etc. or 33% Etc. at pit hardening: harvest stage in both seasons.

Table 8: Effect of water regimes at different physiological stages on yield parameters of Manzanillo olive cultivar during 2006-2007 and 2007-2008 seasons

	Fruit set (%)		Yield/tree (Kg)		Fruit weight (g)	
Treatments	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008
100% through all season (Control) (4099.26 m^3)	29.83a	34.1a	36.93a	33.9a	6.39a	6.29a
66% from harvest to inflorescence emergence (3925.86 m^3)	28.47a	33.3a	36.57ab	33.1ab	6.3ab	6.25ab
66% from inflorescence emergence to pit hardening (3568.93m^3)	25.7b	28.5b	28.77d	26.9d	5.98d	5.88d
66% from pit hardening to harvest (3407.58 m^3)	29.7a	32.2a	34.9b	30.8b	6.14c	6.01c
33% from harvest to inflorescence emergence (3760.82 m^3)	28.8a	33.5a	35.3b	31.23bc	6.2bc	6.15bc
33% from inflorescence emergence to pit hardening (3054.2 m^3)	23.53c	26.77 c	25.23e	22.95e	5.83e	5.74e
33% from pit hardening to harvest (2736.24 m^3)	27.27ab	31.4ab	30.9c	29.5cd	5.76ef	5.6f
new L.S.D. (0.05)	1.104	1.274	1.105	1.55	0.126	0.138

Sex Ratio: As for the sex ratio, data presented in Table 8 indicated that trees irrigated with 100% Etc. through along season (control), recorded the highest significant values (68.2 and 75.3) in both seasons followed in a descending order by those irrigated with 66% Etc. and 33% Etc. at pit hardening: harvest stages following by 66% Etc. and 33% Etc. at harvest: inflorescence emergence stage which produced an intermediate significant values. While, trees irrigated with 33% Etc. or 66% Etc. at inflorescence emergence: pit hardening stages gave lower values in this respect in both seasons respectively. There were no significant differences between stages of experiment except trees irrigated either with control or 66% Etc. harvest: inflorescence emergence or inflorescence emergence: pit hardening and 33% Etc. at inflorescence emergence: pit hardening stages in the first season only and trees irrigated with either control or 66%.Etc. or 33% Etc. at inflorescence emergence: pit hardening in second season only.

Length of Inflorescence: With respect to inflorescence length, it is obvious that trees irrigated with 100% Etc. through along season (control) stage recorded the highest significant values (2.89 and 2.84) in both studied seasons followed in descending order by those irrigated with 66% Etc. and 33% Etc. at pit hardening: harvest. On the contrary, trees irrigated with 66% Etc. and 33% Etc. at Inflorescence emergence: pit hardening stage recorded lower significant values in both seasons. There are significant differences between all stages of experiment except those trees irrigated with either control or 66%Etc.or 33% Etc. at pit hardening: harvest stages in both seasons.

Yield Parameters: Data shown in Table 8 revealed that fruit set, yield and fruit weight varied significantly among deficit irrigation treatments.

Fruit Set%: It can be noted from Table 8 that fruit set% showed a significant negative response for the deficit irrigation treatments. Trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (29.83 and 34.1%), followed in a descending order by those irrigated with 66% Etc. at stages from pit hardening: harvest stage or harvest: inflorescence emergence stage. On the contrary, trees irrigated with33% Etc. at inflorescence emergence: pit hardening stage gave the lowest significant values (23.53 and 26.77) in this respect in both seasons, respectively. There were no significant differences between all stages of experiment except the stages of experiment either tree irrigated with 66% Etc. or 33% Etc. at inflorescence emergence: pit hardening stage in both seasons.

Yield: As for the yield, it was cleared from the previously mentioned data that trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (36.93 and 33.9%) in both seasons, followed in a descending order by those irrigated with 66% Etc. and33% Etc at stage of harvest inflorescence emergence. While, trees irrigated with 33% Etc. or 66% Etc at inflorescence emergence: pit hardening stages of the experiment were achieved lower significant values in the both seasons. There were significant differences between all stages of experiment, except the stage of experiment then trees irrigated either as control or with 66% Etc. or 33%Etc. at harvest: inflorescence emergence or 66%Etc. at pit hardening: harvest stages in first season but in second season there are no significant differences between stages of experiment, except the stage of experiment trees irrigated control and 33%Etc at inflorescence emergence: pit hardening stage.

