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Effect of Sustained Deficit Irrigation and Rice Straw Mulching on Yield and Fruit Quality of Manzanillo Olive Trees.

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Abstract: *The study was carried out during 2012, 2013 seasons onolive trees (Olea europaea L.) cv. Manzanillo grown at El-Maghara Experiment Station, Sinai, Egypt. Selected treeswere planted at 5x5 meters apart in sandy soil, watered from wells using drip irrigation system. The trial was a factorial experiment,hence sustained deficit irrigation100%, 90%, 80%, 70%, 60%, or 50% from crop evapotranspiration (Etc)throughout season, the occupied mainplot, whereas rice straw mulching at 1680, 2520 and 3360 kg/f located in the sub-plots, during summer months until harvest date. The results showed that total yield per tree, fruit quality i.e weight, volume, length, width, flesh thickness and moisture content, besidessaponification number of oil recorded the highest values with higher both irrigation level and mulching rate treatments. On the contrary the amount of extracted oil, oil acidity value and water used efficiency showed an adverse correlation with irrigation level and mulching rate treatment. Applying mulching in summer enhanced yield and fruit quality. Furthermore, sustained irrigation deficit and mulch treatment had an efficient strategy for arid and semi-arid regions. Olive cultivar Manzanillo planted in arid and semi-arid condition depended on irrigation from wells and limited water preferably to be used for the purpose of oil production.*

Consequently sustained irrigation deficit (100, 90, 80, 70, 60, 50ETc) provided with rice straw mulching at 1680, 2520 and 3360 kg/f could be used as an efficient strategy for Manzanillo olive trees grown for oil production in arid and semi-arid regions with limited water resources.

Key word:*Manzanillo olive - Sustained deficit irrigation – Mulching – Yield- Fruit Quality*.

I. Introduction

Olive (*Olea europaea* L.) is considered the main and one of the best adapted fruit speciesin many arid and semi-arid regions around the Mediterranean (Fernández et al., 1997, Villalobos et al., 2000 andMoriana et al., 2002). Irrigation in the arid and semi-arid regions depends on wells. Limitation of water availability and the rapid depletion of water resources available, increases the need to prudent management of irrigation water in these regions is necessary in order to increase water use efficiency and decrease water consumption. Irrigation deficit is one of the best used strategies when there is a scarcity of water. Irrigation water deficit of crops fruit trees is one of the cultural practice which are used widely in many areas of the world in recent years to reduce the amount of water applied with minimal or no reduction in fruit production (Girona et al., 1993; Behboudian 1997; Marsal and Girona, 1997 and Marsal et al., 2002). However, the current trend in the irrigation of olive trees is to develop sustained deficit irrigation (SDI), applies to fixed fraction of the evapotranspiration rate throughout the irrigation season (Goldhamer et al.,1994 ; Patumi et al., 1999; Tognetti et al., 2006; and d'Andria et al., 2008) and/or regulated deficit irrigation (RDI) strategies, causes a temporary and controlled water deficit in specific phonological stage, in order to reduce the amount of water applied with minimal or no reduction in fruit production i.e before flowering, the first phase on growth when most cell division, the second phase of fruit development corresponding to the pit hardening period and the third phase of fruit when the oil is accumulated(Gómez-Rico et al., 2007; d′Andria et al., 2009; Moriana et al., 2013 and Zeleke and Ayton 2014). Whereby, the water applied at a rate less than the needs of evapotranspiration with only very small reductions in yield (Goldhamer, 1999 and Tognetti et al., 2005). Moreover, complementary irrigation for optimizing the usage of limited water available from renewable resources in rain fed areas and in a region where water availability is greatly limited (Attalla et al., 2011 and Lodolini 2014). Extensive researches were conducted on olive trees regarding irrigation deficit in relation to yield, olive oil production, oil quality and water used efficiency (Patumi et al., 2002; Moriana et al., 2003; Tognetti et al., 2006; Grattan et al., 2006; Berenguer et al., 2006; Toplu et al., 2009; d′Andriai et al., 2009 and Grijalva-Contreras et al., 2013).

Rice straw is considered one of the most important plant waste problems. Most farmers left behind the rice straw. Rice straw can be used as mulch. In addition, rice straw is very cheap source of mulching material and can be economically utilized.

Moreover, Liu et al. (2014) showed that soil mulching is used to increase soil water storage in the top 100 cm of the soil profile compared to the control treatment and eliminate weeds competition for water and nutrients. Zhang et al. (2005) and Vial et al.(2015) found that mulching with straw reduced soil evaporation loss. Moreover, it improves water infiltration (Faber et al., 2001; Ji and Unger 2001 and Laila and Ali 2011) and

conserved soil moisture (Pandey et al., 2013 and Saikia et al., 2014). In addition, Liu et al., (2014) revealed that soil mulch practices can positively affect citrus fruit yield in extreme weather conditions. However, straw mulching significantly increased yield/tree(Oliveira and Merwin, 2001; Sanchez et al., 2003; Neilsen et al., 2003; Yao et al., 2005; Abouziena et al., 2008 and Pandey et al., 2013).

