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Effect of irrigation regimes on productivity and water utilization efficiency of three oil olive varieties under drip irrigation system.

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ABSTRACT

A field experiment was conducted over a period of two successive growing seasons 2011and 2012 on 14 years old olive trees cultivated in sandy soil located at El-Bostan area in Ali Mubark experimental farm at south Tahrir region to investigate the effect of two different drip irrigation regimes (Traditional irrigation (TI) and deficit irrigation (DI)) on the productivity and water utilization efficiency of three oil olive cultivars (Olea europaea L.), Arbequina, Shamlali and Koroniki. The experimental design was split plot with three replicates (tree) where each tree has four emitters with discharge of 16 (TI) and 12 (DI) L/hr/emitter. Two applied irrigation water amounts (as mean value for two growing seasons) were used 28.61 and 21.46 m^3/tree/year for TI and DI, respectively. The obtained data showed that fresh fruit weight, fruit and oil yield (as mean value for two growing seasons) were significantly decreased when olive trees subjected to deficit irrigation of the three olives varieties. With respect to olive varieties, the highest mean values of fruit weight were obtained from Arbequina variety (1.62 gm) followed by Koroniki (1.32 gm) while the lowest mean fruit weights were obtained with Shamlali (1.19 gm) variety. The percentage of reduction in fruit yield of trees under DI treatment (as mean value for two growing seasons) were 15.3, 15.1 and 14.2 % as compared to TI regime for Shamlali, Arbequina and Koroniki olive varieties, respectively. The highest mean values of oil percentage (fresh weight basis) were obtained when olive trees subjected to deficit irrigation (DI) and Koroniki variety was the highest in oil percentage (19.52%). The highest values of water utilization efficiency (WUtE) were 2.73, 2.63 and 2.96 kg fresh weight fruit/m^3 and were 0.50, 0.51 and 0.60 kg oil/m^3 under deficit irrigation treatments (DI) (as a mean values of the two growing seasons) for Shamlali, Arbequina and Koroniki olive varieties, respectively.

INTRODUCTION

Egypt has reached that the quantity of water available limits its national economic development. As indication of water scarcity in absolute terms, Egypt has passed the threshold value of 1000 m3/capita/year already in nineties. As a threshold of absolute scarcity 500 m3/capita/year is used, this will be evident with population predictions for 2025 which will bring Egypt down to value of 500 m3/capita/year (Ministry of Water Resources and Irrigation, Egypt, 2014).

When water quantity is limiting, irrigation management must shift from maximizing production per unit area towards maximizing the production per unit of water used or consumed, the water productivity. Deficit irrigation is an important tool to achieve the goal of reducing irrigation water use, thus increasing water utilization efficiency (WUtE). Crop WUtE is an important consideration where irrigation water resources are limited. Additionally, recent increases in energy prices make many irrigated producers asking how to increase their water productivity. There are many factors affected the amount of applied irrigation water for olive trees such as environmental condition, soil type and olive varieties. Due to high diversity of microclimate, rainfall and soil types of olive growing areas, mean seasonal irrigations may range from 180m^3/ha to 2,600m^3/ha (Gucci and Tattini 1997). Goldhamer *et al.,* (1993, 1994), in California, applied 8 irrigation regimes on ‘Manzanillo’ olive trees based on Kc of between 0.16 and 0.85 resulting in annual water applications of between 232 and 1016mm. Abdel Nasser and Harhash (2001) reported that the high rate of B fertilization (200g borax/year) at the high level of irrigation (27 m^3/tree/year) resulted in increasing the all of studied olive growth parameters.

Patumi *et al.,* (1999) evaluated the response of olive cvs Kalamata, Ascolana Tenera, and Nocellara del Belice to four irrigation levels: a rain-fed control (T0) and three treatments (T1, T2 and T3) irrigated daily with an amount of 33%, 66% and 100%, respectively of crop evapotranspiration. They found that irrigation treatments have higher yield than in the rain-fed control. The percent of increases in yield with treatment T1 in `Nocellara del Belice' was 200% compared with the rainfed control and with T2 in `Ascolana tenera' and `Kalamata' the yield was 233% and 47% greater than in the control, respectively. The higher oil yield obtained in the irrigated treatments was mainly due to the increase in fruit yield.