Fruit Weight: With respect to fruit weight, it is obvious that trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (6.39 and

Table 9: Effect of water regimes at different physiological stages on physiological measurements of Manzanillo olive cultivar during 2006-2007 and 2007-2008 seasons

Treatments	Opening stomata%per unit leaf area (%)		Leaf water potential (L.W.P)		Transpiration rate (ug H2Ocm-2.S-1)	
	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008
100% through all season (Control) (4099.26 m^3)	32.17a	29.47a	57.45a	54.9a	9.5a	8.43a
66% from harvest to inflorescence emergence (3925.86 m^3)	31.83ab	28.73ab	56.6ab	54.23 a	9.28ab	8.3ab
66% from inflorescence emergence to pit hardening (3568.93m^3)	29.83bc	27.71bc	55.03c	52.6bc	9.18b	8.05b
66% from pit hardening to harvest (3407.58 m^3)	26.2d	24.13 d	50.83e	49.47d	8.86 c	7.65c
33 % from harvest to inflorescence emergence (3760.82 m^3)	31.17ab	27.93bc	55.83bc	52.8b	9.2ab	8.17ab
33% from inflorescence emergence to pit hardening (3054.2 m^3)	28.67c	27.27c	52.57d	51.81 c	8.54d	7.24d
33% from pit hardening to harvest (2736.24 m^3)	25.03e	22.2e	49.3f	46.7e	6.88e	6.84e
new L.S.D. (0.05)	1.477	1.35	0.05626	0.0563	0.318	0.402

6.29%), followed in a descending order by those irrigated with 66% Etc. On the contrary, trees irrigated with 33% Etc. at the stages of experiment inflorescence emergence: pit hardening and pit hardening: harvest achieved lower significant values (5.83g and 5.74g) and (5.7g and 5.6g) in this respect in the both seasons, respectively. There were significant differences between all stages of experiment, except trees irrigated with either control 66% Etc. or 33% Etc. at harvest: inflorescence emergence stages in both seasons.

Olive production is a function of several factors, among those is the primarily fruit set. Fruit set in olives is strongly influenced by soil moisture available during this period. This could be the reason of higher fruit set and therefore subsequently higher production. This result is consistent with the finding of other researchers [8]. The increase in production with water use was explained by Michelakis [8] as a result of higher numbers of fruits. Increased fruit weight could be attributed to the moisture availability after the pit hardening.

Physiological Measurements: Physiological measurements i.e. percentage of opening stomata, leaf water potential and transpiration rate were significantly affected by deficit irrigation treatments according to physiological stage (Table, 9).

Percentage of Opening Stomata: Data cleared out that percentage of opening stomata responded negatively to the deficit irrigation treatments. Trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (32.17and 29.47%) n both season followed in a descending order by those irrigated with 66% Etc. and 33%Etc.either at harvest: Inflorescence. emergence or at Inflorescence. emergence: pit hardening stages since they recorded an intermediate significant values in both seasons, respectively. On the contrary, trees irrigated with 33% Etc. or 66% Etc at pit hardening: harvest stages recorded lower significant values (25.03 and 22.2) and (26.2 and 24.13%) in this respect in the both seasons.

There were no significant differences between all stages of experiment, except when trees irrigated with 66% Etc. and 33%Etc. at pit hardening: harvest and 33%Etc. at inflorescence emergence: pit hardening stage in both seasons.

Leaf Water Potential: As for the leaf water potential, it was found that trees irrigated with 100% Etc. through along season (control), recorded the highest significant values (57.45 and 54.9) followed in a descending order by those irrigated with 66% Etc. and 33%Etc.either at harvest: inflorescence emergence or at inflorescence emergence: pit hardening stages since they recorded an intermediate significant values in both seasons, respectively. On the contrary, trees irrigated with 33% Etc. or 66% Etc at pit hardening: harvest stage gave lower significant values in this respect in the both seasons. There were significant differences between all stages of experiment except when trees irrigated with either control or 66%Etc. or 33%Etc.at harvest: inflorescence emergence stage in the first season only. There are significant differences between stages of experiment except the trees irrigated with either control or 66%Etc. and 33%Etc.at harvest: inflorescence emergence and 66% Etc inflorescence emergence: pit hardening in both seasons.

