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Water Use, Water Use Efficiency, Crop Coefficient and Yield of Olive Trees as Affected by Irrigation Regimes

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ABSTRACT. Two field experiments were carried out during two successive seasons of 1991 and 1992 under the conditions of Fayoum governorate, Egypt. The objective was to study the water use (WU), water use efficiency (WUE), crop coefficients (Kc) and yield of three olive cultivars namely Mission, Dermellaly and Khodairy at three irrigation regimes (60%, 40% and 20% of available soil water).

When trees were irrigated at 60% available soil water, Kc values were 0.70, 0.69 and 0.68 for Mission, Dermallaly and Khodairy cvs, respectively. These crop coefficients indicated that Mission cultivar, had the largest water use (4830 m^3/acre/year) followed by descending order by Dermallaly cultivar (4755 m^3/acre/year) and Khodairy cultivar (4726 m^3/acre/year). The highest yield was achieved on the trees irrigated at 60% available soil water, whereas the lowest yield was obtained with trees irrigated at 20% available soil water and crop coefficients (Kc) was 0.55 for the three olive cultivars used in this study.

Introduction

Water is a limited resource in many areas of the world therefore management technologies to improve the water use are needed. The amounts and quality of irrigation water available in many of the arid and semi-arid regions of the world, are the main limiting factors for the extension of agriculture. Several results in which water use was linked to tree growth and water availability are reported (Stevenson, 1989; Devitt *et al.,* 1994; Hassan and Seif, 1997).

Because water conservation is an important concern, a combination of management practices is needed, coupled with the selection of species and cultivars with low evapotranspiration (ET) rates (Beard *et al.,* 1992).

Reference evapotranspiration (ET) incorporates the climatic factors influencing water requirements into a single measurements (Hansen *et al.,* 1980) and has been used to schedule irrigation for several crops (Jensen and Middleton, 1970 and Hassan and Seif, 1997). The crop coefficient (Kc) has been used for quantifying crop water use (Doorenbos *et al.,* 1979).

The purpose of this study was to determine the actual water use, water use efficiency, crop coefficients (Kc) and yield for three olive cultivars grown in Fayoum governorate, Egypt.

Materials and Methods

This investigation was carried out during 1991 and 1992 seasons on three olive cultivars namely, Mission, Khodairy and Dermellaly cvs grown in Fayoum governorate, Egypt. Three irrigation treatments 60%, 40% and 20% of the available soil water were used in this study. The olive trees were 25-year-old rather uniform in shape and size, planted at 7× 7 m apart and grafted on Chemlali rootstock. The experiment was designed as a factorial experiment in a randomized complete block design (Snedecor and Cochran 1980). The soil texture was loamy, the physical characteristics of the soil are shown in (Table 1).

TABLE 1. Physical properties and soil water constants.

Depth cm	F.C. %	W.P. %	A.W. %	Db. g/cm^3	Particle size distribution			Textural class
					Sand %	Silt %	Clay %	
0-30	32.23	12.15	20.08	1.23	47.97	40.25	11.78	Loamy
30 - 60	25.98	10.15	15.83	1.35	46.97	41.80	11.23	

The calculation of reference evapotranspiration (ET) was made using the modified Penman method (Doorenbos *et al.,* 1979). ET data were collected from a weather station located in Fayoum and used to calculate daily ET. Water use of olive trees was measured by soil moisture measurements (gravimetric method). Soil samples were collected from different locations at a depth of 0-60 cm from the soil surface, before and after irrigation. Amounts of water use (WU) were determined according to Israelsen and Hansen (1962). Crop coefficient (Kc) was calculated using the equation :

Kc = WU / ET (Doorenbos *et al.,* 1979) where WU = water use and ET = reference evapotranspiration. Water use efficiency is defined as kilograms of fruits per one cubic meter of water consumed and was calculated for each cultivar.

At harvest time (mid-September), yield of each tree was determined as kg of fruits/tree.

Results and Discussion

Reference evapotranspiration (ET), mm/month of Fayoum governorate during 1991 and 1992 seasons increased gradually from January up to June, then decreased till December (Fig. 1). Besides, the lowest values of ET were obtained during December and January. While the highest values were achieved in June. The increment of reference evapotranspiration during summer time may be attributed to high temperature, wind speed, net radiation and lower values for relative humidity (Abd El-Samed, 1995).

