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Effect of Deficit Irrigation Regimes and Rice Straw Mulching on Growth and Yield of Olive Trees (*Olea europaea* L.) in Sandy Soil

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ABSTRACT

Field experiment was conducted and located at desert road . Adult and similar olive trees,10 years old during the two growing seasons of 2014 and 2015. Two olive cultivars, Manzanello and Maraki were selected to investigate the effect of irrigation regimes sue has 100% (4384 m^3/feddan), 85% (3892 m^3/feddan) and 70 % (3398 m^3/feddan) which applied after full bloom stage started first of May in both growing seasons–one of most sensitive stage of olive trees –as well as the effect of rice straw mulching treatments. Water scarcity problem is globally getting worse. The vast of majority of annual water supply in Egypt is used for irrigation. So, water saving and conservation is essential object to support agricultural sector especially in the new reclaimed land. The experiment was designed in a split– split plot with three replicates. Data revealed that using 70 % irrigation regimes combined with mulching treatment enhanced vegetative growth characteristics, i.e., shoot length, number of leaves/shoot, leaf area as well as flowering characteristics, i.e., as number of flowers per inflorescence, perfect flowers, sex ratio, number of male flowers, number of female flowers, and flowering density and fruit yield. Minerals as N, P and K in olive leaves were the highest by 70% level combined with rice straw mulching 85 % irrigation level enhanced fruit quality as well as fruit oil content for both cultivars. Water use efficiency (WUE) was increased by decreasing amount of applied water. Highest value of WUE was obtained by using 70% irrigation level. Oil content of fruit in Maraki was higher than Manzanillo such differences were due to their heritability. Economic evaluation of net income recommended using 70% of irrigation regime with rice mulching.

keywords: Olive orchard - Deficit irrigation - Evapotranspiration - Water use efficiency- Oil content- Economic evaluation.

INTRODUCTION

Olive tree (*Olea europaea* L.) is a medium-sized evergreen tree that grows and fruits well under the Mediterranean climate (Haggag *et al*., 2013). The cultivated area of olive in Egypt has increased and reached to 240458 feddan and the fruits production was 541790 tons (EAS, MALR, 2014). Researchers found that mulched trees grew 67% better than those grown on bare soil; many others have shown similar improvements in growth of trees. In addition, the best mulches for overall plant performance are organic materials (Chalker-Scott, 2007).

Olive tree is one of the least damaged plants from drought; it can protect itself by activating internal defense mechanisms against drought stress (Tangu, 2014). Sebastiani *et al.,* (2012) found that irrigation levels significantly modified irrigation plant physiological conditions, vegetative growth and N content of leaves of the two studied olive cultivars. Olive tree is a drought tolerant species withstanding prolonged dry periods using physiological and morphological mechanisms of resistance to water stress (Sebastiani *et al.,* 2012). Temperature has significant effect on potential evapotranspiration and correlated significantly with evapotranspiration (Edoga and Suzzy, 2008). The study of crop water relations is increasingly based on plant response to combinations of soil moisture and atmospheric evaporative demand (Andria *et al.,* 2008). Andria *et al.,* (2002) also found that production and fresh fruit quality of olive trees were positively affected by irrigation level, but a water amount exceeding 66% of ETc did not enhance yield. Oil content and fatty acid composition did not show variations as a consequence of water regime. Soil moisture is important for fruit development, productivity, and oil quality (Gucci *et al.,* 2011). Deficit irrigation starting from the onset of fruit production is sustainable, allowing substantial saving of water in olive orchards (Caruso *et al*., 2011). Fernandes-Silva *et al.,* (2010) mentioned that Irrigation increased fruit yield, due to the greater number of fruits per tree and higher mass per fruit. In addition, differences in oil yield among treatments were closely related to fruit yield. The reduction of water supply for olive trees led to increase oil content and enhanced some of oil quality properties. Yield and yield components (fruit weight, stone weight, humidity and oil content) were not affected by regular deficit irrigation (RDI) treatments (Puertas *et al.,* 2011)

Oil content of fruit was significantly higher in deficit irrigation treated fruit, while no other differences were observed on fruit quality. Yield was 9.6 t/ha, without difference related to irrigation treatments (Rinaldi *et al.,* 2011).

It has been suggested that reducing irrigation for olive trees may improve the percentage of oil extracted and water use efficiency. (Puertas *et al.,* 2011)

Rice straw is used as an organic mulch to regulate the hydrothermal regime of the soil. It is also used for moisture conservation, soil temperature moderation and weed suppression (Khan *et al*., 2002). So, Vivaldi *et al*., (2013) studied the effect of irrigation on two olive cultivars. The results highlighted some varietal differences, Arbequina showed a better response to irrigation, while Coratina performed a higher water use efficiency. The application of organic mulches as a soil cover is effective in improving the quality of soil, decreasing weed density and increasing crop yield, especially in organic farming (Sinkeviciene *et al.,* 2009). Patil *et al*. (2013) mentioned that mulching is a soil and water conservation practice as well as weed management, this practice helps to retain soil moisture, prevents weed growth and enhances soil structure. They also obtained that Paddy straw are the commonest mulching materials used for fruit and vegetable production. Mulching is considered as the most important agricultural practice as it plays an essential role in soil moisture conservation (Taparauskiene and Miseckaite, 2013).

The aim of this study is to investigate the effect of different irrigation water regimes at full bloom stage, which is the most sensitive stage of olive tree to irrigation to the end of the season, and rice straw mulching on the production of two olive cultivars, Manzanello and Maraki, which cultivated in sandy soil.

MATERIALS AND METHODS

1-Experimental Site:

This field experiment was conducted in a private farm located at 64th km Cairo-Alexandria desert road on adult olive (*Olea europaea* L.) trees, 10 years old during the two growing seasons of 2014 and 2015. Two olive cultivars, Manzanillo and Maraki, were grown under drip irrigation system. The trees were cultivated 6 x 3 m apart (almost 233 tree /feddan). Irrigation source of this farm is the ground water from deep well (4500 ppm). The trees were received the standard horticultural management applications according to VERCON (2002). The selected trees were proper healthy, uniform and regular 72 bearing olive trees, distributed on six rows and each row was contained 12 trees (6 trees for each cultivar) were used in this study.

2-Climatic Data:

The daily means of air temperature (maximum and minimum) and relative humidity (maximum and minimum) were recorded by using data logger Model SK-L200THIIα. Measured climatic data are illustrated in Figures 1 and 2. Other climatic factors (wind speed, precipitation, solar radiation and dew point) were collected from nearest automated weather station which located 5 km away of experimental farm. The measured and collected climatic data were used to estimate reference evapotranspiration (ETo). The reference evapotranspiration (ETo) was estimated using Food and Agricultural Organization (FAO) Penman-Monteith (PM) method, FAO 56 presented by Allen *et al.,* (1998).

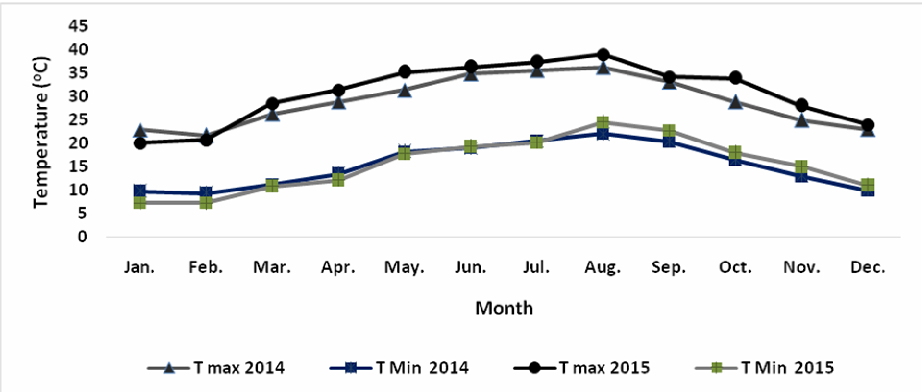

Figure 1. The maximum and minimum air temperature in the experimental site during 2014 and 2015 growing seasons.

