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SEASONAL WATER USE OF DATE PALMS IN THE CENTRAL REGION OF SAUDI ARABIA

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ABSTRACT

A field experiment was conducted to investigate the response of date palm trees, of Seleg cultivar, to different water regimes (50, 100 and 150% of pan evaporation rate), using three irrigation methods: basin, bubbler and trickle irrigation systems. The study was conducted during four successive years (1991 through 1994). The results of this study demonstrated the general trend of yield increase as irrigation quantity increases. The maximum yield was produced from palm trees irrigated with the trickle irrigation system followed by the basin method. The water use efficiency was found to be maximum for trickle irrigated plots followed by the basin plots.

Keywords: *Date palms, crop water use, water use efficiency, trickle irrigation, bubbler irrigation*

1. INTRODUCTION

Date palm tree (*Phoenix dactylifera, L*) is one of the main fruit trees in the Kingdom of Saudi Arabia. The tree is popular in the country and the total number of date palms are about 18.2 million, and is increasing every year. Its production has also increased to reach more than 0.6 million tons per year in 1996, grown in an area exceeding 95 thousand hectares (MAW, 1997). The date palm is a drought resistant and salt tolerant plant. It can tolerate soil salinity up to 4 dS/m without reduction in yield (Ayers and Westcot, 1985). The rooting depth of date palm ranges from 1.5 to 2.5 meters (Doorenbos and Pruitt, 1977), however, 65 to 80% of water is absorbed by roots within 1.2 meter depth (Yaaqoob, 1996). Date palm tree is usually irrigated by basin method, delivering an abundant amount of water based primarily on a farmer's experience. The annual water requirements for a mature date palm range between 115 and 306 cubic meters (1.15 - 3.06 m/ha) (Al-Baker, 1972). If the present trend of palm expansion continues, a considerable amount of irrigation water will be required. However, due to the limited availability of water resources in the Kingdom, the introduction of some water conservation measures, such as modern irrigation systems (trickle and bubbler), is necessary. Thus, the evaluation study of tree water use is important, as this will lead to accurate application of water to eliminate waste.

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The estimate of palm tree water use could also be made from data of other areas of similar climate, such as Al-Hassa (eastern region of Saudi Arabia) (Hussein, 1986; Hilal et al., 1986), Southern California (Furr, 1975), Egypt (Hussein and Hussein, 1982), and Iran (Furr, 1975). Studies on irrigation frequencies have shown that, for palm trees, low frequency and large volume of water per irrigation were more favorable (Hilal et al., 1986). As a result of a study on 'Sakkoti' date palm cultivar at Aswan, it was suggested that an irrigation interval of four weeks applying 71 mm per irrigation is the most suitable (Hussein and Hussein, 1982). Reuveni (1971, 1974) studied the effect of trickle as compared to sprinkler irrigation on growth and yield of date palms. He concluded that trickle irrigation has definite advantages over sprinkler irrigation as the trickle irrigated tree could be grown with limited wetted volume of soil. Experiments have shown significant increase in leaf, flower and fruit production in trickle irrigated palm as compared to sprinkler. The yield of drip irrigated palm trees was significantly higher than those irrigated by sprinklers. A comparison between trickle and bubbler irrigation systems has shown that salt accumulation may be higher in the surface layer for trickle as compared to bubbler (Nimah, 1985).

The efficiency of crop water use (water use efficiency) becomes important when the irrigation water is limited. The water use efficiency is known as the biological ratio of the amount of water used in crop production to produce yield (Howell et al., 1992). Its value could be estimated as the yield function divided by the total water input:

$$WUE = Y_L(W) / W \qquad \ldots (1)$$

where WUE = water use efficiency
$Y_L(W)$ = yield as a function of water applied

The water use efficiency could also be estimated as the yield function divided by the crop evapo-transpiration.

Due to the lack of studies on palm tree water use in the central region of Saudi Arabia, there is a need for research to investigate water requirements and to evaluate the practicality and efficiency of using new irrigation methods such as trickle and bubbler systems on date palm tree agriculture.

The main objective of this research was to investigate the yield response of date palm trees to different irrigation methods (basin, bubbler and trickle) and water regimes (50, 100 and 150% of pan evaporation rate). The specific objectives of this work are to determine the water consumption of date palm trees under different irrigation methods and moisture regimes, and to estimate the water use efficiency of date palms.

2. METHODS AND MATERIALS

The experiments were carried out for four successive years (1991 to 1994) at the College of Agriculture experimental station at Dirab, near Riyadh city, on 27 palm trees (seleg cultivar). The twelve year old palms were grown in sandy loam soil (74% sand, 16% silt and 10% clay; $CaCO_3$: 26.4%, O.M.:0.13%, Ec_e: 2.4 dS/m, bulk density: 1.55

gm cm^{-3}). Trees were planted in three rows with ten meter spacing between the rows. The area was divided into three blocks, each subdivided into three plots comprising three replicates each. An irrigation method, basin, bubbler or trickle was assigned to each block. Each block was subjected to three irrigation treatments based on evaporation losses (E) estimated by class A pan (USWB), at 50, 100 and 150% E. Evaporation rate data throughout the period of the experiment are shown in Fig. 1. Water was monitored through simple current meters, located at each plot and near the water source (at pumping station), as shown in Fig. 2.

