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Olive Trees Productivity in Response to Supplemental Irrigation under North-Western Coastal Conditions in Egypt

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Abstract: This study was carried out during two successive seasons of 2008 and 2009 on mature olive trees cv. Manzanillo. In this study, nine irrigation treatments were used during five months from May to December in an expected "On" year (2008) and an expected "Off" year (2009).The treatments were: No irrigation (rain fed), 60mm once /month, 80mm once/ month, 100mm once/ month, 120mm once/ month, 30 mm twice/ month, 40 mm twice /month, 50 mm twice /month and 60 mm twice/ month. The rainfall in the experimental region recorded 92.0 and 115.0 mm/year in 2008 and 2009, respectively. The result showed that the higher level of irrigation water (60 mm twice/month) during May to September was more effective in increasing the productivity and fruit quality of Manzanillo olive in both seasons. Also leaf nitrogen, potassium, calcium and iron content were increased under such conditions.

Key words: Olive trees · Supplemental irrigation · Productivity · Egypt

INTRODUCTION

Olive (*Olea europaea L.*) is widely cultivated in semiarid areas with Mediterranean climate, where long periods of soil water deficit are usually present during the dry season. Olive tree has been traditionally grown under rain-fed conditions and is considered one of the best adapted species to the semiarid environment [1]. However, under this condition it usually shows a decrease in photosynthesis that limits growth and yield [2]. In this respect olive production was improved by water supply [3, 4]. According to the international olive oil council (IOOC), the world area devoted to olive growing is 8.8 million hectare [5]. This area is centered mainly in the Mediterranean basin, which has about 99% of the world's olive groves. It produced in 2007/2008 around 2,030,800 metric tones of olive oil. In Egypt, olive acreage reached 135692 feddan (56538 ha) and fruiting area recorded 110764 feddan (46152 ha) with total fruit production of 507053 metric tons [6]. Olive offers a great economic potential compared to the other fruit trees grown under the same conditions. It is used for good nutritional (as fresh pickling and for oil production) and medical purposes. Olive production plays an important role in the economy of many Mediterranean countries. Due to limitation of water availability for irrigation in large areas of the world, there is a probability increase the loosing of irrigated land. However, for mature fruit trees, reducing applied water to a certain limit could improve water use efficiency [7]. Applying water to fruit tree crops is a widely used practice but efficient water use has become important only in recent years due to the rapid depletion of available water resources in many areas of the world [8]. Many technologies to improve water efficiency and the management of scarce water resources are available. Among the most promising and efficient-proven technologies are: (I) supplemental irrigation (SI) for optimizing the use of the limited water available from renewable resources in rain fed areas and (II) water harvesting (WH) for improved farmer income in drier environment [9].

The aim of this study was to evaluate the effect of supplemental irrigation on productivity and quality of Manzanillo olive under semi-arid conditions of Matrouh Governorate region, Egypt.

MATERIALS AND METHODS

Plant Material and Experimental Design: This study was conducted during two successive seasons of 2008 and

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2009 at El Hammam region, Matrouh Governorate, Egypt to investigate the effect of different irrigation rates on leaf mineral content, fruiting and fruit quality of olive trees cv. Manzanillo. Thirty years old Manzanillo olive trees, similar as possible in growth, vigor and healthy were planted at 7 x 7 m apart and received regularly the recommended horticultural practices. The rainfall in the experimental region recorded 92.0 and 115.0 mm in 2008 and 2009, respectively according to Matrouh Recourses Management Project (Applied Research Center).Thirty six trees were selected and subjected to nine irrigation treatments during five months beginning from May to December, 2008 and 2009 seasons with four trees for each treatment (one replicate = one tree) in a complete randomized block design as follows:

- T1 -Rain fed only (control).
- T2- Irrigation with 60mm (192 L) once/ tree / month.
- T3- Irrigation with 80 mm (256 L) once/ tree / month.
- T4- Irrigation with 100 mm (320 L) once/ tree / month.
- T5- Irrigation with 120 mm (384L) once/ tree / month.
- T6- Irrigation with 30mm (96 L) twice/ tree / month.
- T7- Irrigation with 40 mm (128 L) twice/ tree / month.
- T8- Irrigation with 50 mm (160L) twice/ tree / month.
- T9- Irrigation with 60 mm (192 L) twice/ tree / month.

At the beginning of the experiment, soil analysis of the experimental orchard was carried out as listed in Table 1.