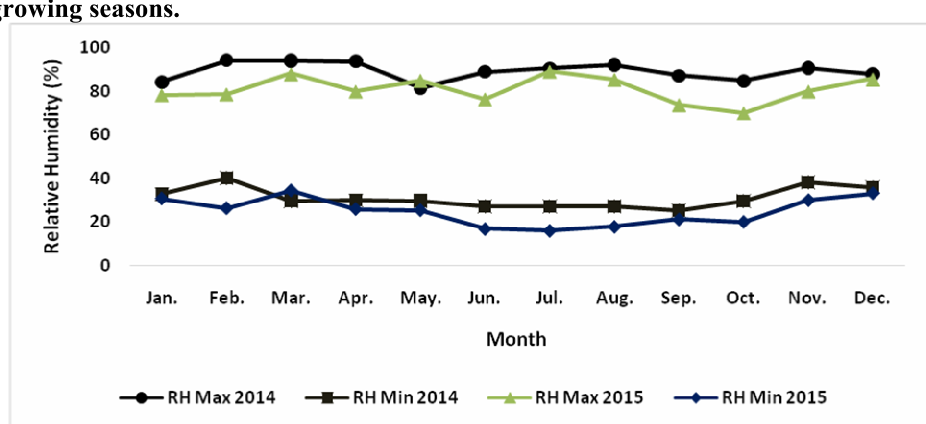

Figure 2. The maximum and minimum relative humidity percentage in the experimental site during 2014 and 2015 growing seasons.

3-Soil and Water Properties:

The soil of experimental site was analyzed two weeks before starting of treatments. The soil texture was loamy sand. Some physical and chemical properties of soil are shown in Tables 1 and 2. The chemical properties of the irrigation water were analyzed two weeks before starting of treatment and shown in Table 3.

Table 1. The physical properties of the experimental soil

Particle size distribution (%) Sand	Silt	Clay	Texture class	Bulk density (g cm^{-3})	Real density (g cm^{-3})	Total porosity (%)	Field Capacity (FC)*	Wilting Point (WP)*	Available Water (AW)*	Water Holding Capacity (WHC)*
84.5	8.50	7.00	Loamy sand	1.49	2.51	40.6	20.9	9.55	11.4	29.4

*** % on dry weight basis**

Table 2. The chemical properties of the experimental soil

OM (%)	pH (1:2.5)	EC (dS m^{-1})	Soluble cations (meq L^{-1}) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Soluble anions (meq L^{-1}) $CO3^{--}$	$HCO3^{--}$	Cl^{-}	$SO4^{--}$	SAR	ESP (%)
0.98	7.63	3.10	9.00	8.00	12.9	1.10	0.00	10.5	18.0	2.50	4.42	4.99

Table 3. The chemical properties of the irrigation water of the experimental site

pH	EC dS / m^{-1} (1:5)	Soluble ions (meq L^{-1}) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{--}$	$HCO3^{-}$	Cl^{-}	$SO4^{--}$	SAR
7.68	4.4	10	8	27.1	0.34	0	2.4	32.5	10.6	9.03

4-Experimental Layout:

The field experiment contained three different factors. The first factor was three irrigation regimes i.e., 100% (4384 m^3/ feddan), 85% (3892 m^3/ feddan) and 70% (3398 m^3/ feddan). The second factor was two cultivars of olive (Manzanillo and Maraki). And the third factor was using rice straw for mulching soul around trees (mulched trees and non-mulched trees) The width of mulch layer was 1 cm and the height was 20 cm .

The different irrigation regimes treatments were started on May in both growing seasons (after the flowering and fruit set growth stage which is the most sensitive stage for irrigation). But the olive trees in our work took the same amount of irrigation water from the first of January until the first of May.

The different irrigation regimes were applied by using a water flow-meter and a valve for each lateral line to control the amount of applied water for different irrigation treatments. The flow-meter was connected with proper fittings to distribute water for the different irrigation regimes. Each irrigation regime treatment has one flow-meter to record the applied water.

The GR drip irrigation lines were applied in sex rows of olive trees ((three rows with straw mulching and three without straw mulching) each row had two GR drip irrigation lines in each irrigation treatment. The distance between each two emitters was 50 cm and the emitter discharge was 4 liter/hr. Each tree has 12 emitters and total discharge was 48 liter/ hr.

Estimation of Irrigation Requirements:

Two steps were followed to estimate the irrigation requirements for olive trees during the both studied seasons; the first step was estimated the evapotranspiration (ETo) by using Penman- Monteith equation, FAO 56 method, presented by Allen *et. al.,* (1998) as follows:

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

Where: ETo is the daily reference evapotranspiration (mm day^{-1}), Rn is the net radiation at the crop surface (MJ m^{-2} day^{-1}), G is the soil heat flux density (MJ m^{-2} day^{-1}), T is the mean daily air temperature at 2 m height (ºC), U_2 is the wind speed at 2 m height (m s^{-1}), e_s is the saturation vapor pressure (kPa), e_a is the actual vapor pressure (kPa), Δ is the slope of vapor pressure curve (kPa $ºC^{-1}$) and γ is the psychometric constant (kPa $ºC^{-1}$). The second step was estimation of irrigation requirements for olive trees by using the following equation according to (Allen *et al.,* 1998) as follows:

IR = (Kc * ETo * (1+LF) * IE * R* Area) /1000

Where:

IR = Irrigation requirements (m^3/feddan).

Kc =Crop coefficient [varied from 0.45 to 0.85 according to growth stage]

ETo = Reference Evapotranspiration (mm/day).

LF = Leaching Requirement (assumed 25% from total irrigation water amount).

IE = Irrigation efficiency of the trickle irrigation system (assumed 85%).

R = Reduction factor of trickle irrigation (60-70 % covered area) because of olive is evergreen tree

Area = the irrigated area (m^2).

1000 = to convert from liter to cubic meter.

5- Horticultural measurements:

A-Vegetative growth:

At the end of harvesting season, during the first week of August the following vegetative characteristics were measured:

Shoot characteristics:

In each season of this study five shoots (one year old) were randomly chosen at each direction (north, south, east and west) of each selected sample tree to measure average shoots length (cm), number of leaves per shoot.

Leaf characteristics:

Leaf fresh weight was measured for previous sample. Leaf area (cm^2) was measured also according to (Ahmed and Morsy, 1999) using the following equation

Leaf area (cm^2) = 0.53 (length x width) + 1.66.

B- Flowering characteristics:

Forty flowering shoots (10 shoots in each direction) per tree were chosen regularly every two week from April till the end of early May and the flowering characteristics such as number of flowers per Inflorescence, number of male flowers, number of female flowers, number of perfect flowers and number of Inflorescences per meter were measured. In addition, some flowering relationships were estimated as follows: perfect flowers percentage was calculated by using the following equation Perfect flowers (%) = (number of perfect flowers / total number of flowers) x 100, also flowering density was estimated using the following equation:

Flowering density = (number of Inflorescences x 100)/ Average shoot length (cm).

Ave. No. of flowers per inflor. =(No. of male flowers +No. of female flowers).

Sex ratio: The ratio of perfect flowers to male flowers was calculated for every replicate. (El-Sharony, 2007).

C-Leaf mineral content:

At the first week of August in the both tested seasons, fifty samples of mature leaf were taken from previously labeled non-fruited shoots on each replicate from the upper third of shoot top as recommended by Piper, (1950).

Sample of 200 g of fresh leaves was cleaned and washed well by tap water. Samples were air dried and putted in an electrical furnace at 70°C to reach a constant weight and finally grounded to be used the wet digested solution which should be ready to estimate N, P and K content which were calculated as percentage of dry weight as follows:

The total nitrogen (N) was determined by modified micro-Keyldahl method as described by Pergl, (1945). The phosphorus (P_2O_5) content was determined colorimetrically according to the method described by Murphy and Riely (1962). The potassium (K_2O) content was determined by flame photometer according to Brown and Lilleland, (1946).

D-Fruit set and yield:

Percentage of fruit set: fruit set percentage at two times first after 21 days from full bloom as initial fruit set and the second 60 days after full bloom as final fruit set according to (Mofeed, 2002).

Fruit set (%) =No. of fruits/No. of total flowers x100

F-Fruit quality:

Thirty fruit per each tree were randomly selected in both seasons and used to determine the fruit quality characteristics i.e., average fruit weight (g), average flesh weight (g), average seed weight (g), fruit length (cm) and fruit diameter (cm).

G-Fruit oil content (%):

The oil was extracted from the fruits, which were dried at 105°C by means of Soxhlat fall extraction apparatus; using petroleum ether at 60-80°C boiling points as described by the AOAC (1975).The stones were taken from the selected fruits to determine the stone weight (g).

H-Water Use Efficiency (WUE):

Water use efficiency (WUE) was calculated according to FAO (1982) as follows:

$$\mathbf{WUE = Y\ (kg) / IR\ (m^3)}$$

which is the ratio of crop yield (Y) to the total amount of irrigation water consumption (IR) in the field during the growing season.

Experimental design:

The experiment was designed in a split-split plots arrangement with three replicates. The irrigation regimes treatments allocated in the main plots, rice straw mulching treatments allocated in the sub plots and the olive cultivars allocated in the sub-sub plots.