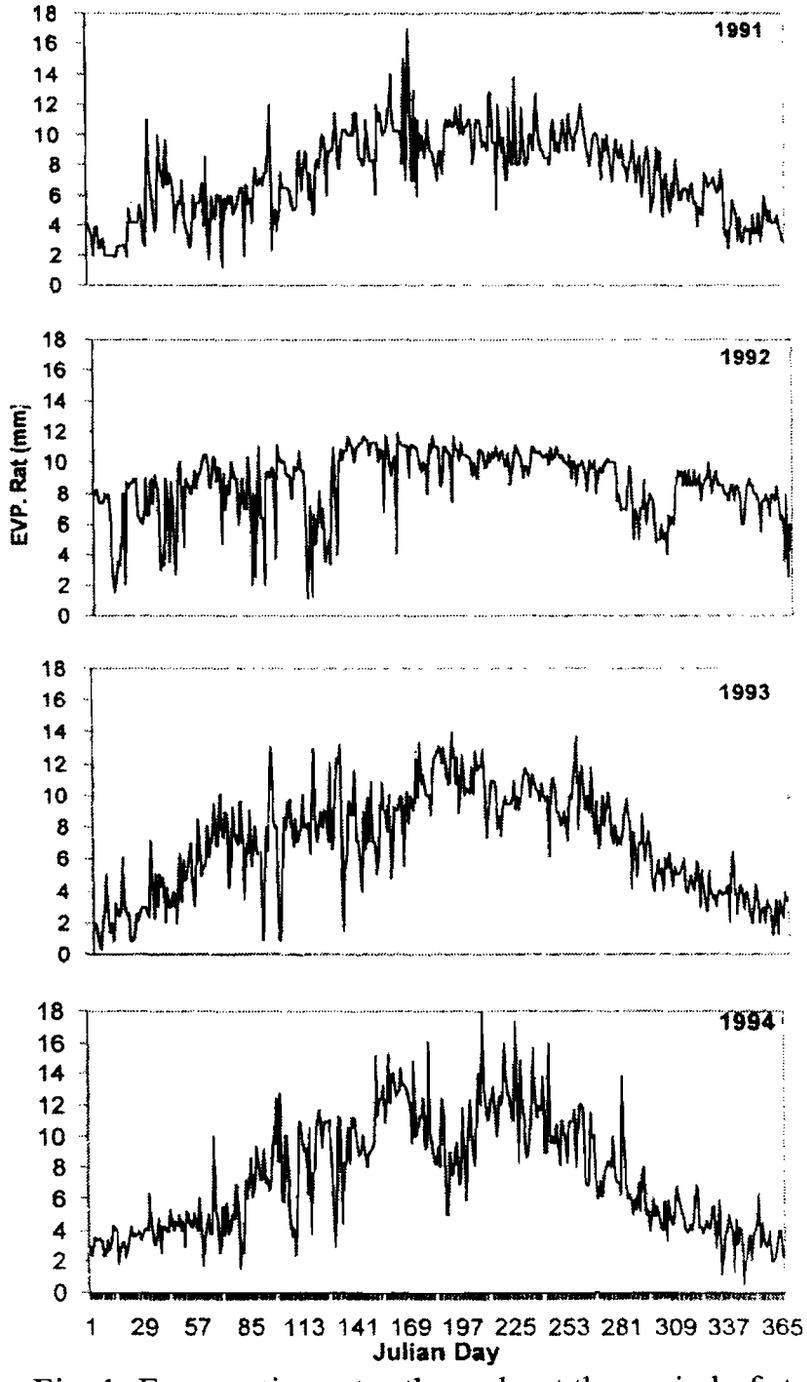

Fig. 1: Evaporation rates throughout the period of study

Water was delivered to irrigation plots from two interconnected water tanks, using two 3.73 KW pumps installed in series to maintain 300 Kpa operating pressure throughout the irrigation system. The water tanks were of six cubic meter capacity each and fed from an adjacent ground water well.