Regulated deficit irrigation (RDI) is a good strategy to save water without major effects on yield (Chalmers *et al.,* 1981) but this approach requires precise knowledge of the crop response to water stress at different physiological growth stages to identify the periods when fruit trees are less sensitive (Fereres and Goldhamer, 1990). In olive trees, water stress in the early growth stages may reduce the yield due to effects on flowering and fruit set (Orgaz and Fereres, 2004).The most resistant to water deficit was occurred at pit hardening in the second phase of fruit development (Goldhamer, 1999). Moriana *et al.,* (2003) compared deficit irrigated trees under continuous deficit irrigation (CDI) and regulated deficit irrigation (RDI) to fully irrigated trees and found that continuous deficit irrigation (CDI) and regulated deficit irrigation (RDI) strategies reduced the ET and consequently the yield and reported that the water use efficiency (WUE) is reduced when the amount of irrigation increases but definitive conclusions on the performance of the two strategies cannot be drawn because ET was different in both deficit irrigation strategies due to different amounts of irrigation applied in CDI and RDI. Iniesta *et al.,* (2009) found that both deficit irrigation strategies, CDI and RDI, caused a higher reduction in olive fruit yield than oil yield due to a higher oil concentration in deficit irrigated trees, without differences between CDI and RDI. Therefore, both irrigation strategies can be used to save a significant amount of irrigation in olive with moderate reductions in oil yield. Lavee *et al*., (1990) found that irrigated olive trees with 75– 200mm in one to three irrigations were effective in increasing yields over rain-fed olives. Another study by Beede and Goldhamer (1994) indicated that mature olive trees irrigated with less than 777 mm were still under water stress. On the other hand, Baratta *et al*., (1986) found that irrigated olive trees with 800–1000mm in season was needed to obtain maximum yield. Also, Zelek *et al*., (2012) investigated the effect of three irrigation regimes, rainfed, R (0% ETc); deficit, D (50% ETc); and irrigated, I (100% ETc) on olive oil content and physical quality parameters of fruits and reported that both D (50% ETc) and I (100% ETc) increase the fruit size of three of the varieties, but had no effect on oil contents compared to rainfed, R (0% ETc) while irrigation water saving was 35% for rainfed, R (0% ETc) treatments compared with the I treatment and the D treatment which resulted in 17.5% water saving with minor effects on fruit size, timing of maturity and oil content. In Spain, Alegre *et al*., (2000) studied the effect of different irrigation regimes (75% , 50% and 0% of ETc) on the yield of the Arbequina cultivar from pit hardening to the beginning of fruit ripening and reported that there is no significant reductions in olive yield.

Many studies has investigated the effect of different strategies of deficit irrigation on olive fruit yield and oil yield and suggested the need for calibrating RDI for each cultivar-environment combination (Goldhamer *et al*., 1994; Patumi *et al*., 1999; Tognetti *et al*. 2006). Anther investigators have shown that irrigation can increase olive fruit yield production (Samish and Spiegel, 1961; Lavee *et al*., 1990; Moriana *et al*., 2003) thereby increasing total oil production per tree. Mitchell and Chalmers (1982) reported that WUtE, expressed as yield per unit applied irrigation water, increased from 4.9 to 8.0 t/ML under RDI in peaches that yielded 48 t/ha. Goldhamer (1999) reported water savings of 25 % for RDI applied to olives trees in California, United States of America, with no reduction in olive fruit yield. Increased WUtE under RDI is due largely to reductions in transpiration, which might be as much as 50 percent (Boland *et al*., 1993b)

Deficit irrigation is a good tool to increase water saving which resulted in increasing water utilization use efficiency (WUtE). Thereby the objective of this study was to investigate the effect of two different irrigation regime: 1- Traditional irrigation (TI) and 2- Deficit irrigation **(DI)** on the fruit fresh weight, olive fruit yield, oil percentage, oil yield and water utilization efficiency (WUtE) for three different oil olive cultivars (Shamlali, Koroniki and Arbequina) in sandy soil under drip irrigation system at south El-Tahrir, El-Bostan region.