I- Economic evaluation:

Economic evaluation of olive fruit production was estimated according to Radinovic *et al*., (2004). The cost of production and yield price was calculated depending on farm`s owner information as follows:

- Total return (EGP / feddan) = Total yield (kg) × (price / (Kg) which was three Egyptian pounds (EGP) in 2014 and four EGP in 2015).
- Water cost = Total water quantity × (water price / m^3 which was 0.5 EGP in 2014 and 0.6 in 2015).
- Operation cost (Fertilizers, Laborers, pesticides and others) = 5500 EGP
- Net income = Total return – (water cost + operation cost)

RESULTS AND DISCUSSION

I- Estimated Evapotranspiration (ETo):

The evapotranspiration (ETo) of experimental site was calculated during the both studied seasons by using the collected climatic data (Fig 3). Data cleared that the values of ETo were deferent during the growing season. Values of ETo ranged from 2.80 mm day^{-1} to 8.45 mm day^{-1} depending on the growing month. The lowest values of ETo were recorded during Dec. 2.83 and 2.80 mm day^{-1} in the first and second seasons, respectively. But the highest values of ETo were recorded during Aug. 8.21 and 8.45 mm day^{-1} during the both seasons, respectively. Increasing the ETo values means increasing of water consumption for olive trees to compensate the amount of consumed water. So, the increasing of air temperature led to increasing of evaporation and water consumption of olive trees. These results may be due to that Evapotranspiration is normally computed from the Penman- Monteith equation using weather data. This equation is affected by principal weather parameters such as radiation, air temperature, humidity and wind speed. These results are matched with those of Edoga and Suzzy (2008).

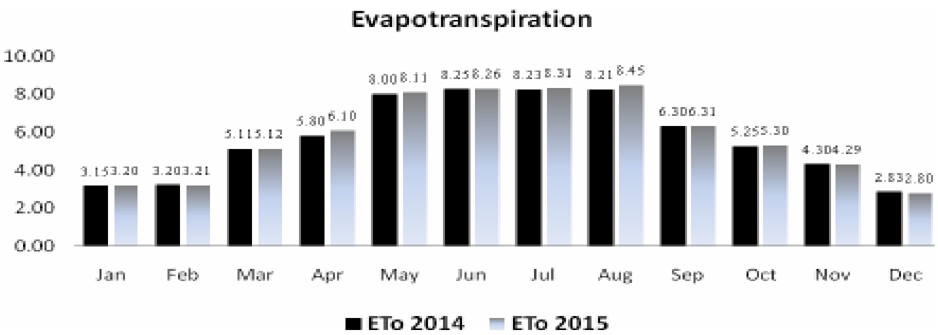

Figure 3. Estimation of Evapotranspiration (ETo) for olive trees at the experimental site during 2014 and 2015 seasons.

II- Estimated and applied irrigation water

Table (4) shows the monthly amount of applied irrigation water. Data illustrated that the applied amount of irrigation water (100% from ETo) was different during the growing season from January to December. The lowest amount of applied water was occurred in Dec., (103 m^3 / feddan). Whereas, the highest amount of applied water occurred in Jul., (585 m^3 / feddan) followed by Aug., (569 m^3 / feddan). Total amount of applied irrigation water of 100% irrigation level was 3908 m^3 / feddan. Actual applied irrigation water is showed in Table (4). It obviously cleared that olive trees of all irrigation regimes treatments i.e., 100%, 85% and 70 % were received the same amount of irrigation water from first of January till first of May in both seasons. The starting of irrigation regime treatments was on first of May up to the end of the growing season (critical stage of olive tree affected by irrigation water). In the same time the period from May till first of January consider the major growing and producing period. The lowest amount of applied water was recorded during Dec., 209, 178 and 147 m^3/feddan for 100%, 85% and 70% irrigation treatments, respectively. Whereas, the highest amount of actual applied water recorded during Jul. and Aug. which were 626, 534 and 441 m^3/feddan for 100%, 85% and 70% irrigation regimes, respectively. The average total amount of applied water both growing seasons was differed among different irrigation treatments which were 4384, 3892 and 3398 m^3/feddan in for 100%, 85% and 70% irrigation regimes, respectively. On the other hand, there was different between estimated and applied irrigation water. For example, when the estimated amount of irrigation at 100% irrigation level was 3908 m^3/feddan, It was 4384 m^3/feddan in 100% of actual applied water treatment, it means that there was much irrigation water than olive tree needs. Besides, the amount of actual applied water in 85% treatment (3892 m^3) is very close from 100% of ETo estimated amount of irrigation water. Obviously, estimating of irrigation requirements for olive trees depending on climatic conditions by Penman Monteith equation is more accurate and water saving than traditional method of on-farm irrigation method, Edoga and Suzzy (2008). These results may be due to the different climatic conditions especially air temperature during different months. So, the increasing of air temperature led to increasing of evaporation and water consumption by olive trees. These results are in agreement with those of Edoga and Suzzy (2008); Farag *et al.,* (2014).

Table 4. Estimated and actual applied irrigation water of olive trees during 2014 and 2015 growing seasons.

Month	Estimated Irrigation Water (m^3/ feddan)			Applied Irrigation Water (m^3/ feddan)		
	2014	2015	Ave.	100% (3.5 h day^{-1})	85% (3 h day^{-1})	70% (2.5 h day^{-1})
Jan.	112	113	113	209	209	209
Feb.	105	106	106	209	209	209
Mar.	249	251	250	313	313	313
Apr.	351	355	353	313	313	313
May (Start)	505	511	508	522	445	368
Jun.	510	516	513	522	445	368
Jul.	572	597	585	626	534	441
Aug.	550	587	569	626	534	441
Sep.	414	418	416	313	267	221
Oct.	266	269	268	313	267	221
Nov.	126	127	127	209	178	147
Dec.	103	103	103	209	178	147
Total	3863	3953	3908	4384	3892	3398

III-a. Vegetative growth:

Date in Table (5) show the effect of different irrigation regimes, mulching, cultivars and their interaction on some vegetative growth of olive trees such as average shoot length (cm), average no. of leaves per shoot and leaf area (cm^2) in both growing seasons.

Regarding the effect of different irrigation regimes, it was shown that irrigation at 70% (3398 m^3/feddan) gave the highest values of shoot length, No. of leaves per shoot and leaf area in both seasons. On the other hand, irrigation at 100% (4384 m^3/feddan) had the lowest values of shoot length and leaf area as well as irrigation at 85% (3892 m^3/feddan) of leaves number per shoot in both seasons.

With respect to type of cultivar, it noticed that Maraki cultivar produced the highest values of leaf area in both seasons and No. of leaves per shoot in the first season only but there was no significant difference between two tested cultivars concern to shoot length in second season.

As regards to mulching treatment, it was noticed that mulched treatment gave the highest values of number of leaves per shoot and leaf area in both growing seasons and shoot length in the second season only but there was no significant difference between type of mulching concern to shoot length in first season.

Concerning the interaction effect among irrigation regime, mulch and olive cultivars, it was showed that irrigation at 70 % of irrigation regime combined with mulching for Maraki cultivar gave the highest values of shoot length and number of leaves per shoot in both growing seasons and leaf area in the second season only but at 85 % of irrigation regime combined with mulching for Maraki cultivar in the first season. In the contrary, irrigation at 100 % of irrigation regime combined with mulching for Maraki cultivar gave the lowest values of shoot length, while irrigation either 85 % or 100% of irrigation regime combined with non-mulching for Manzanillo cultivar gave the lowest No. of leaves per shoot and leaf area (cm^2) in both growing seasons.

The varied trend in vegetative growth parameters of olive trees during both seasons may be resulted from that olive tree is adult (10 years old) so; the root system has been formatted depending on the method of on-farm irrigation process. In addition, the growth of olive tree is slow when it compared with other plants such as vegetables so; its response to change of irrigation regime is also somewhat slow. Besides, olive trees were received the same amount of irrigation water from the beginning of the season till the full bloom stage and the deficit irrigation treatments were started on the first of May. The deference between cultivars may be due genetic and heritability factors. These results are agreed with those of Tangu (2014) Sebastiani *et al.,* (2012).

