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Effect of Sustained Deficit Irrigation and Rice Straw Mulching on Vegetative Growth, Flowering, Yield and Water used Efficiency of Manzanillo Olive Trees.

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Abstract: *This investigation was carried out olive trees (Olea europaea L.) cv. Manzanillo grown in El-Maghara Experiment Station, Sinai, Egypt, during 2013, 2014 seasons. Selected trees were planted at 5x5 meters apart in sandy soil, watered from wells using drip irrigation system. The trial was conducted as split plot design based on randomized complete block design with three replication, sustained deficit irrigation in main plots (100%, 90%, 80%, 70%, 60%, or 50% from crop evapotranspiration (ETc) whole season, and rice straw mulching soil used (1680, 2520 and 3360 kg/f) located in the subplots, during summer months until harvest date, to compare affect on vegetative growth, flowering, yield and water used efficiency on olive trees. The results showed that vegetative growth i.e tree dimensions, shoot growth, leaf characteristics, flowering (panicles number perfect, number of flower per panicle and perfect flower) and yield Kg/tree recorded the highest values with higher both irrigation level and mulching rate treatments. Furthermore, 70% Etc recorded the highest biennial bearing index and 3360 Kg/f rate rice straw mulching succeed in reducing the tendency of olive tree to alternative bearing. Irrigation at 50% Etc produced higher positive effect on water used efficiency.*
Key word: *Manzanillo olive - sustained deficit irrigation - mulching - vegetative growth - flowering - biennial bearing index - yield - water used efficiency.*

I. Introduction

Olive (Olea europaea L.) is considered one of the best adapted fruit species, in many arid and semi-arid regions around the Mediterranean and it is one of the main crops in this area (Fernández et al., 1997 Villalobes et al., 2000 and Moriana et al., 2002). In the arid and semi-arid regions depends on irrigation from wells, limitation of water availability and the rapid depletion of water resources available, this 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 (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 vegetative growth, flowering, yield and water used efficiency (Arzani and Arji 2002; Patumi et al., 2002; Tognetti et al., 2006; Grattan et al., 2006; Palese et al., 2010; Mona Aïachi Mezghani et al., 2012 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; Yao et al., 2005; Neilsen et al., 2003; 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 saved 30% 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 vegetative growth, flowering, yield, alternative bearing and water used efficiency of Manzanillo olive trees under semi and semi-arid conditions.

II. Materials and Methods

This investigation was carried out during 2013 and 2014 seasons, following a preliminary experiment counducted in season 2012, 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). Manzanillo olive cv. planted in 1996 trees grown at (5X5 meter) apart. 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. Soil analysis of experimental and water were carried out as listed in Table (1& 2).

This study is considered a Factorial experiment as it included 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 prevent canopy cover ($C=4/3\ \pi\ ab^2$) 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.

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 term 10, 15 and 20 kg rice straw per tree respectively.

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

Physical analysis of Experimental Soil											
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

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. Morphological characteristics

2.1.1 Tree dimensions

Tree height, both the circumference and diameter were measured using meter scale initial measure in early February and final measure in early November.

2.1.2 Shoot growth

To estimate rate of shoot elongation, 20 new springs per tree were randomly selected and tagged in early February till growth cessation in early November and total number of leaves per shoot were counted and recorded.

2.1.3 Leaf characteristics

Length, width and area of leaf blade were recorded for 20 mature leaves on spring cycle shoots, were estimated by using Portable area mod Li 3100 Ali (Li-cor) in September.

2.2. Flowering characteristics

2.2.1. Panicles number per shoot

Pre- full bloom stage 20 one year-old shoot were chosen at random on each tree. The number of panicles on each shoot was counted and average was calculated.

2.2.2. Number of flower per panicle

Samples of 30 panicles from each tree (just before flower opening) were picked to determine average number of flowers per panicle.

2.2.3. Perfect flower

Samples of 30 panicles for each tree were taken at full bloom stage with in each panicle were examined and the percentage of perfect flowers to total number of flowers was calculated.

2.3. Yield Kg/tree.

Fruits were harvested at the second week of November. Fruit harvesting was conducted manually. Fruit yield were weighted in Kg and recorded.