MATERIALS AND METHODS

Field experimental site:

Field experiment was conducted in sandy soil under drip irrigation system at El-Bostan area in Aly Mubark experimental farm at south Tahrir region during 2011 and 2012 growing seasons to study the effect of two different irrigation regimes traditional irrigation (TI) which the olive trees received 22.23 m^3/tree/year and about 16.67 m^3/tree/year under deficit irrigation (DI) treatments as a mean values of two growing seasons on the productivity and water utilization (WUtE) of three oil olive cultivars Shamlali, Koroniki and Arbequina. The source of irrigation water were deep well and Nile water according its availability. Soil physical and chemical properties of the experimental site were analyzed according to Jackson, (1973) and Page *et. al*., (1982) and presented in Tables 1and 2.

Table 1. Soil physical properties of experimental site

Soil depth, cm	F.C% *	W.P% *	A.W % *	BD, $gmcm^{-3}$	Particle size distribution, % sand	silt	clay	Soil texture class
0-30	12.1	5.4	6.7	1.55	92.9	2.7	4.4	Sandy
30-60	11.9	5.1	6.8	1.60	91.3	4.6	4.1	Sandy
60-90	10.4	4.2	6.2	1.62	90.5	5.6	3.9	sandy

***On weight basis**

Table 2. Soil chemical properties of experimental site

Soil depth, cm	EC^1, dS/m	pH^2	Soluble cations and anions (meq/L) Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	SO_4^{--}	Cl^-
0-30	0.37	8.6	1.20	0.65	1.60	0.2	-----	1.17	0.64	1.9
30-60	0.33	8.8	1.15	0.50	1.40	0.21	-----	1.03	0.52	1.7
60-90	0.38	8.8	1.20	0.53	1.80	0.22	-----	1.12	0.55	2.1

1-EC in soil past **2- pH in Soil:water extract (1:2.5)**

Experimental treatments:

Field experimental in spilt plot design with three trees as a one replicate was used. The main plots were the olive cultivars while the sub plots were the irrigation treatments. The oil olive cultivars were Shamlali, Koroniki and Arbequina (14 year old trees) in high density olive orchard (6*6 m^2, total number of trees per Feddan equal 116 trees). Irrigation treatments were Traditional irrigation (TI) where each tree has four emitters with discharge of 16 l/hr/emitter which are traditionally used in El-Bostan area and deficit irrigation (DI) where each tree has four emitters with discharge of 12 l/hr/emitter. Irrigation treatments were performed for 3 hr/two days at the summer and Autumn seasons and were 3hr/four days at the winter and spring seasons. Mineral and organic fertilizer and other field practices are done as recommended by Horticulture Crop Research Institute, Agriculture Research Center.

Total yield per tree was measured at harvesting time (the second week of November), a representative sample of 2 kg of fruit per tree was taken to determine fruit characteristics (fruit weight, Fruit oil content). Oil percent was determined according to A.O.A.C (1995). Oil yield (kg/tree) was calculated as follows.

Oil yield (Kg/tree) = Oil % x fruit yield (Kg/tree).

Water Utilization Efficiency (WUtE):

Water utilization efficiencies were calculated according to Jensen (1983) as follows:

WUtE=olive fruit yield (kg/fed)/Applied irrigation water (m3/fed)

WUtE= olive oil yield (kg/fed)/Applied irrigation water (m3/fed)

The obtained data were statistically analyzed using statistical package (CoHort, 1986). The mean values for the three replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test was used for comparisons between different sources of variance according to Steel and Torrie (1984).

RESULTS AND DISCUSSION

Applied irrigation water:

Actual applied irrigation water for each irrigation event are measured and the actual amount of total applied irrigation water for Traditional irrigation (TI) and deficit irrigation (DI) were calculated and illustrated in Table 3. It is clear that the total applied irrigation water for (TI) treatment was 28.61 m^3/tree/year for the two growing seasons while the illustrated total applied irrigation water for (DI) treatment was 21.46 m^3/tree/year for the two growing seasons (Table 3).