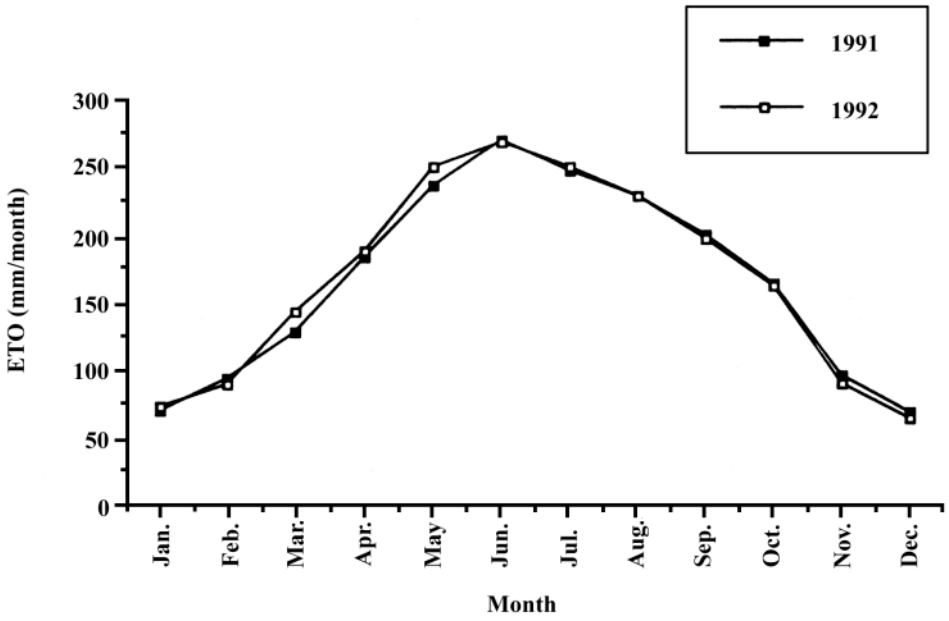

FIG. 1. Monthly reference evapotranspiration in Fayoum governorate during 1991 and 1992 seasons.

Results presented in Table (2) revealed that water use of olive trees was affected by different irrigation regimes and cultivars. Water use was increased by increasing available soil water. The highest values were obtained when trees were irrigated at 60% available soil water (4678 and 4863 m^3/acre in seasons 1991 and 1992, respectively). On the other hand, trees irrigated at 20% available soil water (water stress) showed the lowest values of water use (3742 and 3870 m^3/acre in 1991 and 1992 respectively). Trees irrigated at 40% available

soil water gave a middle values. Mission cultivar recorded the highest values of water use than other cultivars (Table 2). This may be attributed to the higher tree size of Mission trees than those of other cultivars. Similar results in which water use was linked to tree size and water availability are reported (Stevenson, 1989 and Devitt *et al.,* 1994).

TABLE 2. Water use (m^3/acre/year) of three olive cultivars as affected by irrigation regimes during 1991 and 1992 seasons.

	Available soil water		
	60%	40%	20%
Olive cultivar	**1991**		
	m^3/acre	m^3/acre/	m^3/acre
Mission	4753	4140	3753
Dermallaly	4662	4087	3752
Khodairy	4619	4061	3721
Mean	4678	4096	3742
1992			
Mission	4906	4323	3900
Dermallaly	4848	4277	3874
Khodairy	4833	4272	3835
Mean	4863	4291	3870

Data in Figs. (2 and 3) revealed that water use (mm/month) was increased gradually from March up to June, then decreased towards October. Whereas, the maximum values were obtained in June. This increase was due to the development of shoots, flowers, small fruits and evaporative demand. Meanwhile, the lowest values were detected during March and October. This trend was observed for all cultivars and irrigation regimes in the two successive seasons. Similar results are reported for olive trees by Michelakis and Vougloucalou (1988) and by Chartzoulakis *et al.,* (1992). Monthly water use for olive trees varied from one month to another.

Data in Table (3) showed crop coefficients (Kc) for olive trees as affected by irrigation regimes during 1991 and 1992 seasons. Kc decreased by increasing the rate of water stress. Therefore, the lowest values were detected when trees where irrigated at 20% available soil water, where Kc mean value was 0.55 for all cultivars. The highest Kc values were obtained when trees were irrigated at 60% available soil water. Kc values provide a method of adjusting the water-use rates