2.4. Biennial bearing index.

Biennial bearing index of treated 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).

2.4. Water use efficiency

Water use efficiency was estimated for each replication 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 by Geerts and Raes (2009).

Statistical analysis

The obtained data in 2013 and 2014 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 1955).

III. Result and discussion

3.1. Morphological characteristics

3.1.1. Tree dimensions

3.1.1.1. Increment tree high (cm)

Table, 3 illustrate that level 100% Etc irrigation resulted in the highest increment tree high value followed descending by 90%, 80%, 70%, 60% and 50% Etc irrigation treatments in both two seasons, respectively. However, significant differences were noticed between the tested sustained deficit irrigation levels.

Moreover, the highest increment tree high was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree mulching treatments, respectively. Treatments 100% irrigation combined with 20 Kg/tree mulching treatment proved to be the best interaction in this regard.

Table 3. Effect of sustained irrigation deficit level and rice straw mulching on increment tree high (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	12.72 c	13.39b	14.09 a	**13.40 A**	22.73 c	23.19 b	23.69 a	**23.20 A**
90%	11.38 f	11.79 e	12.31 d	**11.83 B**	20.28 f	20.18 e	21.63 d	**20.91 B**
80%	10.34 i	10.63 h	11.09 g	**10.69 C**	18.81 h	19.42 g	19.43 g	**19.22 C**
70%	7.70 l	8.65 k	8.85 j	**8.40 D**	17.26 k	17.70 j	17.93 i	**17.63 D**
60%	6.85 n	6.86 n	7.65 m	**7.12 E**	15.79 n	16.51 m	17.10 i	**16.47 E**
50%	6.55 q	6.63 p	6.67 o	**6.17 F**	13.95 q	14.63 p	15.03 o	**14.54 F**
Mean	**9.26 C**	**9.66 B**	**10.11 A**		**18.14 C**	**18.71**	**19.14 A**	

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

3.3.2. Increment in canopy circumference (cm).

Table (4) shows that irrigation level at 100% gave the highest increment in canopy circumference value followed by, 90%, 80%, 70%, 60% irrigation levels treatments in descending order. Meanwhile, the lowest increment in canopy circumference value was recorded with 50% irrigation in both seasons.

In addition, the highest fruit volume value was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree which recorded the lowest values in this respect.

The combined effects of irrigation levels with mulching treatments showed that 100% level of irrigation with 20 Kg/tree mulching treatments were the most effective treatments in increasing increment in canopy circumference, finally by the corresponding ones of 50% irrigation combined with 10 Kg/tree the less effective in canopy circumference.

Table 4. Effect of sustained irrigation deficit level and rice straw mulching on increment in canopy circumference (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	9.80 c	10.26 b	10.34 a	**10.13A**	15.61 c	17.30 b	17.36 a	**16.76 A**
90%	9.31 f	9.62 e	9.76 d	**9.56 B**	13.99 f	15.00 e	15.52 d	**14.84 B**
80%	8.36 i	8.38 h	9.08 g	**8.61 C**	11.99 i	12.52 h	13.29 g	**12.60 C**
70%	7.35 l	7.56 k	7.90 j	**7.60 D**	10.80 l	10.89 k	11.39 j	**11.03 D**
60%	6.88 o	6.92 n	6.97 m	**6.92 E**	9.55 o	10.42 n	10.48 m	**10.15 E**
50%	6.12 r	6.38 q	6.69 p	**6.40 F**	6.85 r	8.03 q	8.68 p	**7.83 F**
Mean	**7.97 C**	**8.19 B**	**8.46 A**		**11.47 C**	**12.36 B**	**12.79 A**	

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

3.3.3. Increment in canopy diameter (cm)

Table (5) indicates that irrigation at 100% Etc recorded the highest increment in canopy diameter value followed by irrigation at 90%, 80%, 70%, 60% and irrigation 50% Etc, respectively in both seasons.

Furthermore 20 Kg/tree mulching treatments gave the highest increment in canopy diameter followed by 15 Kg/tree and 10 Kg/tree treatments Meanwhile, non significant difference was noticed between 15 Kg/tree and 10 Kg/tree treatments in first season. In the second season, the differences between the three tested mulching treatments were significant.