Table 3. Amount of applied irrigation water (AIW) in m^3/tree/month for the three olive cultivars under Traditional irrigation (TI) and deficit irrigation (DI) for 2011and 2012 growing seasons.

Month	Applied irrigation water			
	2011		2012	
	TI	DI	TI	DI
January	1.92	1.44	1.92	1.44
February	1.73	1.30	1.73	1.30
March	1.92	1.44	1.92	1.44
April	1.92	1.44	1.92	1.44
May	2.88	2.16	2.88	2.16
June	2.88	2.16	2.88	2.16
July	2.88	2.16	2.88	2.16
Augusts	2.88	2.16	2.88	2.16
September	2.88	2.16	2.88	2.16
October	2.88	2.16	2.88	2.16
November	1.92	1.44	1.92	1.44
December	1.92	1.44	1.92	1.44
Total (m^3/tree/year)	28.61	21.46	28.61	21.46
Applied irrigation water (m^3/feddan/year)	3318.8	2489.1	3318.8	2489.1

The maximum rate of applied irrigation water applied were during Summer and Autumn seasons and declined during Winter and Spring seasons. These results are agreed with Abdel- Nasser and Harhash (2001), Beede and Goldhamer (1994) and Barratla et. al., (1986).

Fresh fruit weight, oil percentage, fruit and oil yield

Data in Table 4 showed that the mean values of fresh fruit weight, fruit yield, oil percentage (fresh weight basis) and oil yield of the three olive varieties as affected by irrigation regime during 2011 and 2012 growing season. It is clear that, all studied parameters were significantly decreased with decreasing applied irrigation water except oil percentage of the three varieties, the highest mean values of fruit weight were obtained from trees with TI treatments and the fruit weight significantly decreased with DI treatments. With respect to olive varieties, the highest values of fruit weight were obtained from Arbequina varieties followed by Koroniki while the lowest fruit weights were obtained with Shamlali variety. The highest mean values of fruit yield were 75.00, 69.62 and 67.33 kg/fruit/tree for Koroniki, Shamlali and Arbequina olive varieties, respectively during the first season. Whereas during the second season, the highest mean values were 73.00, 68.67 and 65.33 kg/tree for the same varieties, respectively. These highest values of fruit yield were obtained from trees with TI treatments. Increasing the amount of applied irrigation water has been reported to increase olive fruit yield (Samish and Spiegel, 1961, Patumi *et al.*, 1999, Grattan *et al.*, 2006, lniesta *et al.*, 2009). The same trend was observed in oil yield. Many studies showed that olive oil percentage were increased with deficit irrigation than traditional irrigation (Lavee *et al.*, 1990, Goldhamer *et al.*, 1994 and Tognetti *et al.*, 2006).

The percentage of reduction in fruit yield of tree under DI treatment were 15.7, 15.8 and 14.2% for Shamlali, Arbequina and Koroniki olive varieties, respectively during the first growing season whereas during the second growing season, the percentages of reduction in fruit yield were 15.1, 14.3 and 14.2 % for the same varieties, respectively.

The highest values of oil percentage (fresh weight basis) were obtained from trees under DI treatments. With respect to olive varieties, the highest values of oil percentage were obtained from Koroniki variety. Similar results have been reported by Greven *et al.*, (2009) and Melgar *et al.*, (2008) where, they reported that the higher oil yield in rain-fed olive trees is thought to be coupled with lower water contents in fruits of the olive trees, respect to irrigated ones.

Table 4. Fruit weight (g), fruit yield (kg/tree), oil percentage (%), and oil yield kg/tree for Shamlali, Arbequina and Koroniki olive varieties as affected by irrigation regimes during the two growing seasons 2011 and 2012.