Transpiration Rate: With respect to transpiration rate, it is obvious that trees irrigated with 100% Etc. through along season (control), recorded the highest significant values (9.5 and 8.43) followed in a descending order by those irrigated with 66% Etc. and 33%Etc. at harvest: inflorescence emergence. On the contrary, trees irrigated with 33% Etc. at pit hardening: harvest stage or at

Table 10: Effect of water regimes at different physiological stages on leaf chemical content of Manzanillo olive cultivar during 2006-2007 and 2007-2008 seasons

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Proline (mg/g)	
	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008	2006-2007	2007-2008
%100 through all season (Control) (4099.26 m^3)	1.72a	1.863a	0.323a	0.357a	0.83a	0.95a	0.32cd	0.35c
66% from harvest to inflorescence emergence (3925.86 m^3)	1.66ab	1.807ab	0.31ab	0.34ab	0.80ab	0.92ab	0.33c	0.34c
66% from inflorescence emergence to pit hardening (3568.93m^3)	1.63b	1.763b	0.273ab	0.32ab	0.747b	0.868cd	0.38bc	0.37bc
66% from pit hardening to harvest (3407.58 m^3)	1.6bc	1.71bc	0.265bc	0.207b	0.69c	0.82c	041a	0.39a
33% from harvest to inflorescence emergence (3760.82 m^3)	1.68ab	1.79ab	0.29ab	0.333ab	0.81ab	0.87ab	0.33c	0.35bc
33% from inflorescence emergence to pit hardening (3054.2 m^3)	1.48d	1.54d	0.198cd	0.188c	0.58e	0.78e	43ab	0.40ab
33% from pit hardening to harvest (2736.24 m^3)	1.56c	1.66c	0.211c	0.200bc	0.662d	0857d	0.45a	0.41a
new L.S.D. (0.05)	0.0796	0.0974	0.0563	0.0796	0.056	0.0178	0.059	0.0178

inflorescence emergence: pit hardening showed the lowest significant values in this respect in the both seasons.

There were no significant differences between all stages of experiment, except when trees irrigated with either 66% Etc. or 33%Etc. at pit hardening: harvest and 33%Etc. or 66% Etc. at inflorescence emergence: pit hardening stages in both seasons.

The obtained results are in agreement with those obtained by Moriana *et al.* [12] who reported that the trees in the water deficit and rain fed treatments rapidly recovered from water stress after receiving irrigation water or autumn rainwater, respectively. Also, Gucci [16] showed that there are several mechanisms that allow the olive trees to withstand long periods of drought, high temperature and high irradiance regimes. Stomata close slowly as water deficit increases so that photosynthetic rate can be maintained over a wide range of leaf water potential. The stomata response to vapor pressure deficit is attenuated in highly-stressed plants.

Leaf Chemical Content: Leaf Total Nitrogen Content (%): Data in Table 10 cleared out that leaf total nitrogen content responded as significantly negative to the deficit irrigation treatments. Trees irrigated with 100% Etc. through along season (control) recorded the highest significant values (1.720 and 1.863) in both seasons, followed in a descending order by those irrigated with 66% Etc. and 33%Etc. in the stages of experiment at harvest: inflorescence emergence. On the contrary, trees irrigated with 33% Etc. in the stage of experiment inflorescence emergence: pit hardening or pit hardening: harvest gave lower significant values in this respect in both seasons. There were no significant differences between stages of experiment except those trees irrigated with 33% Etc. either inflorescence emergence: pit hardening or pit hardening: harvest in both seasons.

Leaf Phosphorus Content (%): As for the leaf phosphorus content in Table 10, it was found that trees irrigated with 100% Etc. through along season (Control) recorded the highest significant values(0.323 and 0.357%) followed in a descending order by those irrigated with 66% Etc..in the stages of experiment either harvest: inflorescence emergence or inflorescence emergence: pit hardening while, trees irrigated with 33% Etc. in stage of experiment inflorescence emergence: pit hardening or from pit hardening :harvest receded significant values in this respect in both seasons. There were no significant differences between all stages of experiment.