The interaction between irrigation and mulch treatments reveals that the highest increment in canopy diameter value was recorded with 100% irrigation supported with 20 Kg/tree mulching treatments. On the contrary, the combination of 50% irrigation and 10 Kg/tree gave the least positive effect on increment in canopy diameter.

Table 5. Effect of sustained irrigation deficit level and rice straw mulching on increment in canopy diameter (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	9.29 c	10.27 b	10.56 a	**10.04A**	19.63 b	20.32 b	21.58 a	**20.51A**
90%	8.08 f	8.61 e	8.98 d	**8.56 B**	17.82cd	17.21de	18.31 c	**17.78 B**
80%	7.01 i	7.31 h	7.72 g	**7.35 C**	16.06fg	16.65ef	16.89ef	**16.53 C**
70%	6.10 l	6.21 k	6.23 j	**6.18 D**	14.81 h	14.94 h	15.31gh	**15.02 D**
60%	5.01 l	5.88 k	5.99jk	**5.63 E**	13.71 ij	13.83 i	13.69 i	**13.83 E**
50%	4.77 l	4.79 l	4.83 l	**4.80 F**	12.97 k	13.01 jk	13.24 ijk	**13.07 f**
Mean	**6.17 C**	**7.17 B**	**7.38 A**		**15.83 C**	**15.99 B**	**16.55 A**	

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

3.4. Increment in shoot length (cm)

It is clear from Table (6) irrigation at 100% Etc produced the tallest increment in shoot length as compared with those given 50% irrigation Etc in both seasons. On the other hand, 90%, 80%, 70% and 60% irrigation gave an intermediate effect in this respect.

Furthermore, Table, (6) shows that rice straw mulching treatments induced 20 Kg/tree mulching treatments gave the highest increment in shoot length followed by 15 Kg/tree and 10 Kg/tree treatments, In the first season, the differences between the three tested mulching treatments were significant. Meanwhile, non significant difference was noticed between 20 Kg/tree and 15 Kg/tree treatments in second season.

The interaction between irrigation and mulch treatments illustrates that the highest increment in shoot length was recorded by high irrigation level (100%) provided with 20 Kg/tree mulch treatments. The lowest increment in shoot length value was recorded when the low irrigation level was combined with 10 Kg/tree mulching treatment.

Table 6. Effect of sustained irrigation deficit level and rice straw mulching on increment in shoot length (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	1.87 c	2.03 b	2.17 a	**2.02 A**	7.48 c	7.61 b	7.66 a	**7.58 A**
90%	1.65 f	1.71e	1.73 d	**1.70 B**	6.60 f	7.10 e	7.25 d	**6.98 B**
80%	1.54 i	1.58 h	1.63 g	**1.58 C**	5.91 i	6.06 h	6.14 g	**6.04 C**
70%	1.25 l	1.43 k	1.48 j	**1.39 D**	5.68 l	5.71 k	5.75 j	**5.71 D**
60%	1.15 n	1.16 n	1.90 m	**1.17 E**	4.63 o	5.14 n	5.52 m	**5.10 E**
50%	1.07 q	1.10 p	1.12 o	**1.10 F**	4.34 r	4.52 p	4.45 q	**4.44 F**
Mean	**1.42 C**	**1.50 B**	**1.55 A**		**5.77 C**	**6.02 B**	**6.19 A**	

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

3.3.5. Increment in number of leaves per shoot

Data presented in Table, 7 shows the highest increment in number of leaves per shoot values were recorded with 100% irrigation followed by irrigation at 90%, 80%, 70%, 60% and 50% Etc, respectively.

Furthermore, the highest increments in number of leaves per shoot values were recorded with 20 Kg/tree followed by 15 Kg/tree and 20 Kg/tree treatments in the two seasons.

The interaction effect of irrigation and mulch treatment proved that the highest increment in number of leaves per shoot values were scored with irrigation 100% plus 20 Kg/tree, whilst the lowest values were recorded with irrigation 50% with 10 Kg/tree.