Finally, straw mulching reduced water requirement of crop plants (Liu et al., 2009), and increased water usage efficiency (Tolk et al., 1999). In addition, straw mulching saved30% of irrigation water and increased water use efficiency (Chaudhry et al., 2004; Zhang et al., 2005 and Laila and Ali 2011).

The objective of this study was to evaluate the effect of sustained regulated deficit irrigation and mulching on yield, fruit quality, oil properties and water used efficiency of Manzanillo olive trees under semi and semi-arid conditions.

II. Materials and Methods

This experiment was carried out during 2012 and 2013 seasons at El-Maghara Experiment Station, Desert Research Center, North Sinai Governorate, Egypt (30.43 N longitude, 33.19 E and 200 meter above sea level). On 16-year-oldManzanillo olive trees grown at (5X5 meter) apart. Soil analysis of experimental soil and water were carried out as listed in Table (1& 2). Water was delivered using a localized irrigation system with four drip nozzles of 8L/h each per tree, set a line along the rows at a distance of 0.5 m to 1 m from trunk.

This study is considered a Factorial experiment, as it involved two factors as follows:-

A- Irrigation treatments. Six Irrigation treatments were imposed, that applied various treatments equivalent to 100, 90, 80, 70, 60 and 50 of crop evapotranspiration (ETc). Irrigation supply the crop water demand as equation Etc= ETo×Kr×Kc according to (Allen et al., 1998). ETo mm is the reference evapotranspiration calculated using the FAO-Penman-Monteith (Allen et al., 1998) from an automatic weather station located next to the experimental orchard. Kr (reduction coefficient) according to account for orchard maturity. It applies to canopy cover and is described as Kr=2C/100 were C is preventcanopy cover (C=4/3 π ab2) according to Westwood (1993), when (a) is of canopy height (m) and (b) is half of canopy spread (m). Kc (crop coefficients) was recorded according to (Allen et al., (1998) 0.50, 0.50, 0.50, 0.50, 0.50, 0.50, 0.60, 0.60, 0.60, 0.55, 0.55, 0.55 from Jan. to Dec. respectively in arid and semiarid regions.

Table1. Physical and chemical analyses of experimental soilat El-Maghara region.

Physical analysis of ExperimentalSoil											
Particle Size Distribution											
Depth Cm		**Total sand**		**Silt + clay**		**Textural Class**		**F.C**		**W.P**	
0-30		96.5		3.5		Sand		11.4		4.1	
30-60		98		2		Sand		11.2		4.0	
60-90		97		3		Sand		10.9		3.9	
Chemical analysis of Experimental Soil											
Depth Cm	**CaCO3 %**	**pH**	**EC (dSm^1)**	**Cations (meq./L)**				**Anion (meq./L)**			
				Na^+	**K^+**	**Ca^{++}**	**Mg^{++}**	**CO^-_3**	**HCO^{-3}**	**Cl^-**	**SO^{-4}**
0-30	5.89	7.6	0.6	1.26	0.5	2.5	1.5	-	1.8	1.4	2.11
30-60	3.97	7.5	0.7	1.57	0.08	3	2.0	-	1.8	2	2.85
60-90	4.34	7.4	1.1	3.04	0.05	3.5	2.0	-	2.4	6.1	2.59

Table 2. Chemical analysis of used irrigation water at El-Maghara region.

PH	**EC dSm^{-1}**	**O.M %**	**Solublecations, meq/L**				**Soluble anion, meq/L**			
			Ca^{++}	**Mg^{++}**	**Na^+**	**K^+**	**CO^{-3}**	**HCO^{-3}**	**Cl^-**	**SO^{-4}**
8.32	4.04	1.41	11.41	3.50	24.62	0.70	-	4.43	32.21	3.59

B- Straw mulching treatment: Three treatments of rice straw (*Orayza sativa L.*) mulching were applied 1680, 2520 and 3360 Kg/f rice straw or in other terms 10, 15 and 20 kg rice straw per tree, and referred as M1, M2 and M3 respectively. Mulching materials were manually applied in a layer on both sides of tree rows, 15 cm from trunk tree during summer months up to fruit harvesting. This study is considered a factorial experiment, hence a split plot is devoted to the irrigation levels as main plot whereas straw mulch occupied sub-plot. The element of each factor was replicated three times.

The response of tree yield and fruit quality to the two tested factors was evaluated through the following determinations:-

2.1. Yield Kg/tree.

Fruits were harvested for table purpose at the first week of October whereas those for oil purpose were harvested in the second half of November. Fruit harvesting was conducted manually. Fruit yield were weighted in kg and recorded.