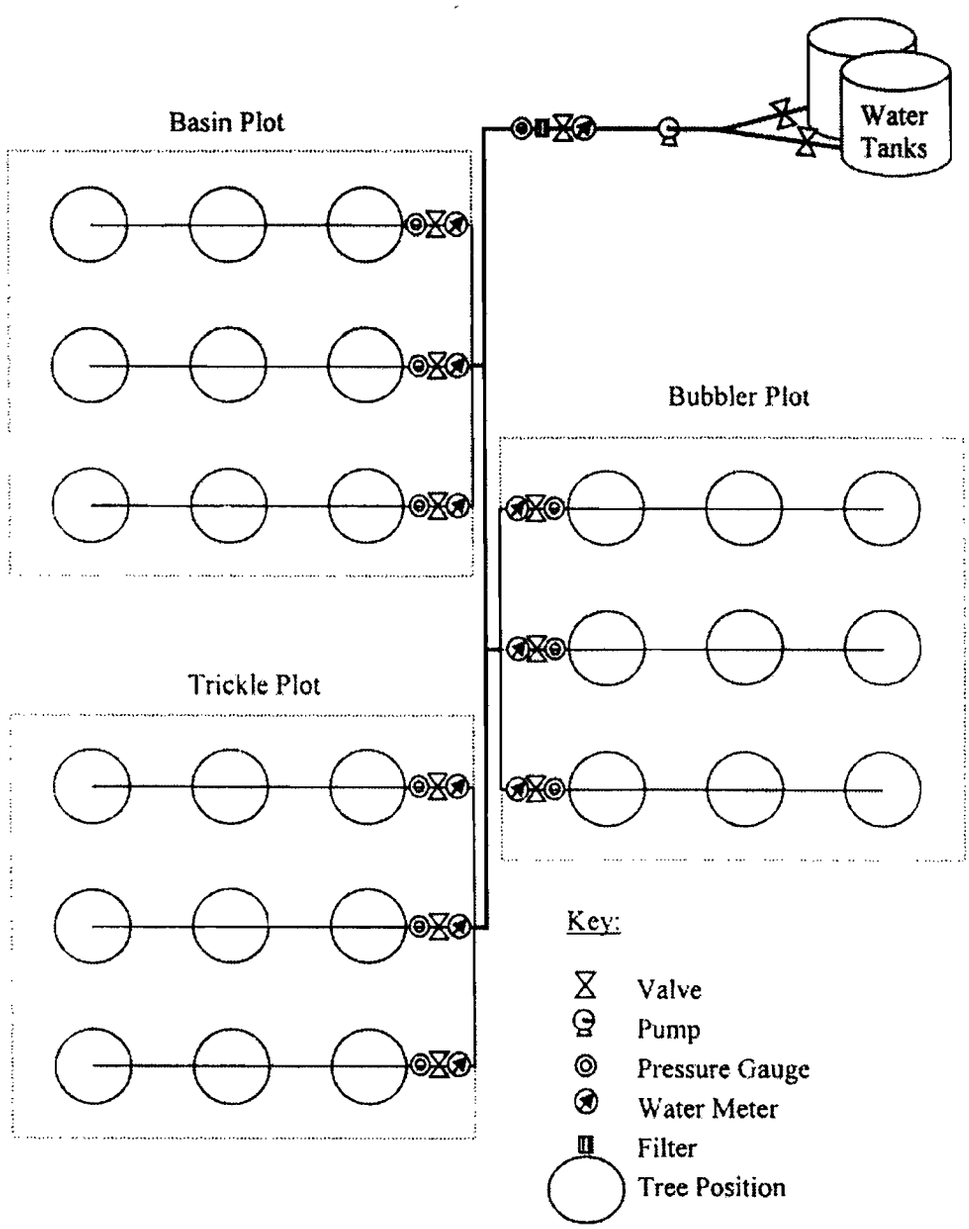

Fig. 2: Irrigation layout of date palm experiment

To ensure uniform distribution in all plots, pipes of 25 mm diameter were used for the pipe network. Palm trees in bubbler plots were designed to receive water from two bubblers at a flow rate of 227 liters per hour. Similarly, two adjustable emitters were used to irrigate every tree in the trickle treatment plots. Both bubblers and emitters selected for the experiment were of the pressure compensating type to further ensure uniform distribution of irrigation water within each plot. Basin water treatments, on the other hand, were designed to receive water from a tab into a three meter diameter basin surrounding each tree. Pressure was monitored throughout the experiment using Bourdon gauges installed at the upstream of each line (feeding three trees), and at the

pumping station. Irrigation frequency was based on two-week periods. However, during spring and summer seasons, one week irrigation frequency was decided following the local scheduling practice. Fertilizer application was kept the same for all the trees in accordance with farm management practices for palm trees.

Data of the four years and their averages were analyzed as a randomized complete block design with split plot arrangement, the irrigation methods assigned to the main plots and the water treatments are the sub-plots. Duncan multiple range test was used (Steel and Torrie, 1984) to test treatment means for the four year averages.

3. RESULTS AND DISCUSSION

Monthly crop water consumption per tree for the various water treatments and irrigation methods for 1991 through 1994 are shown in Fig. 3. Equations based on regression analysis relating total water delivered per tree to the month of the season for each year and water inputs are given in Table 1.