Table 7. Effect of sustained irrigation deficit level and rice straw mulching on increment in number of leaves per shoot (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	4.10 bc	4.65 ab	4.91 a	**4.55 A**	19.32 c	20.11 b	20.29 a	**19.91 A**
90%	3.61cde	3.75 cd	4.02 bc	**3.79 B**	17.52 f	18.58 e	19.06 d	**18.39 B**
80%	2.99 ef	3.13 de	3.43cde	**3.18 C**	15.58 i	16.29 h	16.96 g	**16.28 C**
70%	2.11 g	2.31 fg	2.36 fg	**2.26 D**	15.00 l	15.50 k	15.61 j	**15.37 D**
60%	1.80 g	1.98 g	1.99 g	**1.92 E**	13.92h	14.80 g	14.91fg	**14.54 E**
50%	1.60 g	1.65 g	1.76 g	**1.67 F**	12.51 i	12.81 i	13.53 h	**12.95 F**
Mean	**2.70 C**	**2.91 B**	**3.07 A**		**15.64 C**	**16.35 B**	**16.27 A**	

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

3.3.6. Leaf length (cm)

Table, 8 demonstrates that increasing irrigation level from 100 % to 90%, 80%, 70%, 60% and 50% caused a steady increase in leaf length in both seasons.

Furthermore it is clear that 20 Kg/tree mulch treatment recorded the highest leaf length followed by 15 Kg/tree and 10 Kg/tree treatments.

Moreover, the interaction between irrigation levels and mulching treatments showed that irrigation at 100% supplemented with 20 Kg/tree mulching treatment scored the highest values of leaf length, while the lowest value was recorded with the combination of irrigation 50% and 10 Kg/tree mulching treatment. Other interaction scored in between rather in this respect.

Table 8. Effect of sustained irrigation deficit level and rice straw mulching on leaf length (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	5.43 b	5.44 b	5.50 a	**5.46 A**	5.57 bc	5.72 b	5.73 a	**5.68 A**
90%	5.26 d	5.31 c	5.40 b	**5.32 B**	5.34 d	5.37 d	5.41 c	**5.38 AB**
80%	5.03 g	5.11 f	5.23 e	**5.12 C**	5.23 f	5.18 e	5.22 e	**5.23 BC**
70%	4.90 i	4.90 i	4.95 h	**4.92 D**	5.10 h	5.23 g	4.24 g	**4.87 CD**
60%	4.67 l	4.76 k	4.82 j	**4.75 E**	4.80 j	5.01 i	5.03 i	**4.95 CD**
50%	4.43 o	4.51 n	4.58 m	**4.51 F**	4.71 k	4.73 k	4.77 k	**4.74 D**
Mean	**4.95 C**	**5.00 B**	**5.08 A**		**5.14 A**	**5.21 A**	**5.07A**	

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

3.3.7. Leaf width (cm)

Table, 9 illustrates that 100% irrigation level gave the highest leaf width followed descendingly by 90%, 80%, 70% and 60% irrigation. Meanwhile, irrigation at 50% recorded the lowest fruit oil percentage. Fruit leaf width showed an adverse correlation with irrigation level, hence fruit leaf width was increased as water addition increased.

Furthermore, it is evident that the highest leaf width was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree treatments.

In addition, irrigation at 100% combined with 20 Kg/tree mulching treatment proved to be the most effective treatment in improving leaf width. On the contrary, 50% irrigation combined with mulch treatment 10 Kg/tree gave comparatively the lowest values in this respect.

Table 9. Effect of sustained irrigation deficit level and rice straw mulching on leaf width (cm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	1.79 abc	1.80 ab	1.86 a	**1.81 A**	1.94 bc	1.96 ab	2.03 a	**1.98 A**
90%	1.76 bcd	1.76 bcd	1.78 bc	**1.77 B**	1.91 bcd	1.92 bcd	1.92 bcd	**1.92 B**
80%	1.69 def	1.71 cde	1.72 bcde	**1.71 C**	1.85 de	1.87 cde	1.91 bcd	**1.88 B**
70%	1.64 efh	1.66 efg	1.67 efg	**1.66 D**	1.80 efg	1.82 ef	1.84 de	**1.82 C**
60%	1.60 gh	1.62fgh	1.62 fgh	**1.61 E**	1.64 i	1.75 fgh	1.79 efg	**1.73 D**
50%	1.40 h	1.54 h	1.54 h	**1.54 F**	1.70 hi	1.73 gh	1.74 fgh	**1.72 D**
Mean	**1.67 B**	**1.68 B**	**1.70A**		**1.81 B**	**1.84 A**	**1.87A**	

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

3.3.8. Leaf area (cm^3)

Table, 10 indicates that increasing irrigation level and mulching rate treatments results in increasing leaf area in the both seasons.