Tree Blooming and Fruiting: Twenty shoots of one year old were selected at random and labeled for every selected tree to determine number of inflorescence/meter. Also, number of flowers / inflorescence was counted and recorded. Samples of 30 panicles from each tree were taken at full bloom. Flowers within each panicle were examined and the number of perfect flowers to the total number of flowers was calculated. Number of set fruitless on the previously tagged shoots was recorded in late May and fruit set percentage was calculated on the basis of the total number of flowers. In addition, final fruit retention was recorded also on each of the previously tagged shoots just before harvesting and the percentage of fruit shedding was calculated on the basis of the number of fruit set. In early September of each season, fruits were picked, weighted in kg to determine yield (kg /tree).

Fruit Properties: The fruits were harvested as soon as they attained maturity indices of the mature stage. Sample consist of 100 fruits which randomly selected from each treated tree to study the effect of different treatment on fruit physical properties i.e. fruit weight (g), fruit dimensions (length and diameter), flesh and stone weight(g). Also, fruit volume (cm^3), moisture content% and flesh thickness (cm) were determined. Chemical properties i.e. fruit oil content, oil acidity % and Saponification number were determined according to A.O.A.C. [10].

Leaf Nutrient Content: At the first week of September of each season, leaf sample (30 leaves) was taken from the middle of non fruiting shoots (one year old) around the periphery of each tree [11], washed and oven dried at 70 ºC until constant weight, then the dry leaves were ground and digested for the different elements determination [12]. Nitrogen was determined by Micro-Kjeldahl method [13], phosphorus was determined by the method of Murphy and Riely [14], potassium was determined by Flame Photometer according to the method of Brown and Lilleland [15], while calcium and magnesium were determined by titration against versenate solution (Na-EDTA) [12] .Iron and manganese were determined by using Atomic Absorption Spectrophotometer (Jarill-Ash850).

Statistical Analysis: The data collected through out course of this study were statically analyzed according to Snedecor and Cochran [16] and LSD test was used for comparison between treatments.

Table 1: Physical and chemical properties of experimental soil site

	Physical properties			Chemical properties						Cations (meq /l)				Anions (meq /l)		
Depth (cm)	Sand %	Clay%	Silt %	SP	pH	EC dS/m	CEC	OM%	$CaCO_3$ %	Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	Cl^-	SO_4^{--}
0-20	45.20	13.33	41.47	0.60	7.6	4.10	7.09	0.64	33.96	0.32	0.30	0.75	0.06	0.22	1.00	0.21
20-50	23.90	24.77	51.33	27.9	7.9	1.56	5.02	0.57	17.82	0.24	0.08	0.16	0.03	0.17	0.27	0.07
50-90	16.30	29.39	54.31	29.8	7.4	10.33	6.71	0.29	13.24	0.47	0.71	1.25	0.04	0.09	2.23	0.15

RESULTS AND DISCUSSION

Tree Blooming and Fruiting: The data concerning tree blooming as a result of the studied treatments, in both 2008 and 2009 seasons, are listed in Table 2. In both seasons, the eight irrigation treatments (T2-T9) significantly increased the number of inflorescences in Manzanillo olive as compared with that of non irrigation treatment (T1) in most cases. Moreover, all irrigation treatments raised the number of flowers comparing with that of the rain fed treatment (control) and the differences were significant in most cases. In the meantime, the number of perfect flower/panicle under the eight irrigation treatments (T2-T9) were markedly increased as compared with that of the control (rain fed only),except T6 (30 mm twice / month) in the second season. These results indicated that irrigation allows the number of inflorescences per meter to increase in olive growing area where rainfall is scarce. Moreover, water availability increases flowering [17-22]. Results agreed with those of Mitchell *et al.* [23]. This might be due to the increase in carbohydrates content during flower differentiation as a result of the irrigation treatments. In view of the present data in both seasons, fruit set percent significantly increased as a result of irrigation treatments in most cases (T2-T9) when compared with that of the control (non irrigated). In the meantime, fruit drop% increased under the rain fed condition only (control) comparing with irrigation treatments and the differences among them were significant in most cases. Likewise, the irrigation treatments (T2-T9) significantly increased the total yield /tree as compared with that of the rain fed only.