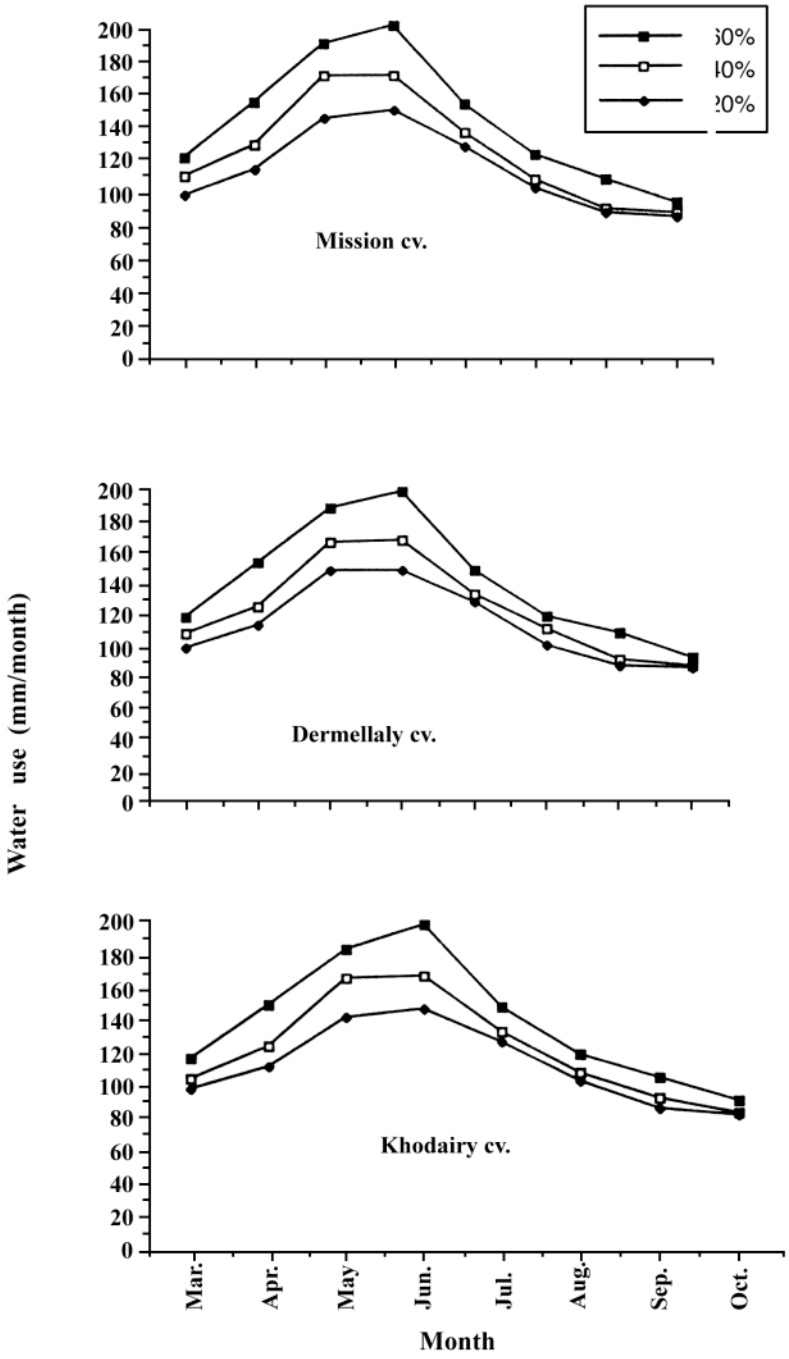

FIG. 2. Water use of three olive cultivars as affected by irrigation regimes under Fayoum conditions during 1991.