2.2. Biennial bearing index.

Biennial bearing index of treated Manzanillo olive trees under different studied treatments was determined according to the equation of Wilcox (1944) as follows = 100× ((difference between two successive yields) / (sum of two successive yields)).

2.3. Fruit quality

Samples of hundred healthy fruits were randomly taken from tree canopy to determine some fruit quality parameters (fruit weight (g), fruit volume (cm^3), fruit length (mm) fruit diameter (mm), and pulp thickness (mm). Fruit moisture content was determined from 50g of olive fruits, hence they were dried in an oven at 80^oC till a constant weight. Fruit oil content was determined by extracting dry material (50 g) with 40-60^o C petroleum ether using a Soxhlet apparatus, and some parameters of oil quality as Acidity (Oleic acid) and Saponification number were determined according to (A.O.A.C. 1995).

2.4. Water use efficiency

Water use efficiency was estimated as a ratio between fresh fruit yield and total available seasonal water computed, obtained according the next equation WUE= Yield kg/water applied (mm), as mentioned byGeerts and Raes (2009)

Statistical analysis

The obtained data of 2012 and 2013 seasons were subjected to analysis of variance according to Clarke and Kempson (1997). Means were differentiated using Duncan multiple rang test at the 0.05 level (Duncan 1995).

III. Result and Discussion

3.1. Tree yield (kg)/tree

Table 3 shows that irrigation level at 100% Etc gave the highest yield (kg)/tree followed by descending 90%, 80%, 70%, 60% irrigation Etc treatments, respectively. Moreover, reducing irrigation level to 50% Etc has recorded the lowest tree yield. Yield was significantly affected by irrigation level. However, significant differences in tree yield were produced negatively by reducing irrigation rate.

Furthermore, M3 mulching treatment (3360 Kg/f or 20Kg/tree) induced the highest tree yield followed by M2 (2520 Kg/f or 15Kg/tree) and M1 (1680 Kg/f or10 Kg/tree) mulching treatments in descending order. However, a positive correlation was found between tree yield and rice straw mulching rate.

In addition, irrigation at 100% Etc combined with M3 (3360 kg/f or 20Kg/tree) mulching treatment proved to be the most effective treatment in improving yield (Kg)/tree. On the contrary, 50% Etc irrigation combinedwithmulch treatment M1 (1680 kg/f or10 kg/tree) gave comparatively the lowest values in this respect.

Table 3. Effect of sustained irrigation deficit level and rice straw mulching on yield (Kg)/tree of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation (ETc) Crop Evapotranspiration	2012 Rice straw mulching				2013 Rice straw mulching			
	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	14.10 a	14.67 a	14.78 a	**14.52 A**	49.60 b	50.67 a	50.76 a	**50.34 A**
90%	13.65 d	13.71 cd	13.87 c	**13.74 B**	48.30 d	48.34 d	49.35 c	**48.66 B**
80%	13.02 fg	13.20 f	13.41 e	**13.21 C**	47.15 fg	47.21 ef	47.27 e	**47.21 C**
70%	12.75 hi	12.78 hi	12.92 gh	**12.82 D**	47.15 fg	47.21 ef	47.27 e	**46.06 D**
60%	12.30 kl	12.45jk	12.62 ij	**12.46 E**	44.60 j	44.62 j	44.70 j	**44.64 E**
50%	12.03 m	12.15 lm	12.20 lm	**12.13 F**	43.34 l	43.45 k	43.55 k	**43.45 F**
Mean	**12.98 C**	**13.16 B**	**13.30 A**		**46.36 C**	**46.71 B**	**47.11 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.2. Biennial bearing index

Table, 4 illustrates that biennial bearing index of Manzanillo olive trees showed reversible correlation with the studied sustained deficit irrigation treatments. Olive trees received 100% Etc. showed significantly less tendency to irrigation bearing, as they recorded the lowest biennial bearing index value, whereas those received 70% Etc. recorded the highest biennial bearing value. Other studied sustained deficit irrigation treatments recorded inbetween values in this respect.

Furthermore, applying high rate of rice straw mulching succeed in reducing the tendency of olive tree to alternative bearing as compared with those received low rate of rice straw mulching the mulching. The moderate mulching rate recorded an intermediate value in this respect.

In addition, 100% Etc treatment combined with high and moderate mulching rates proved to be the most efficient interactions in reducing tree tendency to alternative bearing. On the contrary 70% Etc combined with high mulching rate and 60% Etc provided with low mulching rate showed to be the lowest efficient interactions in this respect.