Table 5. The effect of irrigation regimes, mulching, cultivars and their interactions on average shoot length (cm), average number of leaves per shoot and leaf area (cm^2) of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	Average shoot length (cm)			Average no. of leaves per shoot			Leaf area (cm^2)		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)									
4384 m^3 -100%	M0	17.67cd	15.60e	13.73B	21.33i	28.33d	26.33B	4.65f	4.80ef	4.85B
	M1	13.37fg	8.27h		31.00b	24.67g		4.53f	5.41cd	
3892m^3 -85%	M0	12.17fg	15.90de	14.68B	18.33j	25.33f	24.33C	4.38f	5.54c	5.26A
	M1	19.17bc	11.50g		29.00c	24.67g		4.30f	8.84a	
3398 m^3 -70%	M0	20.12b	14.07ef	18.14A	23.93h	26.00e	27.65A	4.91d-f	5.30c-e	5.27A
	M1	13.44fg	24.94a		28.33d	32.33a		4.55f	6.30b	
Mean(A xB)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	15.52B	15.67B	16.78B	26.17BC	23.67D	26.13BC	4.59D	4.34D	4.73CD
	Mara.	11.94D	13.70C	19.51A	26.50B	25.00CD	29.17A	5.11C	6.19A	5.80B
Mean(A xC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	16.64BC	14.04D	17.10B	24.83C	21.83D	24.97C	4.73C	4.96C	5.10BC
	M1	10.82E	15.34CD	19.19A	27.83B	26.83B	30.33A	4.97C	5.57A	5.43AB
Mean (Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	16.65A	15.19B		21.20C	26.56B		4.65C	5.21B	
	Mara.	15.33B	14.90B		29.44A	27.22B		4.46C	6.18A	
Mean (B)		15.99A	15.05A		25.32B	26.89A		4.55B	5.70A	
Mean (C)		15.92A	15.12A		23.88B	28.33A		4.93B	5.32A	
	Second season (2015)									
4384 m^3 -100%	M0	11.17f	14.33de	13.25C	15.56g	27.67c	23.76B	5.10e	6.08c	5.49B
	M1	16.83c	10.67f		26.67c	25.17d		5.46de	5.32de	
3892m^3 -85%	M0	13.50e	14.72de	14.33B	19.17e	17.17f	21.21C	4.91ef	6.37c	6.12A
	M1	18.83b	10.28f		31.00b	17.50f		5.80cd	7.41ab	
3398 m^3 -70%	M0	19.56b	15.83cd	18.53A	27.00c	24.61d	27.78A	4.45f	7.10b	6.11A
	M1	13.75e	25.00a		26.83c	32.67a		5.04e	7.85a	
Mean(A x B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	14.00C	16.17B	16.66B	21.11D	25.08C	26.92B	5.28D	5.35CD	4.75E
	Mara.	12.50D	12.50D	20.42A	26.42B	17.33E	28.64A	5.70C	6.89B	7.48A
Mean(A x C)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	12.75D	14.11C	17.70B	21.61D	18.17E	25.81B	5.59B	5.64B	5.78B
	M1	13.75CD	14.56C	19.38A	25.92B	24.25C	29.75A	5.39B	6.60A	6.45A
Mean(B x C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	14.74B	14.96B		20.57D	23.15C		4.82D	6.52B	
	Mara.	16.47A	15.32B		28.17A	25.11B		5.43C	6.86A	
Mean (B)		15.61A	15.14A		24.37A	24.13A		5.12B	6.69A	
Mean (C)		14.85B	15.89A		21.86B	26.64A		5.67B	6.15A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

b. Flowering:

Influence of flowering characteristics of olive tree i.e. number of flowers per inflorescence, perfect flowers, flowering density, number of male flowers number, of female flowers and sex ratio to different irrigation regimes, mulching treatments and cultivars are shown in Tables (6 and 7).

Regarding the effect of different irrigation regimes, it was showed that irrigation at 70% (3398 m^3/ feddan) gave the highest values of all flowering characteristics except flowering density in both seasons and sex ratio in the second season. On the other hand, irrigation either 85 % or 100% of irrigation regime had the lowest values of those parameters in both seasons.

With respect to type of cultivar, it noticed that Maraki cultivar produced the highest values of all flowering characteristics in both seasons.

As regards to mulching treatment, it was noticed that mulched treatment gave the highest values of all flowering characteristics but there was no significant difference between two type of mulching concern to perfect flowers, female flowers and sex ratio in the first season.

Concerning the interaction effect among irrigation regime, mulch and olive cultivars, it was showed that irrigation at 70 % of irrigation regime combined with mulching for Maraki cultivar gave the highest values of all flowering characteristics except perfect flowers and sex ratio in second season, male flowers and Flowering density in both seasons, which it was high in Manzanillo cultivar of irrigation70%, 85% with mulch concern to male flowers only. In the contrary, irrigation at 85%, 100% of irrigation regime combined with no-mulching for Manzanillo cultivar gave the lowest values of all flowering characteristics except male flowers in both growing seasons.

These results may be due to that suitable availability of water especially in 85% irrigation regime enhanced the initiation of olive tree flowering because it prevent water stress effects. Besides, straw mulch enhanced flowering characteristics of olive tree because of its positive effects of plant growth and prevents weed growth and its competition on water and nutrients in the soil. The deference between cultivars may be due genetic factors and heritability. These results are matched with those of Andria *et al.,* (2002); Gucci *et al*., and Caruso *et al.,* (2011).

Table 6. The effect of irrigation regimes, mulching, cultivars and their interactions on average No. of flowers per inflor., perfect flowers (%) and flowering density of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	Ave. no. of flowers per inflor.			Perfect flowers (%)			Flowering density		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)									
4384 m^3	M0	13.44g	21.00a	16.95B	58.56e	87.29c	72.16B	76.06j	134.62d	136.23A
-100%	M1	14.99f	18.37c		54.24fg	88.57b		112.12f	222.13a	
3892m^3	M0	10.25h	20.68ab	16.55B	51.41h	90.67a	71.77B	84.22h	130.06e	115.83B
-85%	M1	16.62e	18.67c		55.54f	89.45ab		86.70g	162.35b	
3398 m^3	M0	16.76e	19.57b	18.66A	63.19d	90.44a	74.52A	83.30h	139.09c	109.11C
-70%	M1	17.62d	20.69ab		73.75g	90.72a		131.10e	82.96i	
Mean(Ax B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	14.22D	13.44E	17.19C	56.40D	53.48E	58.47C	94.09E	85.46F	107.20D
	Mara.	19.69B	19.68B	20.13A	87.93B	90.06A	90.58A	178.37A	146.21B	111.02C
Mean(A xC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	17.22CD	15.46E	18.17B	72.92B	71.04C	76.82A	135.34F	107.14E	111.20D
	M1	16.68D	17.64BC	19.16A	71.40C	72.49B	72.23B	167.12A	124.52B	107.03C
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	13.48D	20.42A		57.72B	89.47A		81.19D	134.59B	
	Mara.	16.41C	19.24AB		54.51C	89.58A		109.97C	155.81A	
Mean (B)		14.95B	19.83A		56.11B	89.52A		95.58B	145.20A	
Mean (C)		16.95B	17.83A		73.59A	74.04A		107.89B	132.89A	
	Second season (2015)									
4384 m^3	M0	11.44hi	19.45c	15.43C	55.24ef	94.86a	73.57B	102.42f	135.73c	121.20A
-100%	M1	12.27h	18.54d		52.65f	91.53bc		72.91i	173.76b	
3892m^3	M0	8.00i	20.10b	16.08B	42.38g	92.29b	70.15C	59.26k	136.55c	119.52B
-85%	M1	15.91fg	20.33b		55.94e	90.01c		84.49h	197.76a	
3398 m^3	M0	13.83g	17.42e	17.27A	61.68d	91.91b	77.18A	70.71j	110.04e	96.28C
-70%	M1	16.21f	21.62a		62.62d	92.51b		117.89d	86.48g	
Mean(Ax B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	11.86D	11.96D	15.02C	53.95D	49.16E	62.15C	87.66E	71.88F	94.30D
	Mara.	19.00B	20.22A	19.52B	93.20A	91.15B	92.21AB	154.74B	167.16A	98.26C
Mean(Ax C)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	15.45C	14.05D	15.63C	75.05B	67.33D	76.79A	119.07C	97.90E	90.37F
	M1	15.41C	18.12B	18.92A	72.09C	72.98C	77.56A	123.33B	141.13A	102.19D
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	11.09D	18.99B		53.10D	93.02A		77.46D	127.44B	
	Mara.	14.80C	20.16A		57.07C	91.35B		91.76C	152.67A	
Mean (B)		12.94B	19.58A		55.08B	92.18A		84.61B	140.05A	
Mean (C)		15.04B	17.48A		73.06B	74.21A		102.45B	122.22A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