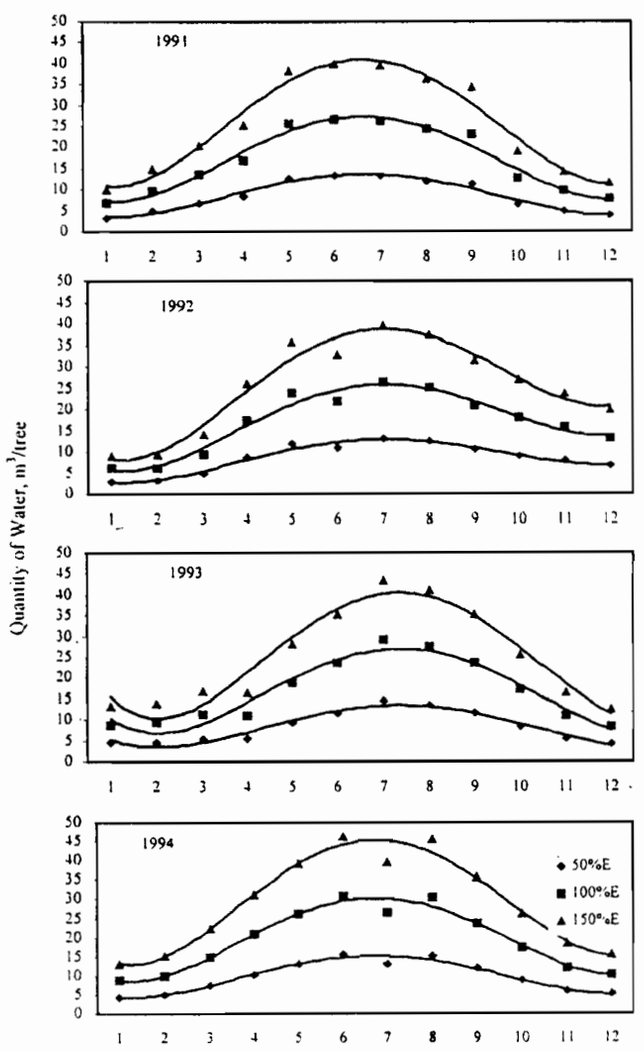

Fig. 3: Monthly distribution of date palm tree water consumption

Table 1: Coefficients of regression equations of the four years of study and at different water treatments

Expr. year	Water Treatment	Equation form: $W=ax^4+bx^3+cx^2+dx+e^*$					
Year		a	b	c	d	e	R^2
	50%E	0.0117	-0.310	2.3788	-4.4372	6.0178	0.9669
1991	100%E	0.0235	-0.619	4.7576	-8.8745	12.036	0.9669
	150%E	0.0352	-0.929	7.1363	-13.312	18.053	0.9669
	50%E	0.0091	-0.239	1.8096	-2.8696	4.181	0.9635
1992	100%E	0.0183	-0.477	4.6191	-5.7392	8.362	0.9635
	150%E	0.0274	-0.716	5.4287	-8.6088	12.543	0.9635
	50%E	0.0129	-0.375	3.4042	-9.9576	14.479	0.9643
1993	100%E	0.0258	-0.751	6.8085	-19.915	28.958	0.9643
	150%E	0.0387	-1.126	10.213	-29.873	43.438	0.9643
	50%E	0.0124	-0.330	2.5834	-5.0363	7.2175	0.9701
1994	100%E	0.0247	-0.660	5.1669	-10.073	14.435	0.9701
	150%E	0.0371	-0.990	7.7503	-15.109	21.653	0.9701

(*Where W: Water volume, x: Month, a, b, c, d, e: Coefficients)

The cumulative annual water delivered for the various water regimes and irrigation methods for the same periods were also obtained and are shown in Fig. 4

The water quantities delivered by the various irrigation methods are similar for each irrigation treatment (50, 100 and 150% E), since the amounts of irrigation requirements for all irrigation methods were based on evaporation rate of pan evaporation measurements. Rainfall during the experiment was insignificant in the area, the total annual rainfall during the period of experiments being 0.8, 52, 180 and 2.6 mm for 1991, 1992, 1993 and 1994 respectively. However, rainfall was considered in the calculation of crop water requirements. As expected, the water consumed by the tree, based on evaporation rate, increases during summer months. The amount of this increase could reach four-folds compared to winter month consumption, this fact being used in planning palm tree irrigation scheduling.

The comparison between amounts of water given to palm trees over the four years of study (Fig. 5), indicates that, the total seasonal amounts for the first year (1991) were 304.5 (3.05 m/ha), 203 (2.03 m/ha) and 101.4 m^3/tree (1.01 m/ha) for water treatments of 150, 100 and 50% E respectively. In 1992 the water volumes were 314.9 (3.14 m/ha), 210 (2.1 m/ha) and 105 m^3/tree (1.05 m/ha). In the third year (1993), the volumes delivered were 327 (3.27 m/ha), 218 (2.18 m/ha) and 109 m^3/tree (1.09 m/ha). In the last year of study (1994) the annual date palm consumption were 349.3 (3.5 m/ha), 232.9 (2.33 m/ha) and 116.4 m^3/tree (1.16 m/ha) for the irrigation treatments of 100, 100 and 50% E respectively. These results show a slight difference, mainly due to variations in climatological conditions. The analysis of yield for the various irrigation methods indicates that the maximum average yield was obtained for palm trees irrigated with trickle methods, followed by basin irrigated trees (Fig. 6).