Table 4. Effect of sustained irrigation deficit level and rice straw mulching on biennial bearing index of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation (ETc) Crop Evapotranspiration	Rice straw mulching			
	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	55.73 h	55.10 i	54.89 j	**55.24 E**
90%	55.93 g	55.81 h	56.12 f	**55.95 D**
80%	56.73 b	56.30 de	55.80 h	**56.28 C**
70%	55.98 g	56.48c	56.91 a	**56.46 A**
60%	56.73 b	56.36 d	55.96 g	**56.35 B**
50%	56.54 c	56.29 de	5.23 ef	**56.35 B**
Mean	**56.27 A**	**56.06 B**	**55.98C**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

These results are in harmony with those studies which used sustained or continuous deficit irrigation on olive trees by Grattan et al., (2006) who found that tree yield was increased with increasing irrigation water level from 15 up to 107% Etc. Moreover, Patumi et al., (2002) indicated that yield is positively affected by irrigation and restitution of 66% of ETc was necessary to achieve good yield. Also, d'Andria et al., (2008) and Patumi et al., (1999) conducted that applications of water in excess of 66% ETc during the whole season led to increase in production.Furthermore,irrigation scheduling is critical for olive orchards as it affects fruit yield (Poblete-Echeverria et al., 2014). Also, these results are in agreement when competently irrigation is concerned. In this respect, Lodolini (2014) mentioned that total fruit yield per tree was increased as the water irrigation increased and Attalla et al., (2011) 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 trees inboth seasons.

Concerning, the positive effect of mulch treatments from summer to fruit harvest, on tree yield the previous studies of Oliveira and Merwin, 2001, Sanchez et al., 2003,Neilsen et al., 2003, Yao et al., 2005, Hassan et al., (2006),Abouziena (2008),Liu et al., (2014), and Sing and Sidhu 2014 emphasized that result. Moreover, Zhang et al., (2014) found that mulching combined with surface irrigation induced higher yield of grapevines.

3.3. Fruit quality

3.3.1. Fruit weight (g).

Table , 5 illustrates that100% Etc irrigation level resulted in the highest fruit weight value followed descending by 90%, 80%, 70% , 60% and 50% Etc irrigation treatment in both seasons. However, significant differences were noticed between the tested sustained deficit irrigation levels.

Moreover, the highest fruit weight was recorded with M3 followed by M2 and M1 mulching treatments, respectively.

Concerning the interaction between the tested irrigation levels, and mulching treatments, 100% irrigation combined with M3 mulching treatment proved to be the best interaction in this regard.

3.3.2. Fruit volume (cm^3)

Table (6) shows that irrigation level at 100% gave the highest fruit volume value followed by, 90%, 80%, 70%, 60% irrigation levels treatments in descending order. Meanwhile, the lowest fruit volume value was recorded with 50% irrigation in both seasons.

In addition, the highest fruit volume value was recorded with M3 (6.83 and 5.69 cm3) followed by M2 (6.79 and5.65 cm3) and M1 (6.71 and 5.60 cm3) which recorded the lowest values in this respect in the first and second seasons, respectively. Meanwhile, non significant difference was noticed between M3 and M2 in first season.In the second season, the differences between the three tested mulching treatments were significant.

Table 5. Effect of sustained irrigation deficit level and rice straw mulching on fruit weight (g) of Manzanillo olive trees during 2012 and 2013seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	6.82 c	7.09 b	7.23 a	**7.04 A**	5.86 c	6.01 b	6.16 a	**6.01 A**
90%	6.48 e	6.61 d	6.75 c	**6.61 B**	5.48 f	5.60 e	5.71 d	**5.60 B**
80%	6.02h	6.15 g	6.29 f	**6.15 C**	5.04 i	5.18 h	5.31 g	**5.18 C**
70%	5.67 k	5.79 j	5.91 i	**5.79 D**	4.75 jk	4.81 j	4.96 i	**4.84 D**
60%	5.30 m	5.40 l	5.63 k	**5.44 E**	4.43 m	4.56 l	4.71 k	**4.58 E**
50%	4.97 p	5.08 o	5.19 n	**5.088F**	4.35 m	4.36 m	4.38 m	**4.36 F**
Mean	**5.88 C**	**6.02 B**	**6.17 A**		**4.99 C**	**5.09 B**	**5.21 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

Table 6. Effect of sustained irrigation deficit level and rice straw mulching on fruit volume (cm^3) of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	7.05 b	7.38 a	7.42 a	**7.28 A**	5.96 b	6.07 a	6.09 a	**6.04 A**
90%	6.90 cd	6.91 cd	6.94 bc	**6.92 B**	5.81 cd	5.86 c	5.89 bc	**5.85 B**
80%	6.78 def	6.79 def	6.82 cde	**6.80 C**	5.66 efg	5.71 de	5.75 de	**5.71 C**
70%	6.64 ghi	6.68 fgh	6.73 efg	**6.68 D**	551 hi	5.57 gh	5.62 fg	**5.57 D**
60%	6.51 jk	6.54 ijk	6.58hij	**6.54 E**	5.38 jkl	5.41 jk	5.47 ij	**5.42 E**
50%	6.38 l	6.42 jkl	6.48 jkl	**6.43 F**	5.26 m	5.29 lm	5.34 klm	**5.30 F**
Mean	**6.71 B**	**6.79 A**	**6.83 A**		**5.60 C**	**5.65 B**	**5.69 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