It could be concluded that the water stress affected the percentage of fruit drop. Olive tree has been traditionally grown under rain-fed conditions and is considered one of the best adapted species to the semi-arid environment [1], although under these conditions it usually shows a decrease in photosynthesis that limits growth, increase fruit drop and decrease yield [2]. Moreover, the tree might drop some of its fruits to save the growth [24]. These results were in accordance with the findings of Michelakis *et al*. [25], Patumi *et al.* [26] and Aurora *et al*. [27] .They showed that fruit tree productivity was increased with increasing irrigation level.

Fruit Properties

Physical Proprieties: The data concerning fruit physical proprieties of the studied treatments in both 2008 and 2009 seasons are presented in Tables 3 and 4. Fruit weight, fruit volume, fruit length, fruit diameter, flesh thickness, pulp &stone weight, pulp/stone ratio and fruit moisture content during "on" or "off" year under all irrigation treatments were significantly higher than that of the control (rain fed only), while fruit diameter significantly increased under all irrigation treatments comparing with that of the control, except T6 in 2008 and T2 in 2009.The previous results showed that the water stress treatments was not effective to decrease fruit volume and the management practice of water applying was more effective in increasing it and this might be due to that the trees take its time to build up more carbohydrates and then increased the fruit volume [28]. In addition, results were in agreement with those obtained by Moriana *et al.* [4], Patumi *et al.* [26] and Goldhamer [29]. The obtained results indicated that the water stress and the management practices of water application was more effective in increasing the flesh thickness (mm) and the application of irrigation water twice was more effective than the one application (T2) and the control. Similar findings were found by Patumi *et al.* [26], d andria *et al.* [30] and Lavee *et al.* [31]. The present results indicated that the management practice of water application affected

Table 2: Tree blooming and fruiting of Manzanillo olive as affected by supplemental irrigation.

Treatments	Total number of inflorescences per meter		Total number of flowers per panicle		Number of perfect flowers per panicle		Fruit set (%)		Fruit drop (%)		Yield (kg / tree)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
T1	17.34^{f}	21.24^{e}	10.63^{c}	8.25^{c}	12.88^{g}	12.05^{f}	3.48^{g}	3.56^{f}	7.37^{a}	10.00^{a}	21.31^{e}	17.69^{g}
T2	21.08^{f}	24.30^{d}	10.88^{bc}	9.13^{bc}	14.48^{f}	13.23^{e}	3.91^{f}	3.85^{ef}	6.86^{a}	9.28^{ab}	28.38^{de}	19.17^{f}
T3	21.76^{de}	27.18^{c}	11.40^{a}	9.85^{ab}	16.33^{e}	13.63^{ed}	4.37^{e}	4.28^{de}	5.34^{b}	8.10^{c}	41.59^{dc}	20.93^{e}
T4	23.97^{c}	29.50^{b}	11.33^{abc}	9.60^{ab}	17.95^{c}	14.60^{bcd}	5.13^{d}	4.77^{bc}	4.47^{b}	8.10^{c}	52.14^{ab}	24.58^{c}
T5	26.91^{a}	31.90^{a}	12.13^{a}	10.58^{a}	18.78^{b}	15.78^{a}	6.09^{b}	5.10^{b}	4.73^{b}	6.51^{d}	57.12^{a}	26.39^{b}
T6	21.08^{f}	24.48^{d}	11.43^{a}	10.65^{a}	14.58^{f}	10.95^{f}	3.97^{f}	3.91^{ef}	7.36^{a}	8.83^{bc}	34.95^{d}	19.65^{ef}
T7	21.93^{d}	26.10^{c}	10.18^{c}	10.18^{ab}	17.15^{d}	13.88^{cde}	4.71^{e}	4.63^{cd}	5.37^{b}	8.03^{c}	38.19^{d}	22.56^{d}
T8	24.82^{b}	28.80^{b}	11.60^{ab}	10.38^{a}	18.60^{bc}	14.85^{abc}	5.58^{c}	5.22^{b}	4.45^{b}	6.00^{de}	47.12^{bc}	25.91^{b}
T9	25.33^{b}	32.88^{a}	10.68^{bc}	10.55^{a}	19.60^{a}	15.30^{ab}	7.08^{a}	6.29^{a}	4.15^{b}	5.55^{e}	58.59^{a}	27.83^{a}

Means followed by the same letter in each column are not significantly different at P=0.05.

Table 3: Fruit proprieties of Manzanillo olive as affected by supplemental irrigation.