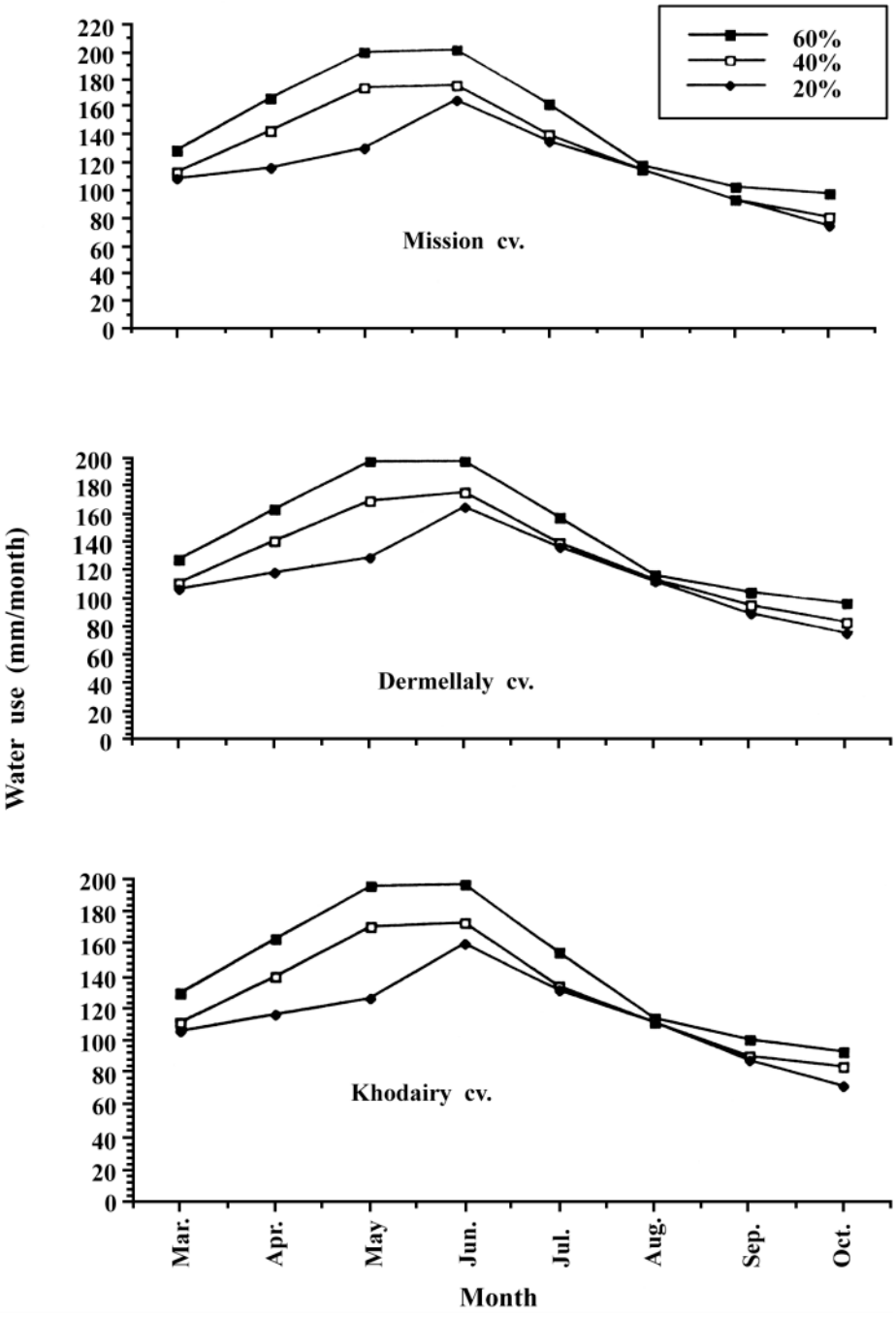

FIG. 3. Water use of three olive cultivars as affected by irrigation regimes under Fayoum conditions during 1992.

to compensate for the variation in climatic conditions that influences evaporative demand (Caspari *et al.,* 1994 and Levitt *et al.,* 1995). The increase in Kc was recorded during March and April. This may be attributed to several factors such as low temperature and net radiation with high relative humidity which seemed to play a role in reducing ET. Water use can be predicted by use of crop coefficient (Kc) the differences between cultivars in crop coefficient were found only with the high available soil water (Table 3). The crop coefficient (Kc) indicated that Mission cv. had more water use than Dermallaly cv. and the lowest was Khodairy cv. under high available soil water. However, the three cultivars had the same value of Kc when trees irrigated at 20% available soil water. Similar findings were found for some landscape tree species (Levitt *et al.,* 1995).

TABLE 3. Crop coefficient (Kc) of three olive cultivars as affected by irrigation regimes during 1991 and 1992.

	Mission			Dermallaly			Khodairy		
Month	Available soil water			Available soil water			Available soil water		
	60%	40%	20%	60%	40%	20%	60%	40%	20%
1991									
Mar.	0.94	0.85	0.76	0.92	0.84	0.76	0.91	0.81	0.76
Apr.	0.84	0.69	0.61	0.38	0.67	0.61	0.81	0.67	0.60
May	0.80	0.71	0.60	0.79	0.70	0.62	0.77	0.70	0.60
Jun.	0.74	0.63	0.55	0.73	0.62	0.55	0.73	0.61	0.54
Jul.	0.61	0.54	0.51	0.59	0.53	0.51	0.59	0.53	0.50
Aug.	0.53	0.46	0.44	0.51	0.48	0.43	0.52	0.47	0.45
Sep.	0.53	0.44	0.43	0.53	0.44	0.43	0.52	0.45	0.42
Oct.	0.57	0.53	0.51	0.55	0.52	0.51	0.55	0.51	0.50
Mean	0.69	0.61	0.55	0.68	0.60	0.55	0.67	0.59	0.55
1992									
Mar.	0.89	0.79	0.75	0.88	0.77	0.74	0.91	0.78	0.74
Apr.	0.88	0.76	0.61	0.86	0.74	0.62	0.86	0.74	0.61
May	0.80	0.69	0.52	0.79	0.68	0.51	0.79	0.69	0.51
Jun.	0.75	0.65	0.61	0.73	0.65	0.61	0.73	0.65	0.60
Jul.	0.64	0.56	0.53	0.63	0.55	0.54	0.63	0.54	0.53
Aug.	0.51	0.50	0.50	0.51	0.50	0.49	0.50	0.49	0.49
Sep.	0.51	0.47	0.47	0.53	0.48	0.44	0.51	0.46	0.45
Oct.	0.60	0.49	0.45	0.59	0.51	0.47	0.58	0.52	0.45
Mean	0.70	0.61	0.55	0.69	0.61	0.55	0.69	0.61	0.55