The combined effects of irrigation levels with mulching treatments showed that 100% level of irrigation with M3and/or M2 mulching treatments were the most effective treatments in increasing fruit volume, followed finally by the corresponding ones of 50% irrigation combined with M1 the less effective fruit volume.

3.3.3. Fruit length (mm)

Table (7) indicates that irrigation at 100% Etc recorded the highest fruit length value followed by irrigation at 90%, 80%, 70%, 60% and irrigation 50% Etc, respectively in both seasons.

Furthermore M3 mulching treatments gave the highest fruit length followed by M2 and M1 treatments in both seasons.

The interaction between irrigation and mulch treatments reveals that the highest fruit length value was recorded with 100% irrigation supported with M3 mulching treatments. On the contrary, the combination of 50% irrigation and M1 induced the least positive effect on fruit length.

Table 7. Effect of sustained irrigation deficit level and rice straw mulching on fruit length (cm) of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	2.32 abc	2.35 ab	2.39 a	**2.35 A**	2.30 ab	2.32 a	2.32 a	**2 .13 A**
90%	2.28 bcd	2.28 bcd	2.28 bcd	**2.28 B**	2.28 ab	2.28 ab	2.29 ab	**2.28 B**
80%	2.22 d-g	2.24 c-f	2.26 cde	**2.24 C**	2.26ab	2.27 ab	2.27 ab	**2.27 C**
70%	2.17 fgh	2.19 e-h	2.20 d-h	**2.19 C**	2.18 cd	2.18 cd	2.22 bc	**2.20 D**
60%	2.12 hij	2.12 hij	2.15 ghi	**2.13 D**	2.15 cd	2.15 cd	2.16 cd	**2.15 E**
50%	2.05 j	2.05 j	2.0 ij	**2.06 E**	2.12 d	2.13 d	2.14 cd	**2.13 F**
Mean	**2.19 A**	**2.21 A**	**2.23 A**		**2.22 A**	**2.22 A**	**2.23 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.3.4. Fruit diameter (mm)

It is clear from Table, 8 that irrigation at 100% Etc produced the widest fruits as compared with those given 50% irrigation Etc in both seasons. On the other hand, 90%, 80%, 70% and 60% irrigation produced an intermediate effect in this respect.

Furthermore, Table, 8 shows that rice straw mulching treatments induced non significant effect on fruit diameter in both seasons.

The interaction between irrigation and mulch treatments illustrates that the highest fruit diameter was recorded by high irrigation level (100%) provided with M3 mulch treatments. The lowest fruit diameter value was recorded when the low irrigation level was combined with M1 mulching treatment.

Table 8. Effect of sustained irrigation deficit level and rice straw mulching on fruit diamter (cm) of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	2.26 b	2.27b	2.30 a	**2.28 A**	2.15 c	2.17 b	2.19 a	**2.17 A**
90%	2.22 de	2.23 cd	2.24 c	**2.23 B**	2.12ef	2.1 de	2.14 cd	**2.13 B**
80%	2.21 ef	2.21 ef	2.21 ef	**2.21 C**	2.11 fg	2.11 fg	2.12 def	**2.14 C**
70%	2.19 gh	2.20 fg	2.20 fg	**2..20 D**	2.10 gh	2.10 gh	2.10 gh	**2.10 D**
60%	2.15 ij	2.16 i	2.18 h	**2.16 E**	2.08 ij	2.08 ij	2.09 hi	**2.08 E**
50%	2.10 l	2.12 k	2.14 j	**2.12 F**	2.05 l	2.06 kl	2.07 jk	**2.06 F**
Mean	**2.19 C**	**2.20 B**	**2.21 A**		**2.10 B**	**2.10 B**	**2.12 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.3.5. Flesh thickness (mm)

Data presented in Table, 9 shows the highest flesh thickness values were recorded with 100% irrigation followed by irrigation at 90%, 80%, 70%, 60% and 50% Etc, respectively.

Furthermore, flesh thickness was negatively affected by reducing the mulch treatments rate from M3 to M1 in the first season. The highest flesh thickness values were recorded with M3 followed by M2 and M1 treatments in the second season.

The interaction effect of irrigation and mulch treatment proved that the highest flesh thickness values were scored with irrigation 100% plus M3, whilst the lowest values were recorded with irrigation 50% with M1.