	Fruit weight (g)		Fruit volume (cm^3)		Fruit length (cm)		Fruit diameter (cm)		Flesh thickness (mm)		Stone weight (g)	
Treatments	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
T1	3.42^{e}	3.22^{f}	32.75^{c}	31.00^{e}	1.95^{d}	1.88^{d}	1.38^{f}	1.38^{d}	0.35^{d}	0.38^{f}	1.01^{d}	0.96^{h}
T2	4.06^{d}	4.05^{e}	38.50^{b}	37.75^{d}	2.13^{c}	1.93^{cd}	1.48^{e}	1.45^{cd}	0.41^{c}	0.40^{e}	1.06^{d}	1.04^{g}
T3	4.30^{c}	4.28^{d}	41.50^{a}	41.50^{ab}	2.23^{b}	1.90^{d}	1.65^{cd}	1.53^{c}	0.50^{b}	0.49^{d}	1.29^{c}	1.30^{e}
T4	4.45^{ac}	4.40^{bc}	41.50^{a}	41.25^{ab}	2.30^{ab}	2.10^{b}	1.70^{bc}	1.68^{b}	0.52^{b}	0.53^{c}	1.44^{ab}	1.41^{c}
T5	4.50^{ab}	4.44^{ab}	42.50^{a}	42.00^{ab}	2.28^{ab}	2.13^{b}	1.83^{a}	1.75^{ab}	0.58^{a}	0.59^{a}	1.50^{a}	1.49^{a}
T6	4.00^{d}	4.12^{e}	36.50^{b}	39.00^{cd}	2.13^{c}	1.93^{cd}	1.45^{ef}	1.53^{c}	0.31^{c}	0.40^{ef}	1.07^{d}	1.10^{f}
T7	4.34^{bc}	4.33^{cd}	41.75^{a}	40.50^{bc}	2.23^{b}	2.05^{bc}	1.60^{d}	1.55^{c}	0.52^{b}	0.54^{c}	1.35^{c}	1.34^{d}
T8	4.46^{abc}	4.46^{ab}	42.00^{a}	41.25^{ab}	2.30^{ab}	2.28^{a}	1.65^{cd}	1.73^{ab}	0.61^{a}	0.57^{b}	1.37^{bc}	1.42^{cb}
T9	4.58^{a}	4.49^{a}	43.25^{a}	42.75^{a}	2.33^{a}	2.38^{as}	1.75^{ab}	1.83^{a}	0.60^{a}	0.60^{a}	1.51^{a}	1.46^{ab}

Means followed by the same letter in each column are not significantly different at P=0.05.

Table 4: Fruit proprieties of Manzanillo olive as affected by supplemental irrigation.

	Pulp weight (gm)		Pulp /Stone ratio		Fruit moisture (%)		Fruit oil content (%)		Oil acidity (%)		Saponification number	
Treatments	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
T1	2.42^{b}	2.26^{b}	2.40^{b}	2.36^{c}	57.54^{c}	55.73^{e}	21.53^{a}	21.85^{ab}	0.60^{d}	0.60^{e}	211.48^{ab}	211.80^{g}
T2	3.01^{a}	3.02^{a}	2.85^{a}	292^{a}	60.91^{b}	59.60^{d}	21.50^{a}	21.53^{ab}	0.63^{cd}	0.63^{de}	213.93^{ab}	213.63^{f}
T3	3.01^{a}	2.98^{a}	2.35^{bc}	2.29^{cd}	60.86^{b}	61.58^{c}	21.38^{b}	21.30^{ab}	0.65^{cd}	0.64^{d}	215.38^{ab}	215.48^{e}
T4	3.02^{a}	2.98^{a}	2.11^{d}	2.11^{ef}	63.90^{a}	63.15^{b}	21.25^{cd}	21.00^{ab}	0.79^{a}	0.72^{b}	169.28^{b}	218.38^{d}
T5	3.01^{a}	2.95^{a}	2.02^{d}	1.98^{f}	64.39^{a}	63.70^{ab}	21.23^{cd}	23.00^{a}	0.78^{a}	0.81^{a}	221.25^{a}	222.13^{b}
T6	3.00^{a}	3.02^{a}	2.75^{a}	2.75^{b}	60.44^{b}	59.45^{d}	21.18^{d}	21.75^{ab}	0.64^{cd}	0.63^{de}	215.25^{ab}	214.00^{f}
T7	2.93^{a}	2.99^{a}	2.24^{dbc}	2.22^{ecd}	61.64^{b}	61.65^{c}	21.23^{cd}	21.30^{ab}	0.68^{bc}	0.68^{c}	216.58^{ab}	215.80^{e}
T8	3.09^{a}	3.04^{a}	2.25^{dbc}	2.14^{ed}	64.13^{a}	63.38^{b}	21.28^{c}	21.13^{ab}	0.72^{b}	0.75^{b}	223.90^{a}	220.60^{c}
T9	3.07^{a}	3.04^{a}	2.04^{d}	2.09^{ef}	63.44^{a}	64.40^{a}	21.20^{cd}	20.55^{b}	0.80^{a}	0.81^{a}	225.23^{a}	223.80^{a}