Irrigation regime	varieties	2011				2012			
		Fruit weight	Fruit yield	Oil,%	Oil yield	Fruit weight	Fruit yield	Oil,%	Oil yield
Traditional irrigation (TI)	Shamlali	1.28	69.62	17.20	11.93	1.29	68.67	17.40	11.96
	Arbequina	1.67	67.33	18.63	12.53	1.80	65.33	17.90	11.70
	Koroniki	1.40	75.00	19.33	14.50	1.54	73.00	18.37	13.40
Mean of TI		1.45a	70.65a	18.39a	12.99a	1.54a	69.00a	17.90	12.35a
Deficit irrigation (DI)	Shamlali	1.13	58.67	18.23	10.73	1.06	58.33	18.57	10.88
	Arbequina	1.46	56.67	19.87	11.29	1.523	56.00	19.03	10.58
	Koroniki	1.23	64.33	20.63	13.31	1.30	62.67	19.73	12.38
Mean of DI		1.28b	59.89b	19.58a	11.77a	1.30b	59.00b	19.11a	11.28b
Mean of varieties	Shamlali	1.21b	64.00ab	17.72b	11.33b	1.18c	63.50ab	17.98b	11.42b
	Arbequina	1.57a	62.00b	19.25a	11.91b	1.67a	60.67b	18.47a	11.14b
	Koroniki	1.32b	69.76a	19.98a	13.90a	1.42b	67.83a	19.05a	12.89a
LSD0.05 for varieties		0.18	5.80	1.45	1.69	0.17	5.94	0.87	1.11
LSD0.05 for irrigation		0.14	4.74	1.18	1.38	0.14	4.85	0.71	0.96

Water utilization use efficiency (WUtE):

Table 5 shows water utilization efficiency (WUtE) for Shamlali, Arbequina and Koroniki olive varieties as affect by irrigation regimes during the two growing seasons 2011 and 2012 expressed as fruit or oil yield per cubic meter of applied irrigation water. Data showed that the highest values of WUtE for the first growing season under DI treatments were 3.523, 3.403and 3.863 kg fresh weight fruit/m^3 and were 0.644, 0.678 and 0.799 kg oil per cubic meter of applied irrigation water for Shamlali, Arbequina and Koroniki olive varieties, respectively. With respect to olive varieties the highest values of WUtE were recorded by Koroniki variety, the same trend was observed for the second growing season. Many studies reported that deficit irrigation increased WUtE for many fruit trees (Mitchell and Chalmers 1982, Goodwin *et al.*, 1998, Boland *et al.*, 1993b, and Goldhamer 1999).

Table 5. Water utilization efficiency (WUtE) for Shamlali, Arbequina and Koroniki olive varieties as affect by irrigation regimes during the two growing season 2011 and 2012.

Irrigation regime	varieties	Applied irrigation water ,m^3/fed	Fruit yield, kg/fed	Oil yield, kg/fed	WUtE Kg fruit/m^3	WUtE Kg oil/m^3
First growing season, 2011						
Traditional irrigation (TI)	Shamlali	3318.8	8075.92	1383.88	2.43	0.42
	Arbequina	3318.8	7810.28	1453.48	2.35	0.44
	Koroniki	3318.8	8700.00	1682.00	2.62	0.51
Deficit irrigation (DI)	Shamlali	2489.1	6805.72	1244.68	2.73	0.49
	Arbequina	2489.1	6573.72	1309.64	2.64	0.53
	Koroniki	2489.1	7462.28	1543.96	2.99	0.62
Second growing season, 2012						
Traditional irrigation (TI)	Shamlali	3318.8	7965.72	1387.36	2.40	0.42
	Arbequina	3318.8	7578.28	1357.20	2.28	0.41
	Koroniki	3318.8	8468.00	1554.40	2.55	0.47
Deficit irrigation (DI)	Shamlali	2489.1	6766.28	1262.08	2.72	0.51
	Arbequina	2489.1	6496.00	1227.28	2.61	0.49
	Koroniki	2489.1	7269.72	1436.08	2.92	0.58

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تأثير معدلات مختلفة من الرى على إنتاجية وكفاءة إستخدام المياه لثلاثة أصناف من الزيتون تحت نظام الرى بالتنقيط