Furthermore, irrigation level at 100% plus 20 Kg/tree mulching treatment proved to be the most effective combination in this respect in two seasons.

Despite the resistance of olive tree to drought and to severe conditions, they usually showed a decrease in photosynthesis resulting in a reduction of the vegetative growth and a significant decline of the productive performance, low yield and alternate bearing behavior under in semiarid and arid regions (Bongi and Palliotti, 1994; Ben Ahmed et al., 2007). On the other hand, irrigation affected significantly of the most physiological parameters, like the leaf water potential and the leaf stomatal resistance (Masmoudi-Charfi et al., 2010).

Table 10. Effect of sustained irrigation deficit level and rice straw mulching on leaf area (cm^3) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	3.42 c	3.49 b	3.54 a	**3.48 A**	3.63 c	3.67 b	3.76 a	**3.69 A**
90%	3.22 f	3.34 e	3.42 d	**3.25 B**	3.46 f	3.48 e	3.61 d	**3.52 B**
80%	3.06h	3.07 h	3.14 g	**3.09 C**	3.25 i	3.28 h	3.40 g	**3.31 C**
70%	2.91 k	2.96 j	3.01 i	**2.96 D**	3.09 l	3.11 k	3.14 j	**3.11 D**
60%	2.82 m	2.86 l	2.90 k	**2.86 E**	3.00 o	3.03 n	3.07 m	**3.03 E**
50%	2.67 p	2.71 o	2.76 n	**2.71 F**	2.83 r	2.90 q	2.94 p	**2.89 F**
Mean	**3.01 C**	**3.05 B**	**3.12 A**		**3.12 C**	**3.24 B**	**3.32 A**	

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

These results go in line with those obtained by Alegre et al.,(2000) found that the vegetative growth decrease with water stress at shoot and level as a consequence of negative effectss RDI-25% on turgor maintenance and assimilation rate. Goldhamer and Fereres (2005) found that many of the RDI regimes reduced vegetative growth (canopy size). Patumi et al., (2002) indicated that the positive effect of irrigation on all plant growth parameters such as shoot growth, tree height, canopy diameter and trunk perimeter compared to non irrigation in olive trees. Moreover, Arzani and Arji (2002) conducted that plant height, shoot number, shoot length, leaf number and leaf area gave a good correlate on with the amount of applied water. Dichio et al., (2002) indicated that lower water availability determined a greater reduction of growth in above-ground. And, Grattan et al., (2006) who stated that the growth change branch length was very responsive to irrigation treatments, Tognetti et al., 2006 found that vegetative development were a function of water available to plants. Khattab et al., (2008) revealed that increasing levels of irrigation increased tree height, canopy diameter, canopy circumference, shoot length, number of leaves per shoot and leaf area. Deficit treatments strongly reduced vegetative growth (Iniesta et al., 2009). Mehanna et al., 2012 showed that vegetative growth parameters (shoot length, leaves density and leaf area) responded negatively to the regime water treatments

Trunk cross-sectional area growth indicated that vegetative growth was proportional to the amount of irrigation (Guillermo Correa-Tedesco et. al., 2010). Ana et al., 2011 showed that vegetative growth was mainly affected by the level of water supply and at the branch scale, water deficits reduced branch length and node numbers.

Also, water status plant influence on shoot elongation, shoot length and leaf area (Mona Aïachi Mezghani et al., 2012 and Aiachi Mezghani Mona et al., 2014).Tree growth was significantly decreased in the moderately stressed trees, decreases averaged 36%, 67%, and 46% for shoot growth, trunk growth, and pruning weights, respectively, over the 4 years of the study (Richard 2015).