Means followed by the same letter in each column are not significantly different at P=0.05.

Table 5: Leaf nutrient content of Manzanillo olive as affected by supplemental irrigation.

	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Calcium (%)		Magnesium (%)		Manganese (ppm)		Iron (ppm)	
Treatments	2008	2009	2008	2009	2008	2009	2008	2009	2009	2009	2008	2009	2008	2009
T1	1.02^{f}	1.18^{e}	0.13^{g}	0.12^{f}	1.02^{e}	0.93^{e}	1.07^{d}	1.04^{f}	0.14^{a}	0.15^{a}	40.00^{a}	31.25^{a}	88.75^{f}	91.25^{e}
T2	1.24^{f}	1.35^{d}	0.14^{f}	0.14^{ed}	1.14^{d}	1.13^{d}	1.33^{cab}	1.13^{e}	0.13^{b}	0.14^{b}	37.75^{b}	30.75^{ab}	91.00^{e}	92.75^{e}
T3	1.28^{de}	1.51^{c}	0.16^{e}	0.15^{cd}	1.15^{d}	1.20^{c}	1.26^{cdb}	1.31^{d}	0.13^{cb}	0.12^{c}	31.50^{c}	29.75^{cb}	100.75^{d}	95.75^{dc}
T4	1.41^{c}	1.65^{b}	0.18^{dc}	0.16^{cb}	1.17^{c}	1.28^{b}	1.40^{ab}	1.56^{c}	0.12^{dbc}	0.12^{cd}	26.00^{d}	29.25^{c}	117.00^{c}	102.00^{b}
T5	1.61^{a}	1.83^{a}	0.20^{b}	0.16^{ab}	1.19^{b}	1.31^{a}	1.47^{ab}	1.72^{b}	0.11^{d}	0.11^{ed}	20.50^{f}	28.00^{d}	117.50^{bc}	110.25^{a}
T6	1.24^{f}	1.36^{d}	0.13^{fg}	0.14^{d}	1.14^{d}	1.14^{d}	1.12^{cd}	1.14^{e}	0.12^{bc}	0.14^{b}	36.50^{b}	31.00^{a}	92.75^{e}	92.75^{de}
T7	1.29^{d}	1.45^{c}	0.17^{de}	0.15^{cd}	1.16^{c}	1.21^{c}	1.27^{cdb}	1.32^{d}	0.13^{b}	0.12^{c}	29.50^{c}	29.25^{c}	102.50^{d}	96.75^{dc}
T8	1.46^{b}	1.60^{b}	0.19^{bc}	0.16^{ab}	1.18^{b}	1.28^{b}	1.39^{ab}	1.59^{c}	0.12^{dbc}	0.11^{d}	23.00^{e}	27.50^{de}	119.25^{b}	99.00^{bc}
T9	1.49^{b}	1.88^{a}	0.21^{a}	0.17^{a}	1.21^{a}	1.32^{a}	1.52^{a}	1.79^{a}	0.11^{dc}	0.10^{e}	20.25^{f}	26.75^{e}	123.25^{a}	109.75^{a}

Means followed by the same letter in each column are not significantly different at P=0.05.

pulp weight when complementary irrigation distributed during critical stages of fruit growth, particularly during the enlargement of mesocarp cells and increases fruit weight, percent of fruit flesh and overall tree production [3, 17, 32, 33].

Chemical Properties: The data concerning fruit chemical properties as affected by the studied treatments in both 2008 and 2009 seasons are listed in Table 4. In both seasons of the study, oil content % of Manzanillo olive did not show a definite trend as result of all irrigation treatments comparing with that of control. All irrigation treatments (T2-T9) increased fruit acidity percentage of Manzanillo olive cv. comparing with that of the control, while, T2 and T6 in both seasons and T3 in 2008 season did not differ significantly comparing with the control. All irrigation treatments (T2-T9) were significantly higher than that of the control in the second season of the study, but the differences among the studied treatments were not big enough to be significant.