Leaf Potassium Content (%): With respect to leaf potassium content in Table 10, it is obvious that trees irrigated with 100% Etc. through along season (control) recorded the highest significant values(0.83 and 0.91%) followed in a descending order by those irrigated with 66% Etc. and 33%Etc.in the stage of experiment harvest: inflorescence emergence while, trees irrigated with 33% Etc. in stages of experiment inflorescence emergence: pit hardening or pit hardening: harvest showed the lowest significant values in this respect in both seasons. There were no significant differences between stages of experiment except trees irrigated with 33% Etc. either inflorescence emergence: pit hardening or pit hardening: harvest and 66%from pit harvesting :harvesting in first season but in second season in trees irrigated with 33% Etc. inflorescence emergence: pit hardening only.

Leaf Proline Content (mg/g): Data shown in Table 10 cleared out that leaf proline content responded as significantly positive to the deficit irrigation treatments. Trees irrigated with 100% Etc. through along season (control) recorded the lowest significant values (0.32 and 0.35mg/g), followed in an ascending order by those irrigated with 66% Etc. and 33% Etc. in the stage of experiment at harvest: inflorescence emergence and 66%Inflorescence emergence: pit hardening stages which produced an intermediate significant values. On the contrary, trees irrigated with 33% Etc. in stages of experiment at pit hardening: harvest or inflorescence emergence: pit hardening stage recorded significant highest values in this respect in both seasons. There were no significant differences between stages of experiment in both seasons.

Leaf proline content has been used as an evaluation parameter for selecting salinity and drought resistant varieties [27]. Furthermore, increasing proline content in the leaves with increasing water regime treatments might be attributed to plants build up proline in the tissues to maintain osmotic balance with the soil solution [29].

CONCLUSION

Thus it can decrease the irrigation water quantities to 66%Etc. at the stage from harvest to inflorescence emergence. While at the stage of inflorescence emergence and fruit growth it cannot allow to decrease the irrigation water quantities

REFERENCES

1. FAOSTAT, 2003. FAO Statistical Databases. Agriculture Data Collection (Primary Crops). Vol. 2003, http:// apps.fao.org/ page/ collections?subset=agriculture.
2. Laraus, J., 2004. The problem of sustainable water use in the Mediterranean and research requirements for agriculture. Ann. Appl. Biol., pp: 254-272.
3. Fereres, E. and M.A. Soriano, 2007. Deficit irrigation for reducing agricultural water use. J. Exp. Bot., 58: 147-159.
4. D'Andria, R., G. Morelli, M. Patumi and Fontanazza, 2002. Irrigation regime affects yield and oil quality of olive trees. Acta Horticulturae, 586: 273-276.
5. Tognetti, R., R. d'Andria, A. Lavini and G. Morelli, 2006. The effect of deficit irrigation on crop yield and vegetative development of *Olea europaea L.* (cvs. Frantoio and Leccino). European Journal of Agronomy, 25: 356-364.
6. Vossen, P.M., M.J. Berenguer, S.R. Grattan, J.H. Connell and V.S. Polito, 2008. The influence of different levels of irrigation on the chemical and sensory properties of olive oil. Acta Horticulturae, 791: 439-444.
7. D'Andria, R., G. Morelli, G. Martuccio, G. Fontanazza and M. Patumi, 1996. Evaluation of yield and oil quality of young olive trees under different irrigation regimes. Italus. Hortus., 3: 23-31. 27
8. Michelakis, N., 1998. Water management and irrigation for olive trees. Proceedings of the international seminar on olive growing, held 1997, Greece.
9. Goldhamer, D.A., 1999. Regulated deficit irrigation for California canning olives. Acta Horticulturae, 474: 369-3721. FAOSTAT, 2003. FAO Statistical Databases. Agriculture Data Collection (Primary Crops). Vol. 2003, http:// apps.fao.org/ page/ collections?subset=agriculture
10. Alegre, S., J. Marsal, M. Mata, A. Arbones, J. Girona and M.J. Tovar, 1999. Regulated deficit irrigation in olive trees (*Olea europaea L. cv. Arbequina*) for oil production. Acta Horticulturae, 586: 259-262.
11. D'Andria, R., A. Lavini, G. Morelli, M. Patumi, S. Terenziani, D. Calandrelli and F. Fragnito, 2004. Effect of water regime on five pickling and double aptitude olive cultivars (*Olea europaea* L.). Journal of Horticultural Science & Biotechnology, 78: 15-23.
12. Moriana, A., D. Perez-Lopez, A. Gomez-Rico, M.L.D. Salvador, N. Olmedilla, F. Ribas and G. Fregapane, 2007. Irrigation scheduling for traditional, low-density olive. Agricultural Water Management, 87: 171-179.
13. D'Andria, R., A. Lavini, G. Morelli, R. Tognetti, G. Aronne, V. Micco, M.L. Ambrosino, A. Paduano, F. Conte, R. Sacchi and L. Sebastiani, 2008. The effect of irrigation management on plant performance and oil quality of two olive cvs. grown in a typical environment of southern Italy. Acta Horticulturae, 791: 297-305.
14. Dabbou, S., C. Hechmi, F. Brahmi, E. Sonia, S. Roberto, T. Agnese, S. Maurizip, M. Gian Francesco and H. Mohamed, 2010. Effect of three irrigation regimes on Arbequina olive oil produced under Tunisian growing conditions. Science Direct - Agriculture Water Management Available online 1 February 2010.
15. Richard, C.R., H. Wiliam and L. Matt, 2011. Influence of Regulated Deficit Irrigation Strategies Applied to '*Arbequina*' Olive trees on oil yield and oil Composition, THE 2011 ASHS Annual Conference, September 25, 2011)
16. Gucci, R., 2006. Implications of water relations on irrigation management of olive trees .Italus Hortus., 13: 61-70.