Table 7. The effect of irrigation regimes, mulching, cultivars and their interactions on no. of male flowers, no. of female flowers and sex ratio of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	No. of male flowers			No. of female flowers			Sex ratio		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)									
4384 m^3	M0	5.57d	2.67f	4.30AB	7.87f	18.33a	12.65B	1.43cd	6.87d	4.31B
-100%	M1	6.86b	2.10g		8.13f	16.27c		1.19d	7.75c	
3892 m^3	M0	4.98e	1.93g	4.07B	5.27g	18.75a	12.49B	1.06d	9.72a	5.12AB
-85%	M1	7.39b	1.97g		9.23e	16.70c		1.25d	8.48b	
3398 m^3	M0	6.17c	1.87g	4.53A	10.59d	17.70b	14.13A	1.72c	9.47a	5.53A
-70%	M1	8.15a	1.92g		9.47e	18.77a		1.16d	9.78a	
Mean(AxB)	CVS (B)	85%	100%	70%	100%	85%	70%	100%	85%	70%
	Manz.	1.95D	2.38C	1.89D	8.00E	7.25F	10.03D	1.31C	1.15C	1.44C
	Mara.	6.19B	6.21B	7.16A	17.30C	17.72B	18.23A	7.31B	9.10A	9.62A
Mean(AxC)	Mulch	85%	100%	70%	100%	85%	70%	100%	85%	70%
	M0	3.46E	4.12CD	4.02D	13.10B	12.01C	14.15A	4.15B	5.39A	5.59A
	M1	4.68AB	4.48BC	5.04A	12.20C	12.96B	14.12A	4.47B	4.86B	5.47A
Mean(BxC)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	2.00C	2.16C		7.91D	8.94C		1.40B	8.68A	
	Mara.	7.47A	5.57B		18.26A	17.24B		1.20B	8.67A	
Mean (B)		6.52A	2.08B		8.43B	17.75A		1.30B	8.67A	
Mean (C)		4.73A	3.86B		13.09A	13.09A		5.04A	4.93A	
	Second season (2015)									
4384 m^3	M0	5.12de	1.00h	3.37B	6.32g	18.45b	12.05B	1.23e	18.45a	7.90A
-100%	M1	5.81bc	1.57f-h		6.46g	16.97c		1.11e	10.81c	
3892 m^3	M0	4.61e	1.55f-h	3.80A	3.39h	18.55b	12.28B	0.74f	11.97b	5.75C
-85%	M1	7.01a	2.03f		8.90f	18.30b		1.27e	9.01d	
3398 m^3	M0	5.30cd	1.41gh	3.60AB	8.53f	16.01d	13.67A	1.61e	11.35b	6.75B
-70%	M1	6.06b	1.62fg		10.15e	20.00a		1.67e	12.35b	
Mean(AxB)	CVS (B)	85%	100%	70%	100%	85%	70%	100%	85%	70%
	Manz.	1.79B	1.28C	1.52BC	6.39D	6.14D	9.34C	1.17D	1.00D	1.64D
	Mara.	5.81A	5.47A	5.68A	17.71B	18.42A	18.00B	14.63A	10.49C	11.85B
Mean(AxC)	Mulch	85%	100%	70%	100%	85%	70%	100%	85%	70%
	M0	3.08D	3.06D	3.36CD	12.39C	10.97E	12.27C	9.84A	6.35B	6.48B
	M1	4.52A	3.69BC	3.84B	11.72D	13.60B	15.08A	5.96C	5.14C	7.01B
Mean(BxC)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	1.74C	1.32D		6.08D	8.50C		1.19C	13.92A	
	Mara.	6.29A	5.01B		17.67B	18.42A		1.35C	10.72B	
Mean (B)		5.65A	1.53B		7.29B	18.05A		1.27B	12.32A	
Mean (C)		4.02A	3.17B		11.88B	13.46A		7.56A	6.04B	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

C . Mineral content:

Date in Table (8) show the effect of different irrigation regimes, mulching, cultivars and their interaction on mineral content of leaves such as N, P and K in both growing seasons.

Regarding the effect of different irrigation regimes, it was showed that irrigation at 70% (3398 m^3/feddan) gave the highest percentage of N, P and K of leaves in both seasons. On the other hand, irrigation at 100% (4384 m^3 / feddan) had the lowest ones of those estimations in both seasons.

With respect to type of cultivar, it noticed that Maraki cultivar produced the highest percentage of N, P and K in both growing seasons but there was no significant difference between two tested cultivars concern to leaf content of nitrogen in the first season.

As regards to mulching treatment, it was noticed that mulched treatment gave the highest percentage of N, P and K in both growing seasons but there was no significant difference between type of mulching concern to leaf content of nitrogen and phosphorus in the first season.

Concerning the interaction effect among irrigation regime, mulch and olive cultivars, it was showed that irrigation at 70 % of irrigation regime combined with mulching for Maraki cultivar gave the percentage of N, P and K in both growing seasons. In the contrary, irrigation at 100 % of irrigation regime combined with non-mulching for Manzanillo cultivar gave the lowest ones of these estimations in both growing seasons.

These results may be due to the suitable availability of irrigation water in the soil which resulted from using 85% of irrigation level led to sufficient amount of nutrient solution in the soil which is available for the root system to absorb and accumulate in the plant leaves. These results are in agreement with those of Sabastiani *et al.,* (2012). Mulching treatment enhanced plant absorption of nutrients from the soil due to its positive effects on plant physiology such as moisture conservation, soil temperature moderation and weed suppression. These results are agreed with those obtained by Khan *et al.,* (2002); Sinkeviciene *et al.,* (2009); Patil *et al.,* (2013).

Table 8. The effect of irrigation regimes, mulching, cultivars and their interactions on N, P and K content (%) of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	N (%)			P (%)			K (%)		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)									
4384 m^3	M0	1.31cd	1.35cd	1.26C	0.180i	0.370cd	0.275C	0.330g	0.690b-d	0.510C
-100%	M1	1.29d	1.08e		0.290g	0.260h		0.540e	0.480f	
3892m^3	M0	1.38c	1.29d	1.35B	0.300g	0.400b	0.344B	0.560e	0.710bc	0.620B
-85%	M1	1.34cd	1.37cd		0.360de	0.317f		0.670cd	0.540e	
3398 m^3	M0	1.36cd	1.48b	1.43A	0.3600de	0.380c	0.398A	0.670cd	0.740b	0.748A
-70%	M1	1.32cd	1.58a		0.350e	0.500a		0.650d	0.930a	
Mean(Ax B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	1.30C	1.36B	1.34BC	0.235E	0.330C	0.355B	0.435E	0.615CD	0.660B
	Mara.	1.22D	1.33BC	1.53A	0.315D	0.358B	0.440A	0.585D	0.625BC	0.835A
Mean (AxC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	1.33B	1.34B	1.42A	0.275D	0.350C	0.370B	0.510D	0.635C	0.705B
	M1	1.19C	1.34B	1.45A	0.275D	0.338C	0.425A	0.510D	0.605C	0.790A
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	1.35AB	1.32B		0.280D	0.333C		0.520C	0.620B	
	Mara.	1.37A	1.34AB		0.383A	0.359AB		0.713A	0.650B	
Mean (B)		1.33A	1.36A		0.307B	0.371A		0.570B	0.682A	
Mean (C)		1.36A	1.33A		0.332B	0.346A		0.617A	0.635A	
	Second season (2015)									
4384 m^3	M0	1.12g	1.54d	1.33C	0.140i	0.370f	0.296C	0.490g	0.650ef	0.620B
-100%	M1	1.26f	1.40e		0.330g	0.343g		0.710cd	0.630f	
3892m^3	M0	1.54d	1.68c	1.65B	0.310h	0.420cd	0.408B	0.760bc	0.740cd	0.733A
-85%	M1	1.54d	1.82b		0.410de	0.490b		0.620f	0.810ab	
3398 m^3	M0	1.40e	1.82b	1.72A	0.430c	0.400e	0.444A	0.710cd	0.690de	0.753A
-70%	M1	1.68c	1.96a		0.430c	0.617a		0.750c	0.860a	
Mean (AxB)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	1.19D	1.54C	1.54C	0.235D	0.360C	0.430B	0.600E	0.690C	0.730B
	Mara.	1.47C	1.75B	1.89A	0.357C	0.455A	0.458A	0.640D	0.775A	0.775A
Mean (AxC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	1.33C	1.61C	1.61C	0.255F	0.365D	0.415C	0.570E	0.750B	0.700CD
	M1	1.33C	1.68C	1.82A	0.337E	0.450B	0.473A	0.670D	0.715BC	0.805A
Mean (BxC)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	1.35C	1.49B		0.293C	0.390B		0.653C	0.693B	
	Mara.	1.68A	1.73A		0.397B	0.450A		0.693B	0.767A	
Mean (B)		1.42B	1.70A		0.342B	0.423A		0.673B	0.730A	
Mean (C)		1.52B	1.61A		0.345B	0.420A		0.673B	0.730A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

D- No. fruits/branch, Fruit set and yield:

Displayed data in Table (9) show the effect of irrigation regimes, mulching, cultivars and their interactions on No. fruits/branch, fruit set and yield in both growing seasons.