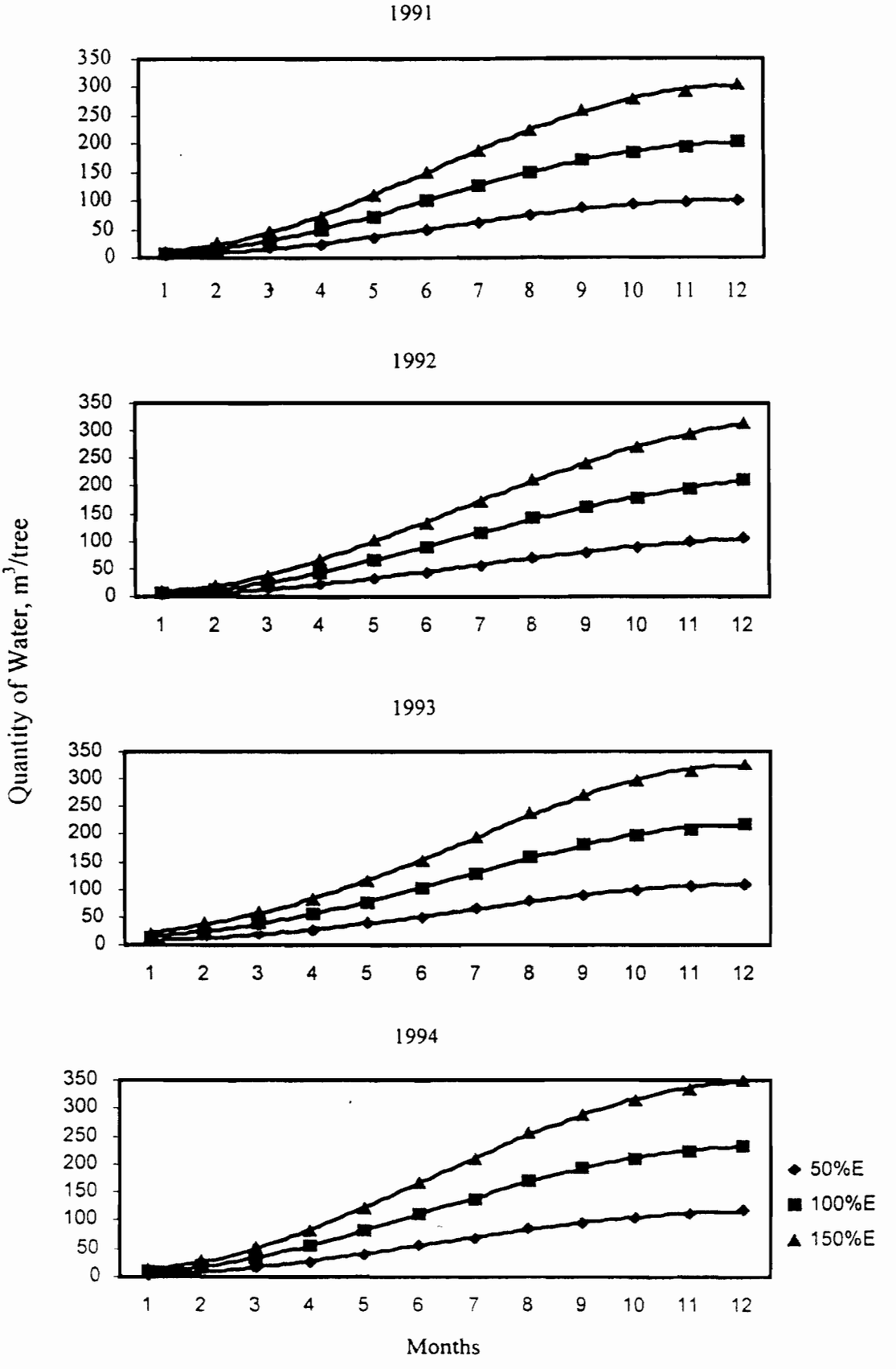

Fig. 4: Annual cumulative water consumption of date palm trees

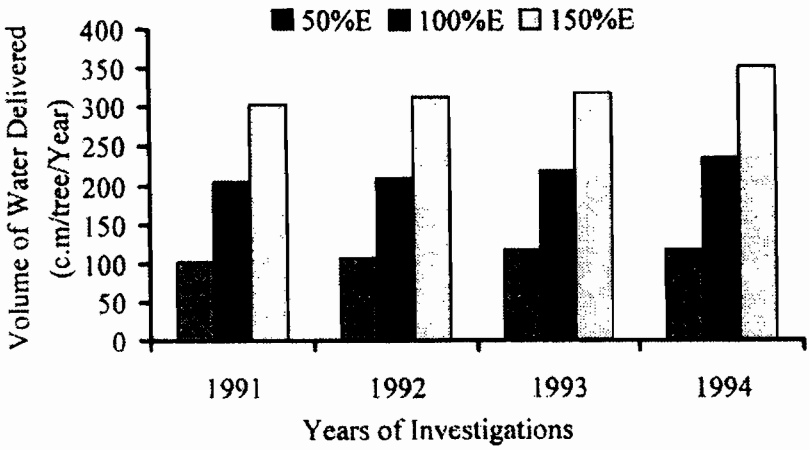

Fig. 5: The water delivered throughout the four years of study

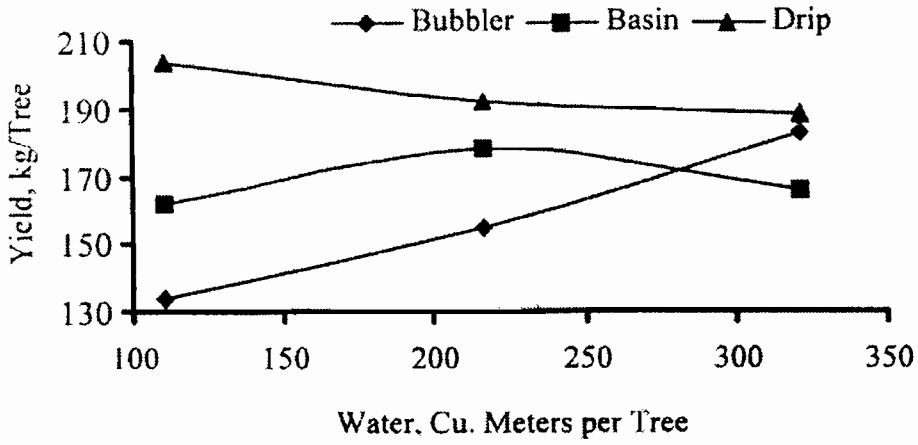

Fig. 6: Average yield-water relation

Statistical analysis shows that the average yield of the date palm irrigated by trickle method is significantly higher than other irrigation systems in the first year (1991), as shown in Table 2. The second year (1992) also shows higher average yield for trickle irrigated palms over yields for basin and bubbler systems, but the difference among average yields of irrigation systems was not found to be statistically significant (Duncan test). The trickle irrigated palms continued to give higher average yield, in the third year, compared to palms irrigated using basin and bubbler irrigation systems, with significant differences compared to average yield of bubbler irrigated trees. The fourth year (1994) also showed higher average yield for trickle irrigated treatments compared to other treatments. Statistical analysis of water treatment effect on yield indicates that the differences among water treatments are insignificant. The better crop response under drip irrigation could be related to the nature of the drip irrigation system, in which water is delivered to the crop slowly over long periods of application through small emitting devices (emitters). This process offers better control and distribution of water in the soil profile to the extent that direct evaporation from the soil surface and deep percolation are reduced compared to other methods, thus most of the water is used up by the plant (Nakayama and Bucks, 1986).

Table 2: Average yields in kilograms per tree for the various irrigation methods and water treatments