From the present results, some irrigation treatments in both seasons affected the chemical properties content. The present results were in agreement with those reported by Lavee *et al*. [3], Spiegel [34], Vitagliano [35] and Lavee and Wonder [36]. Also, similar results were reported by Patumi *et al*. [37] Arnon *et al*. [38] and Toplu *et al*. [39].They observed that the oleic acid content was greatest with 100% crop evapotranspiration treatment which confirms the previously shown effect of irrigation on the onset of oil accumulation. Also, Patumi *et al.* [26] found that the irrigation barely affected the oil fatty acid ratios or composition.

Leaf Nutrient Content: The data concerning leaf nitrogen, phosphorus and potassium content under the studied irrigation treatments in both 2008 and 2009 seasons are listed in Table (5). From the present results, it could be concluded that leaf nitrogen, phosphorus and potassium content was increased with increasing the rate of irrigation water and the application twice was more effective than once and than the control .This might be due to the diffuse of the irrigation water from the soil to the root tissues. These results are in agreement with those reported by Zahran *et al*. [40]. Indeed, the low potassium assimilation is highly correlated with oil accumulation. Deidda [41] indicated that a sharp reduction of fruit sink strength was induced by the water stress. The treatment (60 mm twice /month) caused the highest values of leaf calcium in both seasons, while, the control treatment caused the lowest and the other treatments did not show definite trend (Table 5). Leaf magnesium and manganese content was increased by the control treatment compared with those of remaining irrigation treatments (T2-T9) and the differences among the other treatments were not big enough to be significant in most cases for their effect on leaf magnesium. In both season, leaves from T9 (60 mm twice/ month) contained the highest values of iron and those of T1 (control) and T2 (60 mm once/ month) contained the lowest ones,while the other remaining irrigation treatments were in between with significant differences in some cases(Table 5). These results are in agreement with those obtained by Ahmed [42], Soliman [43] and Celano *et al*. [44], they reported that the total amount of mineral elements was increased in the irrigated olive plants comparing with non-irrigated ones. In addition, Alegre *et al.* [45] found that water stress reduced net assimilation of leaf.

CONCLUSION

From the present results, it is concluded that irrigation with 60 mm twice/ month during May to September was more effective in increasing the productivity and fruit quality of Manzanillo olive during both the "on" and "off" years, as wall as leaf nutrient content (nitrogen, potassium, calcium and iron) under the conditions of the present study.

REFERENCES

1. Giménez, C., E. Fereres, C. Ruz and F. Orgaz, 1997. Water relations and gas exchange of olive trees: diurnal and seasonal patterns of leaf water potential, photosynthesis and stomatal conductance. Acta Horticulturae, 449: 411-415.
2. Bongi, G. and A. Palliotti, 1994. Olive. In: Shaffer, B. anderson, P.C. (Eds.), Handbook of Environmental Physiology of Fruit Crops: Temperate Crops, vol. I. CRC Press, Boca Raton, FL, USA, pp: 165-187.
3. Lavee, S.N., M. Nashof, M. Woodner and H. Harshemesh, 1990. The effect of complementary irrigation add to old olive trees cv. Souri on fruit characteristics, yield and oil production. Advances in Hort. Sci., 4(3): 135-138.
4. Moriana, A., F. Orgaz, M. Pastor and E. Fereres, 2003. Response of a mature olive orchard to water deficits. J. Amer. Soc. Hort. Sci., 128: 425-431.
5. Carbot, K., 2007. Effect del consume del aceite de olive sobre la composicion de laslipoproteinas de baja densidade en indivı´duos de diferentes paı´ses europeos. Tesis doctoral, Univ. de Barcelona, Espana. CE, 2006. Regulamento (CE) n_ 509/2006 do Conselho. J. Oficial Uniao Eur. [Off. J. Eur. Union].
6. Agricultural Statistics, 2008. Ministry of Agriculture, part Ð August.
7. Glenn, D.M., 2000. Physiological effects of incomplete root zone wetting on plant growth and their implications for irrigation management. Hort Sci., 35: 1041-1042.