Balwinder-Singh et al., (2011) found that mulching increased soil water content and this led to significant improvement in crop growth and yield determining attributes where water was limiting.

Patra et al., (2004) when used paddy straw mulch gave the highest increased in plant height, spread in east-west and north-south. El-Metwally and Omaima 2007 showed that soil mulch with rice straw improving growth apple trees, El-Settawy 2009 found that the mulched seedlings displayed growth and biomass higher than that of the unmulched ones, Md. Asaduzzaman et al., (2010) showed that most of the growth parameters were influenced by the mulch materials, Vinod Kumar et al., 2010 showed that significantly higher plant height, number of stems, leaf area and total dry matter per plant were recorded in paddy straw mulched plots and Sarangi et al., 2010 found that leaf area index was higher in mulching treatment. Hegazi and Sayed, (2001) conducted that the application of row cover materials increased significantly number of leaves and leaf area compared with non-mulching. Rajesh Kumar et al., 2012 found that different mulching material improved the vegetative growth of strawberry, Rahman et al., 2013 indicated that growth parameters such as plant height and number of leaves at different days after transplanting were increased significantly with the application of mulching, Devasinghe et al., 2013 found that rice straw mulch-wetdirect seeded rice, especially at initial stages of plant growth (i.e. 35 days after sowing) increased plant height significantly than in nonmulched and dry-direct seeded - rice straw mulch plots, Silva Filho et al., 2014 found that mulch improved the vegetative growth of the kale plants and Zhang et al., 2014 showed that gave the longer shoot length when used rice-straw mulching combined with surface irrigation.

3.2. Flowering characteristics

3.2.1. Number panicles per shoot

Table, 11 shows that number panicles per shoot was significantly affected by irrigation and mulching treatments. Irrigation level of 100% gave the highest number panicles per shoot followed by irrigation at 90%, 80%, 70%, 60% and 50%.

Concerning mulching treatments the highest number panicles per shoot was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree treatments which recorded the lowest values.

Irrigation level at 100% with 20 Kg/tree mulching treatment proved to be the most effective interaction in increasing number panicles per shoot. On the contrary, irrigation at 50% provided with 10 Kg/tree mulching treatment gave comparatively the lowest value in this concern.

3.2.2. Number flower per panicle

Table , 12 illustrate irrigation level 100% Etc resulted in the highest number flower per panicle value followed descending by 90%, 80%, 70% , 60% and 50% Etc in the two seasons, respectively. However, significant differences were noticed between the tested sustained deficit irrigation levels.

Moreover, the highest number flower per panicle was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree mulching treatments, respectively.

Concerning the interaction between the tested irrigation levels, and mulching treatments, 100% irrigation combined with 20 Kg/tree mulching treatment proved to be the best interaction in this regard.

Table 11. Effect of sustained irrigation deficit level and rice straw mulching on number panicles per shoot of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	8.81 c	8.86 b	8.93 a	**8.87 A**	9.65 c	9.81 b	9.86 a	**9.77 A**
90%	8.63 e	8.69 d	8.69 d	**8.67 B**	9.18 f	9.26 d	9.44 d	**9.23 B**
80%	8.33 h	8.43 g	8.52 f	**8.43 C**	8.68 i	9.02 g	9.13 f	**8.94 C**
70%	7.33 k	7.65 j	7.66 i	**7.52 D**	8.36 l	8.40 j	8.45 i	**8.40 D**
60%	6.71 n	6.84 m	6.98 l	**6.84 E**	8.42 n	8.24 m	8.33 l	**8.29 E**
50%	5.51 q	6.49 p	6.62 o	**6.21 F**	8.10 q	8.18 p	8.24 o	**8.17 F**
Mean	**7.55 C**	**7.81 B**	**7.90 A**		**8.70 C**	**8.83 B**	**8.90 A**	