Method	Treatment	1991	1992	1993	1994	Average
Bubbler	50%E	148.00	141.00	99.00	147.00	133.75
	100%E	164.00	157.00	126.00	171.00	154.50
	150%E	201.00	187.00	152.00	190.00	182.50
Basin	50%E	178.00	135.00	167.00	168.00	162.00
	100%E	190.00	137.00	190.00	195.00	178.00
	150%E	172.00	167.00	156.00	167.00	165.50
Trickle	50%E	224.00	193.00	190.00	208.00	203.75
	100%E	207.00	177.00	190.00	193.00	191.75
	150%E	199.00	158.00	186.00	210.00	188.25

Water treatments (50, 100 and 150% E) have demonstrated variable effects on yield. A general trend of increased yield for increased amounts of irrigation water was noticed with bubbler irrigated trees (134 kg/tree for 50% E, 155 kg/tree for 100%E and 183 kg/tree for 150% E). A more realistic trend was shown by the basin irrigated trees. It demonstrated that crop yield tended to increase linearly with water applied, until maximum production is attained, then a drop in production is shown as water increased (162 kg/tree for 50% E, 178 kg/tree for 100% E and 167 kg/tree for 150% E). Drip irrigated palm tree behavior with various water regimes shows slight reduction in average yields as water increases (204 kg/tree for 50% E, 192 kg/tree for 100% E, and 188 kg/tree for 150% E). The behavior of drip irrigation could be attributed to the application process in the method. In drip irrigation only a portion of the soil surface is wetted. However, the root volume wetted beneath the surface is larger due to lateral movement of water and the slow application and redistribution of soil water provide better soil aeration. This condition produced better crop growth and yield, for the 50%E treatment, but as the water volume increases, soil becomes more saturated which restricted soil aeration and thus reduced yield.