8. Kang, S., G. Hu Xiaotao and J.P. Ian, 2002. Soil water distribution, water use and yield response to partial root zone drying under a shallow groundwater table in a pear orchard. Scientia Horticulturae, 92: 277-291.
9. Oweis, T. and A. Hachum, 2003. Improving water productivity in the dry areas of West Asia and North Africa. In: Kijne W. J. Barker, R. Molden, D. (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford, UK, pp: 179-197.
10. A.O.A.C. 1995. Association of Official Agriculture Chemists. Official and Methods of Analysis. The A.O.A.C. 15th. Washington, D.C. U.S.A.
11. Jones, Jr. and J. Benton, 1994. Plant Nutrition Manual. PP. 2.3, 2.6, 2.9 and 2. 11. Micro-Macro Publishing. Inc. 183 Paradise Blvd. Athens. GA. USA.
12. Chapman, H.D. and P.E. Pratt, 1961. Methods of Analysis for Soil, Plant and Water. Davis Agric. Sci. Pull Office Calif. Univ., pp: 220-308.
13. Pregl, F., 1945. Quantitative Organic Micro Analysis. 4th Ed. J.A. Churchill Ltd. London
14. Murphy, J. and J.P. Riely, 1962. A modified single solution method for the determination of phosphorus in natural water. Anal. Chem. Acta. 27: 31-38.
15. Brown, J.D. and D. Lilleland, 1946. Rapid determination of potassium and sodium in plant material and soil extract by flame photometer. Proc. Am. Soc. Hort. Sci., 48: 341-346.
16. Snedecor, G.W. and W.G. Cochran, 1990. Statistical Methods. 7th Edition, the Iowa State Univ. Press. Ames. Iowa, USA, pp: 593 .
17. Barratta, B., T. Caruso, L. Di Marco and P. Inglese, 1986. Effect of irrigation on characteristics of olives in Nocellara del Belice variety. Olea, 17: 195-198.
18. Michelakis, N., 1990. Yield response of table and oil olive varieties to different water use level under drip irrigation. Acta Hort., 286: 271-274.
19. Ozyilmaz, H.and M. Ozkara, 1990. Determination of water consumption of the olive tree under field conditions. Acta Horticulturae, 286: 279-282.
20. Sole Riere, M.A., 1990.The influence of auxiliary drip irrigation, with low quantities of water in olive trees in las Garrigas (cv. Arbequina). Acta Horticulturae, 286: 307-310.
21. Chartzoullakis, K., N. Michelakis and I. Tzompankis, 1992. Effect of water amount and application date on yield and water utilization efficiency of (Koroneiki) olives under drip irrigation. Advanced Hort. Sci., 6(2): 82-84. (Hort. Abst. 63, 5587).
22. Grattan, S.R., M.J. Berenguer, J.H. Connell, V.S. Polito and P.M. Vossen, 2006. Olive oil production as influenced by different quantities of applied water. Agricultural Water Manage., 85: 133 -140.
23. Michelakis, N., E. Vouyoukalou and G.Clapaki, 1995. Plant growth and yield response of olive tree cv. Kalamon for different levels of soil water potential and methods of irrigation. Advance in Horticultural Sci., 9: 136-139.
24. Gomez-Rico, A., M.D. Salvado, A. Moriana, D. Perez, N. Olmedilla, F. Ribas and G. Fregapane, 2005. Influence of different irrigation strategies in a traditional Cornicabra cv. olive orchard on virgin olive oil composition and quality. Food Chemistry, 100: 568-578.
25. Mitchell, P.D., P.D. Jerne and D.J. Shalmers, 1984. The effect of regulated water deficits on pear tree growth, flowering, fruit growth and yield. J. Amer. Soc. Hort. Sci., 109(5): 604-606.
26. Patumi, M., R. D'Andria, V. Marsilio, G. Fontanazza, G. Morelli and B. Lanza, 2002. Olive and olive oil quality after intensive monocone olive growing (*Olea europaea* L. cv. Kalamata) in different irrigation regimes. Food Chem., 77(1): 27-34.
27. Aurora, G.R., A.M. Salvador, B.A. Moriana, D.P. Nicola, F. Ribas and G. Fregapane, 2007. Influence of different irrigation strategies in a traditional Cornicabra cv. olive orchard on virgin olive oil composition and quality. Food Chemistry, 100: 568-578.
28. Faci, J.M., M.J. Berengurer, J.L. Espada and S. Gracia, 2002. Effect of variable water irrigation supply in olive (*Olea europea* L.) cv. Arbequina in Aragon (Spain). I. Fruit and oil. Acta Hort. 586: 341- 344.
29. Goldhamer, D.A., 1999. Regulated deficit irrigation for California olives. Acta Horticulturae, 474: 369-372.
30. D'Andria, R., A. Lavini, G. Morelli, M. Patumi, S. Terenziani, D. Calandrelli and F. Fragnito, 2004. Effects of water regimes on five pickling and double aptitude olive cultivar (*Olea europaea* L.). J. Hort. Sci Biotechnol, 79(1): 18-25.