Yield per tree for all olive cultivars was significantly increased by increasing available soil water (Table 4). Therefore, the highest yield was achieved on the trees irrigated at 60% available soil water, and the lowest yield was obtained with trees irrigated at 20% available soil water. The low yield may be due to the

low flower density in the two seasons (Abd El-samed, 1995). Khodairy cultivar gave the highest yield per tree followed by Dermallaly then Mission (Table 4). Lavee *et al.,* (1990) found that the yield per olive tree was doubled on irrigated trees compared with non-irrigated trees. The best water use efficiency for olive production was obtained when trees were irrigated at 60% available soil water (Table 4). Our results indicated a higher water use efficiency for Khodairy cv. than Dermallaly and Mission cultivars.

TABLE 4. Yield and water use efficiency of three olive cultivars as affected by irrigation regimes during 1991 and 1992 seasons.

Olive cultivar	1991				1992			
	Available soil water				Available soil water			
	60%	40%	20%	Mean	60%	40%	20%	Mean
Olive yield (kg fruits/tree)								
Mission	58.67a	38.67a	29.33a	42.22B	67.67a	47.67a	24.33a	46.56B
Khodairy	76.00a	59.67a	44.33a	60.00A	79.67a	60.33a	39.33a	59.78A
Dermallaly	61.33a	47.33a	24.33a	44.33B	60.00a	52.67a	23.33a	47.33B
Mean	65.33A	48.56B	32.66C		71.11A	53.56B	28.99C	
Water use efficiency (kg fruits/m^3 water)								
Mission	1.05a	0.8a	0.67a	0.84B	1.19a	0.95 a	0.54a	0.89B
Khodairy	1.42 a	1.25a	1.02a	1.23A	1.41a	1.22a	0.88a	1.17A
Dermallaly	1.13a	0.99a	0.56a	0.89B	1.17a	1.06a	0.52a	0.92B
Mean	1.20A	1.01B	0.75C		1.26A	1.08B	0.65C	

Means of cultivars, treatments or interactions followed by the same letters are not significantly affected at P = 0.05 according to Duncan multiple range test.

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تأثير رجيم الرى على الاستخدام المائي وكفاءة استخدام الماء ومعامل المحصول والإنتاج لأشجار الزيتون

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المستخلص . تم إجراء التجارب الحقلية خلال موسمين متتالين (١٩٩١و١٩٩٢) تحت ظروف الحقل بمحافظة الفيوم ، مصر . ويهدف البحث إلى دراسة : الاستخدام المائي وثوابت المحصول وكفاءة الماء المستخدم والمحصول لأشجار ثلاثة أصناف من الزيتون هي الميشين ، الخضيري والدرميلالي تحت ثلاث مستويات من الرى وهى ٢٠٪ ، ٤٠٪ و ٦٠٪ من الماء الميسر للتربة .

وأوضحت النتائج أنه عند ري أشجار الزيتون بالمعاملة ٦٠٪ من الماء الميسر في التربة ، كانت قيم ثوابت المحصول هي ٠,٧ ، ٠,٦٩ و ٠,٦٨ للأصناف : الميشن ، الدرميلالي والخضيرى على الترتيب . وقد أظهرت ثوابت المحصول أن الصنف الميشن كان الأعلى احتياجا للماء المستخدم (٤٨٣٠ م^3/ إيكر/ السنة) يليه الدرميلالي (٤٧٥٥م^3/ إيكر/ السنة) بينما كان الخضيري هو الأقل في قيم الماء المستخدم (٤٧٢٦م^3/ إيكر/ السنة) وقد أعطت معاملة الري ٦٠٪ من الماء الميسر أعلى محصول ، بينما أقل محصول متحصل عليه كان من معاملة الري بـ ٢٠ ٪ من الماء الميسر بالتربة وكانت ثوابت المحصول ٠,٥٥ لجميع أصناف الزيتون الثلاثة المستخدمة في هذه الدراسة .