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تمت هذه الدراسة خلال موسمى النمو ٢٠١١-٢٠١٢ بمزرعة على مبارك التابعة لمركز البحوث الزراعية جنوب التحرير(أراضى رمليه) لدراسة تأثير الرى على إنتاجية و كفاءة إستعمال المياة لعدد ٣ أصناف من الزيتون لانتاج الزيت عمرهذه الأشجار ١٤ سنة وكانت مسافات الزراعه ٦م*٦ م بإجمالى ١١٦ شجرة للفدان تحت نظام الري بالتنقيط فى تصميم القطع المنشقة مرة واحدة فى ٣ مكررات(إجمالى عدد الأشجار للمكررة الواحدة ٣ شجرات) حيث إشتملت المعاملات الرئيسية على ٣ أصناف هى شملالى وأربيكوين وكروناكى بينما كانت المعاملات التحت رئيسية هى الرى بالعجز و الرى التقليدى وتم تنفيذ معاملات الري بإستخدام ٤ نقاطات لكل شجرة وتم إستخدام نوعين من النقاطات مختلفة التصرف وكان تصرف النقطات ١٢ و ١٦ لتر/ساعه لمعاملات الرى بالعجز (DI) و الري التقليدى ((TI) على التوالى وكانت اهم النتائج المتحصل عليها كمتوسط للموسمين :-كانت كميات المياه المضافة هى ٢٨.٦١ و ٢١.٤٦ م ٣ /شجرة/سنه (متوسط الموسمين) لمعاملات الرى التقليدى و الرى بالعجز على التوالى. تم الحصول على أعلى متوسط لوزن الثمره الرطب ١.٧٤ جم/ثمره للصنف اربيكوين بينما كان اقل وزن ١.٢٨٥ جم/ثمرة للصنف شملالي بينما أدى إنخفاض كمية المياة المضافة الى إنخفاض معنوى فى متوسط الوزن الرطب للثمرة للأصناف الثلاثة من ١.٤٩٧ الى ١.٢٨٥ جم/ثمرة (متوسط الموسمين).تم الحصول على أعلى متوسط امحصول الثمار الطازج ٧٤.٠٠ كجم ثمار/شجرة للصنف كروناكى بينما كان أقل متوسط لمحصول الثمار هو ٦٦.٣٣ كجم/شجرة للصنف اربيكوين بدون فرق معنوى عن الصنف شملالى ٦٩.١٥ كجم/شجرة(متوسط الموسمين) تحت تأثير الري التقليدى.كانت اعلى نسبة للزيت على أساس الوزن الرطب للصنف كروناكى ١٨.٨٥% وبدون فرق معنوي عن الصنف أربيكوين ١٨.٢٧% وأقل نسبة للزيت للصنف شملالى بمتوسط ١٧.٣٠% وادى أنخفاض كمية المياه المضافة الى زيادة معنوية فى متوسط نسبة الزيت للثمار للأصناف الثلاثة من ١٨.١٤ % إلى ١٩.٣٤% على أساس الوزن الرطب(متوسط الموسمين).كان أعلى محصول للزيت ١٦١٨.٢ كجم زيت/فدان للصنف كروناكى بالمقارنة بالصنفين أربيكوين وشملالى وبدون وجود فرق معنوى بينهما وكذلك ادى انخفاض كمية المياة المضافة الى إنخفاض معنوى فى متوسط محصول الزيت(متوسط الموسمين).أعلى قيمة لكفاءة إستعمال مياه الرى WUtE كانت ٢.٧٨، ٢.٦٣، ٢.٩٦ كجم ثمار طازج أو ٠.٥٠، ٠.٥١، ٠.٦٠ كجم زيت لكل متر مكعب من مياه الرى المضافة للأصناف الثلاثه شملالى وأربيكوين وكروناكى على التوالى(متوسط الموسمين) تحت تأثير الرى بالعجز (DI).مماسبق يتضح أهمية زراعة الصنف المناسب للمنطقة مثل كروناكى و الذى يعطى أعلى محصول زيت وهو أقل الأصناف إنخفاضا فى محصول الثمار الطازج والزيت عند تعرض المحصول للإجهاد المائى عن طريق النقص فى كمية مياه الرى المضافة وكذلك يعطى أعلى اعلى كفاءة إستعماليه لكميات المياه المضافة.