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

Table 12. Effect of sustained irrigation deficit level and rice straw mulching on number flower per panicle of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	13.59 c	13.73 b	13.88 a	**13.73 A**	13.84 c	13.99 b	14.11 a	**13.98 A**
90%	13.22 f	13.38 e	13.49 d	**13.63 B**	13.40 f	13.63 e	13.74 d	**13.59 B**
80%	13.02 i	13.16 h	13.20 g	**13.13C**	13.31 i	13.36 h	13.37 g	**13.35 C**
70%	12.83 l	12.87 k	12.90 j	**12.87 D**	13.06 l	13.16 k	13.23 j	**13.15 D**
60%	12.50 o	12.57 n	12.62 m	**12.56 E**	12.96 o	13.05 n	12.93 m	**12.98 E**
50%	12.2 q	12.40 o	12.45 o	**12.37F**	12.67 r	12.78 q	12.80 p	**12.75 F**
Mean	**12.91 C**	**13.02 B**	**13.09 A**		**13.21 C**	**13.33B**	**13.36 A**	

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

3.2.3. Number perfect flowering per panicle

Table, 13 shows that irrigation level at 100% gave the highest number perfect flowering per panicle value followed by, 90%, 80%, 70%, 60% irrigation levels. Meanwhile, the lowest number perfect flowering per panicle value was recorded with 50% irrigation in both seasons.

In addition, the highest fruit volume value was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree which recorded the lowest values in this respect.

The combined effects of irrigation levels with mulching treatments showed that 100% level of irrigation with 20 Kg/tree mulching treatments were the most effective treatment in increasing number perfect flowering per panicle, finally by the corresponding ones of 50% irrigation combined with 10 Kg/tree the less effective number perfect flowering per panicle.

Table 13. Effect of sustained irrigation deficit level and rice straw mulching on number perfect flowering per panicle of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	7.35 abc	7.55 ab	7.87 a	**7.59 A**	7.81 c	7.85 b	7.99 a	**7.88 A**
90%	6.80cde	6.86cde	7.18bcd	**6.95 B**	7.58 f	7.71 e	7.76 d	**7.68 B**
80%	6.63 de	6.72cde	6.96bcde	**6.77 BC**	7.17 i	7.27 h	7.32 g	**7.25 C**
70%	6.51 de	6.57 de	6.61 de	**6.56CD**	6.91 l	6.93 k	7.05 j	**6.96 D**
60%	5.50 f	4.61e	6.46 de	**6.12 E**	6.54 o	6.67 n	6.79 m	**6.67 E**
50%	6.26 e	6.30 e	6.36 e	**6.31 DE**	6.35 r	6.39 g	6.40 p	**6.39 F**
Mean	**6.51 B**	**6.74 AB**	**6.91 A**		**7.06 C**	**7.13 B**	**7.22 A**	

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

Concerning, the positive results of sustained deficit irrigation levels and mulch application treatments from summer to fruit harvest in harmony with previous studies of irrigation levels and soil mulching reported by Rallo et al., 1994 mentioned that water stresses reduce the number of flowers per inflorescence and increase pistil abortion, Martin et al., 1994 found that lack of water during flower differentiation results in partially developed flowers with malfunctioning or absent pistils. And Mehanna et al., 2012 found that the flowering parameters (No. of total flowers/ inflorescence, sex ratio and length of inflorescence) trees irrigated with 100% Etc. through along season (control) recorded the highest values, following by 66% Etc. and 33% Etc. at pit hardening: harvest stage, followed in a descending order by those irrigated with 66% Etc. and 33% Etc. at harvest: inflorescence emergence stage which produced an intermediate. Irrigation regime affects differently on flowering Mona Aïachi Mezghani et al., 2012

Tedeschini et al., (2003) found that the highest number of flowers was obtained in mulching, Patra et al., (2004) when used paddy straw mulch gave the highest number of flowering per plant of guava cv. Sadar. Adnan Younis Bhatti 2012 founded that straw mulch produced highest number of flower spikes per plant, floret per spike and flowers per plant also straw mulch encourages flower production both qualitatively and quantitatively in freesia plants. Devasinghe et al., 2013 found that rice straw mulch increased panicle number per unit area and number of spikelets per panicle in wet direct seeded rice - rice straw mulch in both seasons.

3.3. Tree yield (kg)/tree

Table, 14 shows that level irrigation at 100% Etc gave the highest yield (kg)/tree followed by descending 90%, 80%, 70%, 60% irrigation Etc. Moreover, reducing level irrigation 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 mulching treatment 3360 kg/f or 20Kg/tree induced the highest tree yield followed by 2520 kg/f or 15kg/tree and 1680 kg/f or10 kg/tree mulching treatment in descending order. However, a positive correlation was found between tree yield and rate rice straw mulching.