Table 9. Effect of sustained irrigation deficit level and rice straw mulching on fruit flesh thickness (cm) of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	0.80 bc	0.81 ab	0.82 a	**0.81 A**	0.68 bc	0.69 ab	0.70 a	**0.69 A**
90%	0.78 de	0.79 cd	0.79 cd	**0.79 B**	0.68 bc	0.68 bc	0.68 bc	**0.68 A**
80%	0.76 fg	0.77 ef	0.78 de	**0.77 C**	0.67 cd	0.66 de	0.67 cd	**0.67 B**
70%	0.74 hi	0.75 gh	0.75 gh	**0.75 D**	0.67 cd	0.66 de	0.66 de	**0.66 B**
60%	0.71j	0.73 i	0.74 hi	**0.73 E**	0.64 f	0.64 f	0.65 ef	**0.64 C**
50%	0.68 l	0.69 kl	0.70 jk	**0.69 F**	0.62 g	0.65 ef	0.64 f	**0.74 C**
Mean	**0.75 B**	**0.76 A**	**0.76 A**		**0.67 A**	**0.66 A**	**0.66 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.3.6. Fruit moisture %

Table, 10 demonstrates that increasing irrigation level from 50% to 60%, 70%, 80%, 90% and 100% caused a steady increase in fruit moisture content in both seasons.

Furthermore it is clear that M3 mulch treatment recorded the highest fruit moisture followed by M2 and M1 treatments.

Moreover, the interaction between irrigation levels and mulching treatments showed that irrigation at 100% supplemented with M3 mulching treatment scored the highest values of fruit moisture content, while the lowest value was recorded with the combination of irrigation 50% and M1 mulching treatment. Other interaction scored in between rather in this respect.

Table 10. Effect of sustained irrigation deficit level and rice straw mulching on fruit moisture of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	53.98 b	54.29 b	55.35 a	**54.54 A**	51.33c	52.44b	53.43a	**52.40 A**
90%	51.72 d	52.83 c	53.14c	**52.56 B**	50.41d	50.44d	50.74cd	**50.53 B**
80%	50.29 ef	50.41ef	50.58 e	**50.43 C**	50.17de	50.20de	50.25d	**50.20 B**
70%	49.81gh	49.95gh	50.08 fg	**49.95 D**	49.22fg	49.49ef	50.03de	**49.58 C**
60%	48.40j	48.84 i	49.69 h	**48.98 E**	48.73g-i	48.73g-i	48.98f-h	**48.81 D**
50%	47.34 l	47.89 k	48.14 jk	**47.80 F**	46.91j	48.13i	48.45hi	**47.83 E**
Mean	**50.25 C**	**50.70 B**	**51.16 A**		**49.46 C**	**49.91 B**	**50.31 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.3.7. Fruit oil percentage %

Table, 11 illustrates that 50% irrigation level gave the highest fruit oil content followed descendingly by %60, 70%, 80% and 90% irrigation. Meanwhile, irrigation at 100% recorded the lowest fruit oil percentage. Fruit oil percentage showed an adverse correlation with irrigation level, hence fruit oil percentage value was increased as water addition decreased.Furthermore, it is evident that the highest fruit oil percentage was recorded with M1 followed by M2 and M3 treatments.

In addition, irrigation at 50% combined with M1 mulching treatment proved to be the most effective treatment in improving fruit oil percentage. On the contrary, 100% irrigation combined with mulch treatment M3 gave comparatively the lowest values in this respect.

Table 11. Effect of sustained irrigation deficit level and rice straw mulching on fruit oil content of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	Mean	10 kg/tree	15 kg/tree	20 kg/tree	Mean
100% Etc	36.94k	35.86l	34.52 m	**35.77 F**	35.82 n	34.41 o	33.70 p	**34.64 F**
90% Etc	37.46 i	37.35 j	37.29 j	**37.37 E**	36.42 l	36.21 m	36.15 m	**36.26 E**
80% Etc	38.67h	38.55h	37.79 i	**38.34 D**	37.52 j	37.34 k	36.58 l	**37.15 D**
70% Etc	41.15e	39.65f	39.16g	**39.99 C**	40.84 g	39.53 h	38.04 i	**39.47 C**
60% Etc	42.46c	42.31c	41.44d	**42.07 B**	42.88 d	41.71 e	41.39 f	**41.99 B**
50% Etc	44.46a	44.38a	43.90b	**44.25 A**	43.75 a	43.56 b	43.17 c	**43.49 A**
Mean	**40.19 A**	**39.68 B**	**39.02 C**		**39.54 A**	**38.79 B**	**38.17 C**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

3.3.8. Oilacid value

Table, 12 indicates that increasing irrigation level and mulching rate treatments results in increasing acid value in the first season. Such increment disappeared in the second season with irrigation level and mulching rate treatments.