Regarding the effect of different irrigation regimes, it was showed that irrigation at 70% (3398 m3 / feddan) gave the highest values of No. fruits/branch, fruit set and yield in both seasons except fruit set in the first season, which it had irrigation at 85% (3892 m^3/feddan). On the other hand, irrigation at 100% (4384

m^3 /feddan) had the lowest ones of those parameters in both seasons.

With respect to type of cultivar, it noticed that Maraki cultivar produced the highest value of fruit yield in both growing seasons and No. fruits/branch in the second season, while Manzanillo cultivar with respect to fruit set in both growing seasons and No. fruits/branch in the first season.

As regards to mulching treatment, it was noticed that mulched treatment gave the highest value of fruit yield, while non- mulched treatment with respect to No. fruits/branch and fruit set in both growing seasons.

Concerning the interaction effect among irrigation regime, mulch and olive cultivars, it was showed that No. fruits/branch and fruit set gave the highest value of irrigation at 85 % of irrigation regime combined with non-mulching for Manzanillo cultivar in the first season, irrigation at 70% of irrigation regime combined with non-mulching for Maraki cultivar in the second season. With respect to yield (kg/tree) had the highest value of irrigation at 70% of irrigation regime combined with mulching for Maraki cultivar in both growing seasons. In the contrary, No. fruits/branch and fruit set gave the lowest value of irrigation at irrigation at 100 % of irrigation regime combined with non-mulching for Manzanillo cultivar of these parameters in both growing seasons except No. fruits/branch in the second season. With respect to yield (kg/tree) had the lowest one of irrigation at 100% of irrigation regime combined with non-mulching for Manzanillo cultivar in both growing seasons.

Irrigation of olive trees by suitable amount of water such as 70% and 85 % levels enhanced the fruit set characteristics as well as fruit yield may be due to availability of water and mineral nutrients in the root zone of plant. Increasing irrigation amount such as 100% level led to leaching mineral nutrients away of root zone distribution. These results are agreed with those of Andria *et al*., (2002); Gucci *et al*., (2011); Caruso *et al*., (2011); Fernandes-Silva *et al*., (2012). They mentioned that production of olive tree was positively affected by irrigation level, but a water amount exceeding 66% of ETo did not enhance yield.

The effect of mulching on fruit set and yield may be due to the positive effects of organic mulches on moisture conservation, soil temperature moderation and weed control. These are in agreement with Khan *et al.,* (2002); Sinkeviciene *et al.,* (2009).

The differences of fruit set and yield between both seasons in olive cultivars may be due to biennial bearing cycles of olive trees and the heritability differences between both cultivars (Vivaldi *et al*., 2013).

Table 9. The effect of irrigation regimes, mulching, cultivars and their interactions on No. of fruits/branch, fruit set % and yield (Kg/tree) of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	No. of fruits/branch			Fruit set (%)			Yield (Kg / tree)		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)									
4384 m^3	M0	5.94de	5.08f	5.59C	44.20c	24.19j	34.32C	12.33j	22.33g	20.33C
-100%	M1	5.88de	5.45ef		39.23e	29.67h		21.00h	25.67e	
3892 m^3	M0	8.57a	6.12cd	6.92B	83.61a	29.59h	46.71B	18.33i	24.00f	24.08B
-85%	M1	6.25cd	6.73c		37.61f	36.05g		27.67d	26.33e	
3398 m^3	M0	7.53b	8.02ab	7.35A	44.93b	40.98d	49.90A	22.33g	30.67c	28.83A
-70%	M1	7.94b	5.89de		45.06b	28.47i		29.33b	33.00a	
Mean(AxB)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	5.91D	7.41A	7.74A	41.71C	60.61A	45.00B	16.67F	23.00E	25.83B
	Mara.	5.27E	6.42C	6.96B	26.93F	32.82E	34.72D	24.00D	25.17C	31.84A
Mean(AxC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	5.51E	7.35B	7.78A	34.19D	56.60A	42.95B	17.33F	21.17E	26.50B
	M1	5.67E	6.49D	6.92C	34.45D	36.83C	36.77C	23.33D	27.00C	31.17A
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	7.35A	6.41B		57.58A	31.59C		17.66C	25.67B	
	Mara.	6.69B	6.02C		40.63B	31.39C		26.00B	28.33A	
Mean (B)		7.02A	6.22B		49.10A	31.49B		21.83B	27.00A	
Mean (C)		6.88A	6.36B		44.58A	36.01B		21.67B	27.17A	
	Second season (2015)									
4384 m^3	M0	2.52gh	2.67gh	2.75C	22.03e	13.73i	18.43C	2.67i	8.33f	5.63C
-100%	M1	2.38h	3.44ef		19.40g	18.55g		2.50i	9.00f	
3892 m^3	M0	3.09fg	4.10cd	3.82B	38.63b	20.40fg	25.97B	4.00h	16.33d	12.63B
-85%	M1	3.79c-e	4.28c		23.82d	21.05f		15.00e	15.20e	
3398 m^3	M0	5.34b	7.67a	5.25A	38.61b	44.03a	31.60A	6.00g	20.00b	17.75A
-70%	M1	4.43c	3.55d-f		27.33c	16.42h		17.67c	27.33a	
Mean(AxB)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	2.45E	3.44D	4.89B	20.71D	31.22B	32.97A	2.58F	9.50D	11.84C
	Mara.	3.06D	4.19C	5.61A	16.14E	20.73D	30.22C	8.67E	15.77B	23.67A
Mean(AxC)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	2.59C	3.60B	6.50A	17.88E	29.51B	41.32A	5.50E	10.17D	13.00C
	M1	2.91C	4.04B	3.99B	19.98D	22.44C	21.87C	5.75E	15.10B	22.50A
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	3.65B	4.81A		33.09A	26.05B		4.22D	14.89B	
	Mara.	3.53B	3.76B		23.52C	18.68D		11.72C	17.18A	
Mean (B)		3.59B	4.29A		28.30A	22.36B		7.97B	16.03A	
Mean (C)		4.23A	3.65B		29.57A	21.10B		9.56B	14.45A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.

I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

E. Fruit quality:

Recorded data in Table (10 & 11) show the effect of irrigation regimes, mulching, cultivars and their interactions on some fruit characteristics such as average fruit weight, average flesh weight and average seed weight, fruit length, fruit diameter of olive fruits.

Concerning the effect of irrigation regimes, using 85% irrigation regime gave the highest values of previous fruit characteristics in the both seasons except fruit length in the second season followed by irrigation at 70% whereas, the irrigated trees by 100% level gave the lowest values of these parameters in the both seasons.

Regarding cultivars, Maraki was better than Manzanillo in average fruit weight and average seed weight in the both seasons, and average flesh weight fruit length, fruit diameter in the first season only. But there was no significant difference between two tested cultivars in the second season.

Obviously, data show that mulched treatment was better than non-mulched treatment and gave the highest values of these parameters.

The interaction among the three factors of study had significant differences. The combining among 85% irrigation regime, mulched treatment for Maraki cultivar gave the highest values of previous fruit characteristics in both growing seasons except fruit length in the second season followed by irrigation at 70%, mulched treatment for Maraki cultivar. Whereas, 100% irrigation regime combined with either non-mulched or mulched treatment for Manzanillo cultivar gave the lowest values of these ones in both growing seasons.

The supreme effect of irrigation on fruit quality such as fruit weight, flesh weight and stone weight may be due to the enhancement effect of water on tree growth without suffered stress and that encouraged root system absorption of nutrients and available water which led to increase photosynthesis rate as well as fruit weight. These are matched with findings of Fernandes-Silva *et al*., (2010); Puerta *et al*., (2011). The increments of fruit quality characteristics may be due to the role of straw mulch in prevent water evaporation from the soil, modified soil temperature and reduce the weed growth. The same findings were obtained by Khan *et al.,* (2002); Chalker-Scott, (2007); Sinkeviciene *et al.,* (2009); (Patil *et al.,* Taparauskiene and Miseckaite, 2013).