31. Lavee, S., E. Hanoch, M. Wodner and H. Abramowitch, 2007. The effect of predetermined deficit irrigation on the performance of cv. Muhasan olives (*Olea europaea* L.) in the eastern coastal plain of Israel. Sci. Hort. 112: 156-163.
32. Dettori, S., M.R. Filligheddu and M. Pala, 1990. Influenza del regime idrico su sviluppo e maturazione delle drupe di olivo. Proceedings Problematiche Qualitative dell'olio di Oliva, Sassari, pp: 169-178.
33. Dettori, S. and G. Russo, 1993. Influenza della cultivar e del regime idrico su quantita e qualita dell'olio di oliva. Olivae, 49: 36-43.
34. Spiegel, P., 1955. The water requirement of the olive trees, critical period of moisture stress and the effect of irrigation upon the oil content of its fruits. Proceedings 14th International Horticultural Congress, 2: 1363-1373.
35. Vitagliano, C., 1969. Osservazioni comparative sull'olio prodotto da oliveti intensivi irrigui ed in coltura tradizionale asciutta. Scienza e Tecnica Agraria, 6/7: 169-176.
36. Lavee, S. and M. Wonder, 1991. Factors affecting the nature of oil accumulation in fruit of olive (*Olea europaea* L.) cultivars. J. Horticultural Sci., 66: 583-91.
37. Patumi, M., R. D'Andria, G. Fontanazza, G. Morelli, P. Giorio and G. Sorrentino, 1999. Yield and oil quality of intensively trained trees of three cultivars of olive (*Olea europaea* L.) under different irrigation regimes. J. Hort. Sci. Biotechnol, 74: 729-737.
38. Arnon, D., B.G. Alon, Y. Uri, B. Loai, N. Yogev and K. Zohar, 2008. The effect of irrigation level and harvest mechanization on virgin olive oil quality in a traditional rain-fed `Souri' olive orchard converted to irrigation. J. the Science of Food and Agriculture, 88(9): 1524-1528.
39. Toplu, C., D. Onder, S. Onder and E. Yıldız, 2009. Determination of fruit and oil characteristics of olive (*Olea europaea* L. cv. 'Gemlik') in different irrigation and fertilization regimes. African J. Agricultural Res., 4(7): 649-658.
40. Zahran A.M., A. I. Resk and A. M. Eissa, 1987. Effect of irrigation and non-irrigation on leaf mineral composition and yield of olive cultivars. Ann. Agric. Sci., 32(1): 591-600.
41. Deidda, P., 1968. Osservazioni sull'accrescimento delle drupe nell'olivo: variazioni di alcuni macroelementi nelle foglie e nei frutti ed andamento dell'inolizione. Studi Sassaresi, Sez. III Annali della Facolta di Agraria dell' Universita di Sassari, 16: 1-15.
42. Ahmed, B.R., 1990. Physiological studies on drought resistance of Fig transplants. PhD Thesis, Fac. of Agric. Hort. Dept. Ain Shams Univ. Cairo, Egypt.
43. Soliman, S.S., 1992. Effect of certain soil moisture levels on some physiological responses of manfalouty pomegranate trees. MSc. Thesis, Fac. of Agric. Hort. Dept. Assuit Univ. Egypt.
44. Celano, G.B., Dichio, G. Montanaro, V. Nuzzo, A.M. Palese and C. X Iloyannis, 1999. Distribution of dry matter and amount of mineral elements in irrigated and non-irrigated olive trees. Acta Hort. 474: 381.
45. Alegre, S., J. Marsal, A. Arbones, J. Girona and M.J. Tovar, 2002. Regulated deficit irrigation in olive trees *(Olea europaea* L. cv. Arbequina) for oil production. Acta Horticulturae, 586: 259-261.