Furthermore, irrigation level at 100% plus M3 mulching treatment proved to be the most effective combination in this respect in first season. In the second season there were no significant differences between the tested combinations irrigation levels and mulching treatments in this respect.

Table 12. Effect of sustained irrigation deficit level and rice straw mulching on oilacid value in oil acid of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	0.91 ab	0.91ab	0.92 a	**0.92 A**	0.94 a	0.96a	0.96 a	**0.93 A**
90%	0.89 cd	0.89 bc	0.90 bc	**0.89 B**	0.92a	0.93 a	0.94 a	**0.93 A**
80%	0.86 ef	0.87 e	0.88 de	**0.87 C**	0.90a	0.91a	0.92 a	**0.91 A**
70%	0.84gh	0.85 fg	0.85fg	**0.85 D**	0.89 a	0.89 a	0.90 a	**0.89 A**
60%	0.82 ij	0.83 hi	0.83 hi	**0.83 E**	0.87 a	0.88 a	0.89a	**0.88 A**
50%	0.80 j	0.80 j	0.80 j	**0.80 F**	0.84a	0.86 a	0.87 a	**0.86 A**
Mean	**0.85 B**	**0.86 AB**	**0.87 A**		**0.89 A**	**0.90 A**	**0.91 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level

3.3.9. Oil saponification number.

Table, 13shows that saponification number was significantly affected by irrigation and mulching treatments. Irrigation level of 100% gave the highest saponification number followed by irrigation at 90%, 80%, 70%, 60% and 50%.

Concerning mulching treatments the highest saponification number was recorded with M3 followed by M2 and M1 treatments which recorded the lowest values. Moreover, non significant differences were noticed between M2and M1treatments in the second season.

Irrigation level at 100% with M3 mulching treatment proved to be the most effective interaction in increasing saponification number. On the contrary, irrigation at 50% provided with M1mulching treatment gave comparatively the lowest value in this concern.

Table 13. Effect of sustained irrigation deficit level and rice straw mulching on oil saponification number of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation	2012				2013			
(ETc) Crop	Rice straw mulching				Rice straw mulching			
Evapotranspiration	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	226.50bc	227.01b	228.40a	**227.30A**	226.49b	227.27a	227.91a	**227.22 A**
90%	224.30e	225.18d	225.81cd	**225.10B**	225.18cd	225.58c	225.84bc	**225.53 B**
80%	223.49f	223.26f	223.71ef	**223.49C**	224.81de	223.93e	224.70d	**224.48 C**
70%	220.51g	220.90g	222.98f	**221.46D**	220.73g	220.85g	221.76f	**221.11D**
60%	218.53i	218.75i	219.73h	**219.00E**	219.26h	219.39h	219.62h	**219.42 E**
50%	218.06i	218.18i	218.48i	**218.24F**	218.95h	219.01h	219.13h	**219.03 F**
Mean	**221.89C**	**222.21B**	**223.19 A**		**222.57 B**	**222.67 B**	**223.16 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

These results go in line with those obtained by Grattan et al., (2006) who found that individual fruit size was increased with increasing of irrigation water level from 15 – 107% Etc. Moreover, Patumi et al., (2002) indicated that fresh fruit quality was positively affected by irrigation. Also,Patumi et al., (1999) and d'Andria et al., (2008) conducted that applications of water in excess of 66% ETc during the whole season led to increase in fruit quality.Iniesta et al., 2009 maintain that water stress caused a higher oil concentration in deficit irrigated trees. Khattab et al., (2009) indicated that fruit weight, volume, length, diameter, flesh thickness and moisture content were increased under the 100% irrigation level. Chehab et al., (2013) mentioned that there were significant differences observed in oil composition according to the irrigation regime applied. Nikbakht et al., (2011) indicated that the fruit oil content increased under the irrigation level of 75%. Moreover, Ramos and Santos (2010) stated that olive oil yield was significantly higher under rain fed conditions in an ''On year'', among the irrigated treatments olive oil production of treatment sustained deficit irrigation 66% was higher than the fully irrigated treatment. Grattan et al., (2006) found that fruit oil content was increased with the increase of applied water from 15-71% ETc but it decreased from level of 89% to 107% Etc. Also, Khattab et al., (2009) showed that the fruit oil content increased under the irrigation level of 50% actual water needs and oil acidity value was decreased by decreasing irrigation level. Concerning oil quality in response to irrigation deficit showed higher fruit oil content than fully irrigation (Gucci et al., 2014). Meanwhile, Grijalva-Contreras et al., (2013) noticed that applying water during pit hardening to harvest period, decreased oil yield but increased oil content , regulate irrigation deficits were applied 50% Etc during post-harvest period significantly reduced table olive yield. Zeleke and Ayton (2014) mentioned that both extractable oil (mechanical extraction) and total oil (chemical extraction) from the rain-fed treatment (0% of evapotranspiration) were higher than that irrigation deficit (50% of evapotranspiration), and full irrigation (100% of evapotranspiration.