Table 10. The effect of irrigation regimes, mulching, cultivars and their interactions on average fruit weight (g), average flesh weight (g) and average seed weight (g) of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	Average fruit weight (g)			Average flesh weight (g)			Average seed weight (g)		
		Manzanillo	**Maraki**	**Mean (A)**	**Manzanillo**	**Maraki**	**Mean (A)**	**Manzanillo**	**Maraki**	**Mean (A)**
	First season (2014)									
4384 m^3	M0	3.79f	3.98ef	4.27C	3.15f	3.16f	3.53C	0.64e	0.82c	0.73B
-100%	M1	3.93ef	5.36c		3.38ef	4.44c		0.55f	0.92b	
3892m^3	M0	4.06ef	5.28c	5.32A	3.40ef	4.35c	4.47A	0.66de	0.93b	0.86A
-85%	M1	4.50d	7.44a		3.78d	6.33a		0.72de	1.11a	
3398 m^3	M0	4.50d	4.14d-f	4.71B	3.77d	3.23f	3.87B	0.74d	0.91b	0.84A
-70%	M1	4.28de	5.92b		3.64de	4.83b		0.64e	1.09a	
Mean(Ax B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	3.86E	4.28D	4.39D	3.26E	3.59D	3.70CD	0.60D	0.69C	0.69C
	Mara.	4.67C	6.36A	5.03B	3.80C	5.34A	4.03B	0.87B	1.02A	1.00A
Mean(Ax C)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	3.89E	4.67C	4.32D	3.16E	3.87C	3.50D	0.73D	0.80C	0.82BC
	M1	4.65C	5.97A	5.10B	3.91C	5.06A	4.23B	0.74D	0.92A	0.87AB
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	4.12C	4.23C		3.44B	3.60B		0.68C	0.64C	
	Mara.	4.47B	6.24A		3.58B	5.20A		0.89B	1.04A	
Mean (B)		4.17B	5.36A		3.52B	4.39A		0.66B	0.97A	
Mean (C)		4.29B	5.24A		3.51B	4.40A		0.78B	0.84A	
	Second season (2015)									
4384 m^3	M0	5.22f	4.83g	4.97C	4.50f	3.77g	4.09C	0.71f	1.07c	0.88C
-100%	M1	5.22f	4.60g		4.52f	3.57g		0.70f	1.03c	
3892m^3	M0	5.70de	6.07c	6.43A	4.83de	4.90c-e	5.39A	0.87d	1.17b	1.04A
-85%	M1	5.90cd	8.05a		5.07cd	6.77a		0.83d	1.28a	
3398 m^3	M0	5.42ef	5.58de	6.07B	4.65ef	4.45f	5.06B	0.77e	1.13b	1.00B
-70%	M1	6.03c	7.23b		5.18c	5.97b		0.85d	1.27a	
Mean(Ax B)	CVS (B)	100%	85%	70%	100%	85%	70%	100%	85%	70%
	Manz.	5.22D	5.80C	5.73C	4.51D	4.95C	4.92C	0.71E	0.85C	0.81D
	Mara.	4.72E	7.06A	6.41B	3.67E	5.83A	5.21B	1.05B	1.23A	1.20A
Mean(Ax C)	Mulch	100%	85%	70%	100%	85%	70%	100%	85%	70%
	M0	5.03E	5.88C	5.50D	4.14E	4.87C	4.55D	0.89D	1.02B	0.95c
	M1	4.91E	6.98A	6.63B	4.04E	5.92A	5.58B	0.87D	1.06	1.06A
Mean(Bx C)	CVS (B)	M0	M1		M0	M1		M0	M1	
	Manz.	5.44C	5.72B		4.66C	4.92B		0.78C	0.79C	
	Mara.	5.49C	6.63A		4.37D	5.43A		1.12B	1.19A	
Mean (B)		5.58B	6.07A		4.79A	4.90A		0.79B	1.16A	
Mean (C)		547B	6.17A		4.52B	5.18A		0.95B	0.99A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

Table 11. The effect of irrigation regimes, mulching, cultivars and their interactions on average Fruit length (cm), Fruit diameter (cm) of olive trees during 2014 and 2015 growing seasons.

I.R. (A)	Mulch (C)	Fruit length (cm)			Fruit diameter (cm)		
		Manzanillo	Maraki	Mean (A)	Manzanillo	Maraki	Mean (A)
	First season (2014)						
4384 m³	M0	2.14e	2.36c	2.32C	1.78de	1.81de	1.87B
-100%	M1	2.15e	2.63b		1.81de	2.05b	
3892m³	M0	2.23de	2.54b	2.47A	1.81de	1.90cd	1.95A
-85%	M1	2.33cd	2.78a		1.91cd	2.18a	
3398 m³	M0	2.31cd	2.36c	2.40B	1.84de	1.75e	1.86B
-70%	M1	2.31cd	3.62b		1.84de	2.00bc	
Mean (A x B)	CVS (B)	100%	85%	70%	100%	85%	70%
	Manz.	2.15D	2.28C	2.31C	1.80C	1.86BC	1.84C
	Mara.	2.49B	2.66A	2.49B	1.93B	2.04A	1.88BC
Mean (A x C)	Mulch	100%	85%	70%	100%	85%	70%
	M0	2.25D	2.39BC	2.33CD	1.80C	1.86BC	1.80C
	M1	2.39C	2.56A	2.46B	1.93B	2.05A	1.92B
Mean (B x C)	CVS (B)	M0	M1		M0	M1	
	Manz.	2.23C	2.26C		1.81B	1.86B	
	Mara.	2.42B	2.68A		1.82B	2.08A	
Mean (B)		2.25B	2.55A		1.83B	1.95A	
Mean (C)		2.32B	2.47A		1.82B	1.97A	
	Second season (2015)						
4384 m³	M0	2.41de	2.40de	2.41C	1.91cd	1.83d	1.92B
-100%	M1	2.45cd	2.49b-d		1.93c	2.01bc	
3892m³	M0	2.53bc	2.53bc	2.52B	1.98bc	1.83d	2.03A
-85%	M1	2.54bc	2.71a		2.04b	2.26a	
3398 m³	M0	2.59b	2.33e	2.65A	1.97bc	1.92cd	2.04A
-70%	M1	2.58b	2.77a		2.06b	2.20a	
Mean (A x B)	CVS (B)	100%	85%	70%	100%	85%	70%
	Manz.	2.43C	2.54B	2.59AB	1.92B	2.01A	2.01A
	Mara.	2.45C	2.62A	2.55AB	1.92B	2.04A	2.06A
Mean (A x C)	Mulch	100%	85%	70%	100%	85%	70%
	M0	2.41C	2.53B	2.46BC	1.87C	1.91BC	1.95B
	M1	2.47BC	2.63A	2.67A	1.97B	2.15A	2.13A
Mean (B x C)	CVS (B)	M0	M1		M0	M1	
	Manz.	2.51B	2.52B		1.95C	2.01B	
	Mara.	2.42C	2.66A		1.86D	2.16A	
Mean (B)		2.52A	2.54A		1.98A	2.01A	
Mean (C)		2.47B	2.59A		1.91B	2.08A	

Values of specific or interaction effect followed by the same capital and small letters are not significantly different at 5% level.
I.R. (A) = irrigation regimes, Mulching = (B) olive cultivars (Manzanillo and Maraki) (C) = M0 = non-mulched M1 = mulched,

F. Fruit oil content (%):

The effect of different irrigation regimes, mulching, cultivars and their interactions on the oil content (%) of olive fruit are shown in Figure (4).

Generally, applying irrigation water at the rate of 70% enhanced the oil formation in both cultivars. In the contrary, the application of 85% and 100% irrigation level led to decrease the oil content of fruits.

Non-mulched treatment produced a high oil content fruits compared with mulched treatment in both growing seasons.

The fruit of Maraki has higher content of oil than fruit of Manzanillo in both growing seasons.

Data obviously cleared that applied irrigation water at the rate of 70% at non-mulched treatment led to increase the oil content (%) of Maraki which were 29.69 and 28.28 % in the first and second season, respectively.

These results may be due to that decreasing irrigation water amount led to increase the oil concentration in fruit so; the deficit irrigation regime (70%) gave the highest oil content in fruit for both cultivars. These results matched with those of Gucci *et al.*; Rinaldi *et al.*, and Puertas *et al.*, (2011)

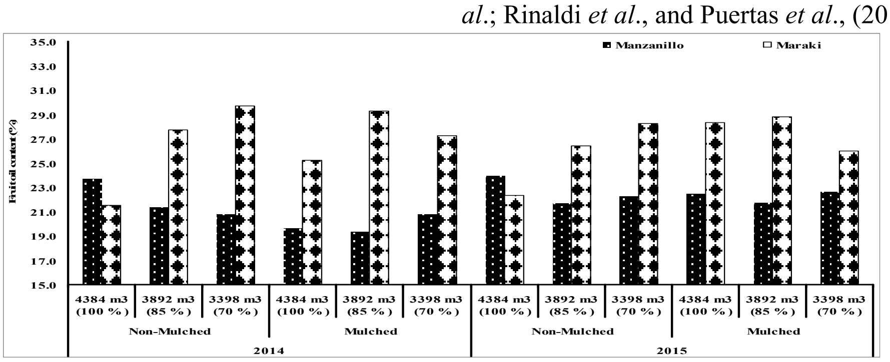

Figure 4. Effect of irrigation regimes, mulching and cultivars on oil content (%) of olive fruit during 2014 and 2015 growing seasons.