In addition, irrigation at 100% Etc combined with 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 combined with mulch treatment 1680 kg/f or10 kg/tree gave comparatively the lowest values in this respect.

Table 14. Effect of sustained irrigation deficit level and rice straw mulching on yield (Kg)/tree of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation (ETc) Crop Evapotranspiration	2013				2014			
	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%	49.60 b	50.67 a	50.76 a	**50.34A**	13.85 c	14.52 b	14.73 a	**14.36A**
90%	48.30 d	48.34 d	49.35 c	**48.66 B**	13.45 f	13.61 e	13.82 d	**13.62 B**
80%	47.15 fg	47.21 ef	47.27 e	**47.21 C**	12.67 j	13.00 h	13.26g	**12.97 C**
70%	47.15fg	47.21ef	47.27 e	**46.06 D**	12.5 k	12.63l	12.82 i	**12.70 D**
60%	44.60 j	44.62 j	44.70 j	**44.64 E**	12.20o	12.30 n	12.42m	**12.30 E**
50%	43.34 l	43.45 k	43.55 k	**43.45 F**	11.73 r	11.95 q	12.15 p	**11.94 F**
Mean	**46.36 C**	**46.71 B**	**47.11 A**		**12.75 C**	**12.00 B**	**13.20 A**	

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

3.4. Biennial bearing index

Table, 15 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 treatments 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 recorded in between values in this respect.

Table 15. Effect of sustained irrigation deficit level and rice straw mulching on Biennial bearing index of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation (ETc) Crop Evapotranspiration	Rice straw mulching			
	10 kg/tree	15 kg/tree	20 kg/tree	**Mean**
100%	56.35 j	55.46 n	55.02 o	**55.61 E**
90%	56.44 i	56.07 m	56.25 k	**56.26 D**
80%	57.64 b	56.82 fg	56.19 l	**56.89 B**
70%	57.79 a	57.79 a	57.34 d	**57.64 A**
60%	57.05 e	56.79g	56.52 h	**56.79 C**
50%	57.40 c	56.86 f	56.38 j	**56.88 B**
Mean	**57.11 A**	**56.63 B**	**56.29 C**	

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

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 combined with high and moderate mulching rate 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.

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, 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 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. Is this respect with Lodolini (2014) total fruit yield per tree 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 in both seasons.

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

3.5. Water used efficiency (yield/mm)

Table, 16 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 found between 20 Kg/tree and 10 Kg/tree mulching treatments in the first season and non significant differences were noticed between 15 Kg/tree and 10 Kg/tree mulching treatments in the second season, although the highest water used efficiency was recorded with 20 Kg/tree followed by 15 Kg/tree and 10 Kg/tree mulching treatments in both seasons.

Table 16. Effect of sustained irrigation deficit level and rice straw mulching on water use efficiency (yield/mm) of Manzanillo olive trees during 2013 and 2014 seasons.

Irrigation	2013				2014			
(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%	4.55g	4.65 g	4.66 g	**4.62 F**	1.29 p	1.36 o	1.38 n	**1.34 F**
90%	4.92 f	4.93 f	5.03 f	**4.96 E**	1.40 m	1.41 m	1.43 l	**1.41 E**
80%	5.40e	5.42 e	5.42e	**5.41 D**	1.48 k	1.52 j	1.55 i	**1.51 D**
70%	5.92 d	6.02 d	6.17 c	**6.04 C**	1.69 h	1.69 h	1.71 g	**1.69 C**
60%	6.82 b	6.82 b	6.84 b	**6.82 B**	1.90 f	1.92 e	1.94 d	**1.92 B**
50%	7.95 a	7.98 a	7.99 a	**7.97 A**	2.19 c	2.24 b	2.27 a	**2.23 A**
Mean	**5.92B**	**5.97 B**	**6.02 A**		**1.65 C**	**1.69 B**	**1.71 A**	

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

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 higher.

These results are in accordance with those reported by Grijalva-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.

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

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