Concerning, the positive results of mulch application treatments from summer to fruit harvest in harmony with previous studiesof soil mulch reported by Ghosh and Bauri (2003) who mentioned that mulching increased individual fruit weight and fruit quality (soluble solids, ascorbic acid content and total sugar) of mango cv. Himsagar trees.

3.4. Water used efficiency

Table, 14 demonstrates that irrigation at 50% Etc produced higher positive effect on water used efficiency followed by irrigation 60%, 70%, 80%, 90% and finally by the corresponding ones received irrigation at 100% Etc.

Furthermore, non significant differences were noticed between M2 and M1mulching treatments in the second season, although the highest water used efficiency was recorded by M3 followed by M2 and M1 mulching treatments in both seasons.

Finally, the interaction between irrigation level and mulching rate treatments showed that 50% irrigation provided with any mulch treatment were the most promising to attain water use efficiency for higher oil content.

Table 14. Effect of sustained irrigation deficit level and rice straw mulching on water use efficiency (yield/mm) of Manzanillo olive trees during 2012 and 2013 seasons.

Irrigation (ETc) Crop Evapotranspiration	2012				2013			
	Rice straw mulching				Rice straw mulching			
	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	1.30 f	1.35 ef	1.36 ef	**1.33 F**	4.55g	4.65 g	4.66 g	**4.62 F**
90%	1.39 e	1.41 e	1.41 e	**1.40 E**	4.92 f	4.93 f	5.03 f	**4.96 E**
80%	1.49 d	1.51 d	1.53 d	**1.51 D**	5.40e	5.42 e	5.42e	**5.41 D**
70%	1.67 c	1.67 c	1.69 c	**1.68 C**	5.92 d	6.02 d	6.17 c	**6.04 C**
60%	1.88 b	1.90 b	1.93 b	**1.90 B**	6.82 b	6.82 b	6.84 b	**6.82 B**
50%	2.21 a	2.23 a	2.24 a	**2.23 A**	7.95 a	7.98 a	7.99 a	**7.97 A**
Mean	**1.66 B**	**1.68 AB**	**1.69 A**		**5.92B**	**5.97 B**	**6.02 A**	

Means within each column or row followed by the same letter (s) are not significantly different at 5% level.

These results are in accordance with those reported byGrijalva-Contreras et al., (2013) the RDI who mentioned that using an ETc of 75% resulted in the highest water-use efficiency for oil or table olive production and Nikbakht et al. (2011) indicated that water use efficiency increased under the irrigation level of 75%. Irrigation level of 75% reduced water use by 29 %. Also, Khattab et al., (2009) showed that the water use efficiency increased under the irrigation level of 50% actual water needs. Moreover, mulching reduces water requirement of crop plants (Liu et al., 2009), At last mulching increases water usage efficiency (14 %) as compared with bare soil treatment (Tolk et aI., 1999) and saves of 30% irrigation water when rice straw was used as mulching (Chaudhry et al., 2004). Zhang et al., (2014) reported that mulching combined with surface irrigation is a useful technique for maximizing water use efficiency. Ram et al., 2013 mentioned that rice straw mulching will be beneficial in increasing yield, and water use efficiency in wheat.

Importance of is using soil mulching to agriculture is to reduce water usage, and conserve soil moisture (Bunna et al., (2011), Laila and Ali (2011) and Chaudhry et al., 2004.), and improves water infiltration (Faber et al., 2001). Mulching reduces water evaporation from soil (Kar and Kumar 2007, Bafeel and Moftah 2008, Ji and Unger 2001 Aragüés et al.,2014, Vial et al., 2015).

Conclusively, In spite of the fact that water is important to enlargement mesocarp cells, increases fruit weight, percent of fruit flesh and overall tree production, we can resort to deficit irrigation or mulching the soil in arid and semiarid when there is a scarcity of water, to reduce the amount of water applied, increased volume of moisture stored in soil structure in addition reduce evaporation by mulching minimal or no reduction in fruit production.

IV. Conclusion

Sustained irrigation deficit and mulch treatments produced a pronounced positive effect on tree yield, fruit characters and oil quality. Oil extracted, acidity oil and water used efficiency were increased with decreased applied water. Therefore, it is preferable to use the strategy of sustained deficit irrigation water in arid and semiarid areas, which keep on the amount of water and make the most of the water available. Moreover, the use application of soil mulching during summer months is beneficialin reducing the avertable impact of high temperature, low humidity and keep the soil moisture to get a satisfactory harvest recipes acceptable for quality, oil fruits, desirable despite, the adverse environment for the growth and production of olive.

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