G .Water use efficiency (WUE):

The effect of different irrigation regimes, mulching, cultivars and their interactions on water use efficiency (WUE) (Kg / m^3) of olive trees are presented in Figure (5).

Data cleared that the WUE affected by irrigation amount. Whenever irrigation amount increased WUE decreased. So, the highest values of WUE obtained by using 70% irrigation regime in both growing seasons. In the contrary, applied water at 100% level led to lowest values of WUE.

The difference between olive cultivars in WUE values was observed in both growing seasons. Maraki cultivar recorded the highest WUE values as compared to Manzanillo cultivar.

Concerning mulching treatment, using of straw mulch had the highest of WUE of olive trees as compared to non-mulched trees.

The highest values of WUE for Maraki and Manzanillo were 2.81 and 2.70 (Kg / m^3) in the first season and 2.22 and 1.21 (Kg / m^3) in the second season, respectively is resulting from using 70% of irrigation level combined with mulched treatment.

These results due to that water use efficiency is a ratio between plant production and the amount of water which the plant has consumed so, the increasing of water amount led to decrease the value of water use efficiency. These are in agreement with those of Puertas *et al*., (2011) and Vivaldi *et al*., (2013).

H. Economic evaluation:

Data in Table (12) display the economic evaluation of total fruits yield (Kg / feddan) of olive cultivars (Manzanillo and Maraki) and net return in Egyptian pounds. The price of Kilogram of olive fruits was three EGP in 2014 and four EGP in 2015. The price of irrigation water was 0.5 and 0.6 EGP per m3 in 2014 and 2015, respectively.

In light of farm`s owner information the total operation cost such as water, fertilizers, labor, pesticides and others were calculated.

The maximum net income resulted from using the irrigation amount of 70% (3398 m^3 / feddan) combined with mulched treatment for Manzanillo and Maraki in both growing seasons. On the contrary, the lowest value of net income resulted from Appling the irrigation at the rate of 100% (4384 m^3), under non-mulching treatment.

Data cleared that irrigation played an important role of olive production income whereas rice straw mulching had an effect on the rate of economic. So, we can recommend with applying irrigation water in rate of 70% (3398 m^3/feddan) to get the highest economic return.

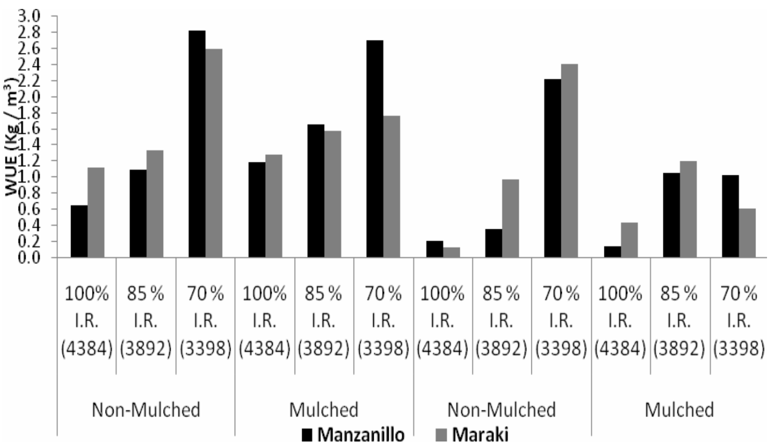

Figure 5. Effect of irrigation regimes, mulching and cultivars on water use efficiency (WUE) of olive trees during 2014 and 2015 growing seasons.

Table 12. Economic evaluation of olive fruits production of Manzanillo and Maraki cultivars under different irrigation regimes and rice straw mulching.

I.R.	Mulch	Cvs.	Yield (Kg/feddan)		Yield price (EGP/feddan		Water price (EGP/feddan)		Total cost (EGP)		Net income (EGP)	
			2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
4384 m^3 -100%	M0	Manza.	2873	622	8619	2488	2192	2630	7692	8130	927	-5642
		Maraki	5203	1941	15619	7764	2192	2630	7692	8130	7927	-366
	M1	Manza.	4893	5825	14679	23300	2192	2630	7692	8130	6987	15170
		Maraki	5981	2097	17943	8388	2192	2630	7692	8130	10251	258
3892 m^3 -85%	M0	Manza.	4271	932	12813	3728	1946	2335	7446	7835	5367	-4107
		Maraki	5592	3805	16776	15220	1946	2335	7446	7835	9330	7385
	M1	Manza.	6447	3495	19341	13980	1946	2335	7446	7835	11895	6145
		Maraki	6135	3542	18405	14168	1946	2335	7446	7835	10959	6333
3398 m^3 -70%	M0	Manza.	5203	1398	15609	5592	1699	2039	7199	7539	8410	-1947
		Maraki	7146	4660	21438	18640	1699	2039	7199	7539	14239	11101
	M1	Manza.	6834	4117	20502	16468	1699	2039	7199	7539	13303	8929
		Maraki	7689	6368	23067	25472	1699	2039	7199	7539	15868	17933

I.R. = irrigation regimes, M0 = non-mulched, M1 = Mulched, M3= cubic meter, Manza. = Manzanillo, cvs. = cultivars EGP = Egyptian pound.

CONCLUSION

Water scarcity problem is globally getting worse. The vast of majority of annual water supply in Egypt is used for irrigation. So, water saving and conservation is essential object to support agricultural sector especially in the new reclaimed land.

The present investigation revealed that, using deficit irrigation regime after full bloom stage of olive tree and rice straw mulch are useful for encouraging vegetative growth and high total yield besides, saving amount of irrigation water. Using 70% of on-farm irrigation water combined with rice straw mulch is useful for increasing the fruit yield as well as water use efficiency. In the light of economic evaluation (net income) we do recommend using deficit irrigation at the rate of 70% (3398 m^3/feddan) which achieved the highest net income.

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تأثير معدلات نقص الري وتغطية التربة بقش الأرز على نمو وإنتاج أشجار الزيتون في الأراضي الرملية

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أجريت هذه التجربة الحقلية في مزرعة بساتين خاصة تقع عند الكيلو ٦٤ (طريق القاهرة- الإسكندرية الصحراوي) على أشجار الزيتون صنفي منزانيللوا ومراقى خلال موسمي النمو ٢٠١٤ و ٢٠١٥ بهدف دراسة تأثير معدلات الري ١٠٠% (٤٣٨٤ م^{٣} / فدان)، ٨٥ % (٣٨٩٢ م^{٣} / فدان) و ٧٠% (٣٣٩٨ م^{٣} / فدان) والتي أضيفت بعد مرحلة التزهير الكامل, وهى من أكثر مراحل نمو شجرة الزيتون تأثرا بالري وذلك ابتداء من شهر مايو. كذلك دراسة تأثير استخدام قش الأرز كغطاء للتربة أوضحت النتائج أن استخدام معدل الري ٧٠% مع التغطية بقش الأرز أدى إلى تحسن خصائص النمو الخضري مثل طول الفرع, عدد الأوراق للفرع ومساحة سطح الورقة. كذلك أدت المعاملة إلى تحسن الصفات الزهرية مثل عدد الأزهار في النورة، عدد الأزهار الكاملة وكذلك الكثافة الزهرية. كما أدى استخدام معدل الري ٧٠% مع تغطية التربة بقش الأرز إلى أعلى نسبة لتركيز العناصر (نيتروجين- فوسفور- بوتاسيوم) في الأوراق. أدى استخدام معدل الري ٨٥ % إلى تحسن صفات المحصول وجودة الثمار. كما زادت كفاءة استخدام المياه بنقص كمية الماء المضافة ونتجت أعلى قيمة لكفاءة استخدام المياه عند استخدام معدل الري ٧٠%. معظم الاختلافات ما بين الصنفين المنزانيللوا والمراقى رجعت إلى العوامل الوراثية. محتوى الثمار من الزيت في الصنف المراقى كان أعلى من الصنف المنزانيللوا لكن المحصول الكلى للثمار اختلف باختلاف موسم النمو. بناءً على التقييم الاقتصادي يمكن التوصية باستخدام معدل الري ٧٠ % مع تغطية التربة بقش الأرز لتحقيق اعلي صافى ربح.