The analysis of yield based on water delivered (water use efficiency, WUE) reveals that when the amounts of irrigation water are increased up to an average level, the WUE is improved. However, further increase of irrigation water may reduce the efficiency. It is clear that, any increase in irrigation water beyond soil water holding capacity (soil water retention characteristics) during growing season will reduce WUE (Fig. 7).

Comparing the volumes of water delivered to palm trees, it is obvious and logical to see that the highest WUE is produced by the 50% E water treatment followed by the 100% E treatment, then the 150% E treatment as shown in Fig. 8. On the other hand, the trickle irrigation method has demonstrated the highest WUE, followed by the basin then the bubbler irrigation system (Fig. 8).

Production functions were developed from polynomial regression analysis of the total marketable yield per tree (Y) and the total water delivered (X). The obtained yield functions for the various irrigation methods were:

$$Y_{bubbler} = 0.2321\,x + 106.81 \quad (R^2 = 0.993) \quad \ldots (2)$$

$$Y_{basin} = -0.0013\,x^2 + 0.5746\,x + 114.18 \quad (R^2 = 1) \quad \ldots (3)$$

$$Y_{trickle} = 0.0004\,x^2 - 0.2402\,x + 225.64 \quad (R^2 = 1) \quad \ldots (4)$$

The average yield function among all irrigation systems was estimated as:

$$Y_{average} = -0.0002\,x^2 + 0.1415\,x + 153.18 \quad (R^2 = 1) \quad \ldots (5)$$