17. Allen, R., L.S. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration – Guidelines for computing crop water requirements- FAO irrigation and drainage paper 56, FAO, Rome. http:// www.fao.org/ docrep/ X0490E/X0490E00.htm.
18. Penman, L., 1975. Evaporation: An introductory survey. Neth. J. Agr. Sci., 4: 9-29 (C.F. Hillel, D., 1975).
19. Fouad, M.M., O.A. Kilany and M.E. El-said, 1992. Comparative studies on inflorescence emergence, fruit-set and yield of some olive cultivars under Giza conditions. Egypt. J. Appl. Sci., 7: 630-644.
20. Wilson, C.C., W.R. Burgess and P.J. Kramei, 1953. Diurnal fluctuatons in water contents of some herbaceous plants. Amer. J. Bot., 40: 97-100.
21. Halma, F.F., 1934. Trunk growth and water relation in the leaves of citrus. Proc. Amer. Soc. Hort., 32: 273-276.
22. Peynodo, A. and R.H. Young, 1968. Moisture changes in intact citrus leaves monitored by a guage technique: Proc. Amer. Soc. Hort. Sd., 92: 211-220.
23. Reda, A.M., 1998. Effect of some drip irrigation treatments on growth, yield and fruit quality in Valencia orange trees under conditions of newly reclaimed land. MSc. Thesis, Fac., of Agric. Zagazig Univ. Egypt.
24. Pregl, F., 1945. Quantitative Organic Micro-Analysis. 4th Ed J. and A. Churchill, Ltd., London.
25. Snell, F.D. and C.T. Snell, 1967. Colorimeteric Method of Analysis. D. van Nestrant Company Inc., pp: 551-552.
26. Jackson, M.L., 1967. Soil Chemical Analysis. Printice-Hall Inc. Englewood Cliffs-N.S.
27. Batels, L.S., R.P. Waldern and L.D. Teare, 1973. Rapid determination of free proline for water-stress studies. Plant and Soil, 939: 205-207.
28. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods, 6th ed., Iowa State Univ. Press, Iowa, USA.
29. Salisbury, F.B. and C.W. Ross, 1992. Plant physiology. 4th ed. Pub. Wadsworth, Belmont, California, U.S.A.