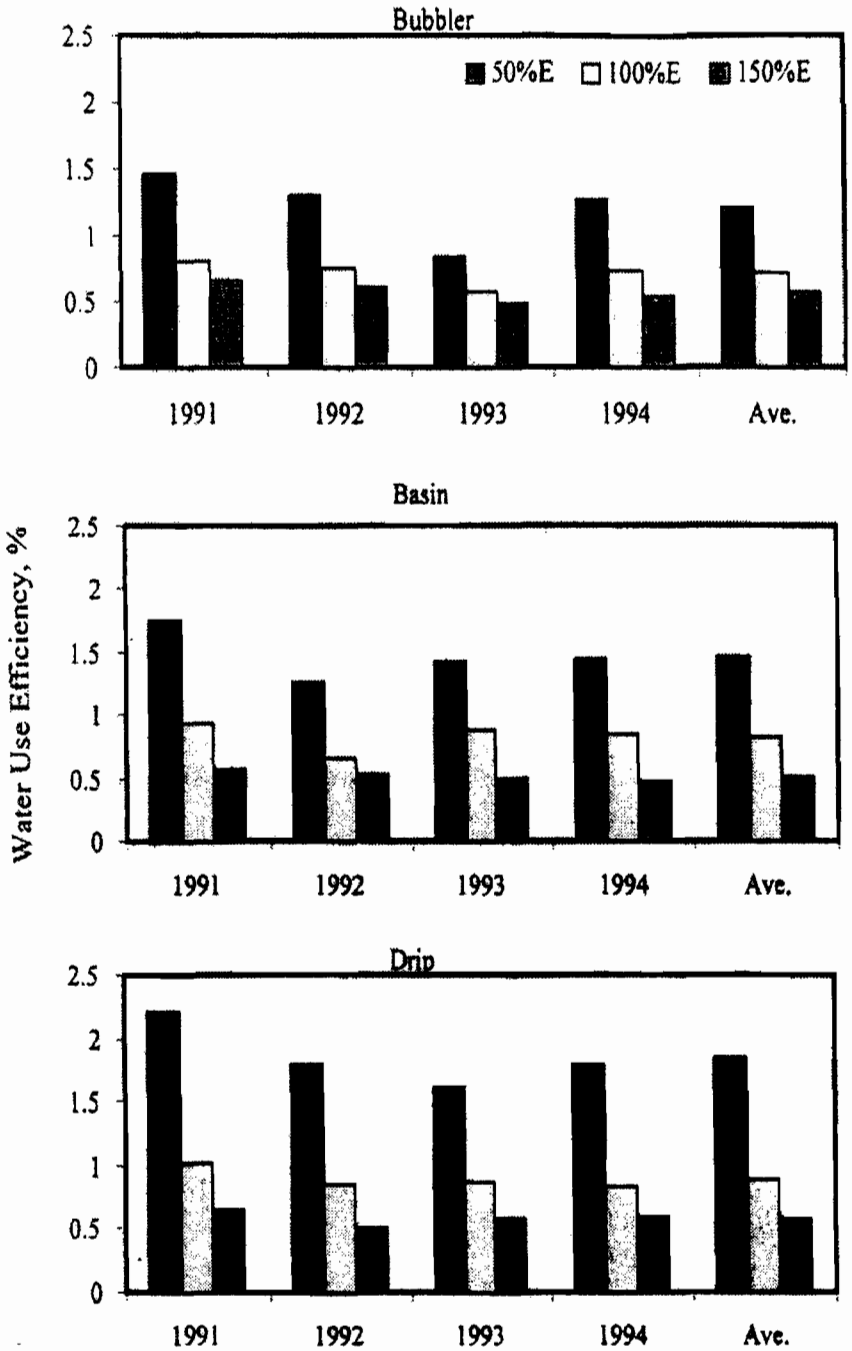

Fig. 7: Water use efficiency of the different irrigation methods throughout the years of experiment

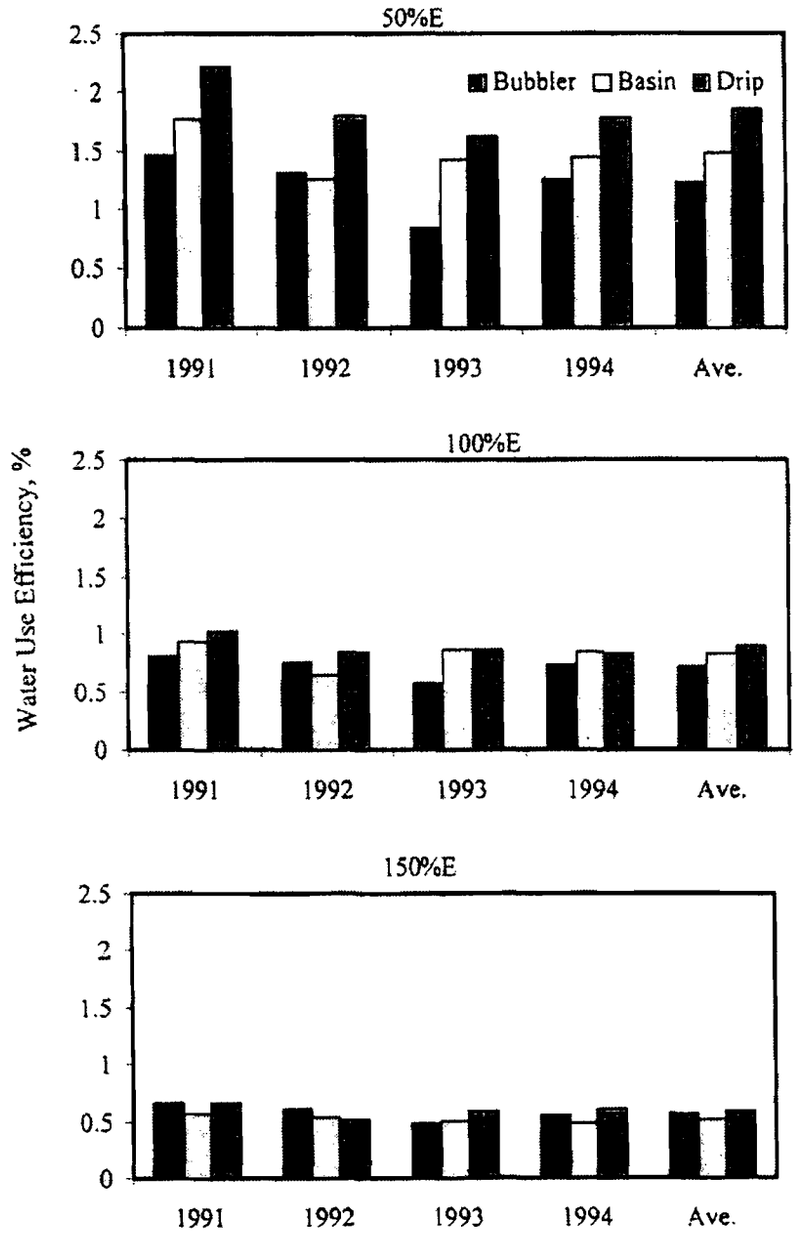

Fig. 8: Comparisons of water use efficiency for the various water treatments

4. CONCLUSIONS

The experiment on date palm tree water consumption has indicated that, the average annual water delivered for date palm trees over the various water treatments and methods were 324 m^3/tree (3.24 m/ha), 216 m^3/tree (2.16 m/ha) and 108 m^3/tree (1.08 m/ha) m^3/tree for 150% E, 100% E and 50% E respectively. The analysis of yield for the different irrigation methods has demonstrated that the maximum average yield was obtained for palm trees irrigated with trickle methods, followed by basin irrigated trees. Differences among water treatments are minimal; in other words, an annual water volume of 108 cubic meters per tree (1.08 m/ha) would be sufficient to produce the highest water use efficiency. The trickle irrigation method has been shown to be the best

method for water use efficiency followed by the basin then the bubbler method.

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