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An Evaluation of Water-Yield Relations in Maize (*Zea mays* L.) in Turkey

Gülay Pamuk Mengü and Mustafa Özgürel
Department of Agricultural Structure and Irrigation, Faculty of Agriculture, Ege University,
35100 Izmir, Turkey

Abstract: The objective of this study was to compare the responses of maize (*Zea mays* L.) to deficit irrigation. A field experiment was conducted during the 1999 and 2000 growing seasons in western Turkey. Irrigation treatments were tested with 100, 70, 50, 30 and 0% replenishment of water depleted at 120 cm soil profile from 100% replenishment treatment at ten days intervals. The irrigation amount ranged between 0 and 323.20 mm in the first year and 0-466.61 mm in the second year of the experiment. Seasonal crop water use values were between 142.19 and 481.91 mm in 1999 and 136.25-599.45 mm in 2000. Average maximum and minimum yields were 10639-10383 kg ha^{-1} for full irrigated treatment (I_{100}) and 3750-2136 kg ha^{-1} for non-irrigated treatment (I_0) in 1999 and 2000, respectively. Water deficit significantly affected maize yield. In both years, yield increased linearly with irrigation applied but the relationship varied from one year to the other. Water Use Efficiency (WUE) ranged from 1.49 to 2.71 kg m^{-3}, while Irrigation Water Use Efficiency (IWUE) varied from 1.44 to 2.55 kg m^{-3} in both years. The yield response factor (ky) relating relative yield decrease to relative evapotranspiration deficit was found to be 0.99 for the data of the two experiments combined. Also, dry matter yields (DM) and leaf area index (LAI) were markedly affected by the irrigation treatments. The finding of this work showed that well-irrigated treatment should be used for maize grown in semi arid regions under no water scarcity.

Key words: Maize, deficit irrigation, grain yield, yield response factor

INTRODUCTION

Water is becoming increasingly scarce worldwide. Aridity and drought are the natural causes of scarcity. More recently however, man-made desertification and water shortages have aggravated natural scarcity while at the same time population is increasing and there is increased competition for water among water user sectors and regions. Rainfall is not sufficient in many regions and predictions on climate change show that problems are likely to increase; thus available water resources are increasingly limited in quantity. In addition, the quality of water is often degraded, so that water resources become less and less available. Irrigated agriculture is therefore forced to find new approaches to meet the demands of water scarcity, environmental friendliness, economic viability and social equilibrium (Pereira, 2006).

Long term average annual precipitation in the Aegean region is about 657 mm, with more than 89% of it falling from October to March. Water loss by evapotranspiration is very high during the growing season. Therefore, irrigation is needed during the growing season to maintain and enhance crop growth and yield. Also, irrigation water is the most important limiting factor for agriculture during the hot and dry summer period of the region. Limited availability of irrigation water requires fundamental changes in irrigation management or the application of water saving methods. A generally applicable procedure is to assess the benefits of changing irrigation water management based on deficit irrigation, which is the practice of deliberately under-irrigating field crops. Under these conditions, there is one way for farmers to maximize their profit from maize production. This is to determine the water-yield relationships of maize crops and to choose the most appropriate irrigation scheduling in order to conserve irrigation water. In this way, optimum irrigation schedules for maize should be determined in order to cope with prevailing conditions and unplanned water shortages in the region. Knowledge of the sensitivity of maize to water stress over the whole growing season or at one of the different growth stages has been widely used in studies aiming to develop deficit irrigation strategies, as well as to determine the yield response factor (k_y) of maize. This is a parameter used to quantify the effect of water stress, derived from the linear relationship between relative seasonal evapotranspiration deficits ($1-ET_a/ET_m$) and relative yield loss ($1-Y_a/Y_m$) (Dagdelen *et al.*, 2006; Yazar *et al.*, 2002; Musick and Dusek, 1980; Doorenbos and Kassam, 1979).

Corresponding Author: Gülay Pamuk Mengü, Department of Agricultural Structure and Irrigation, Faculty of Agriculture, Ege University, 35100 Izmir, Turkey Tel: +90 232 3884000-2728 Fax: +90 232 3881864

Maize is a major commercial field crop in the Aegean region of Turkey. It has become a widely grown feed grain crop particularly as a second crop after wheat or barley. In Turkey, maize production is about 3,000,000 Mg of grain maize from 545,000 ha (Anonymous, 2006). Maize is sensitive to water deficit. This sensitivity to water stress means that when water is limited it is difficult to implement irrigation management strategies without incurring important yield losses (Lamm *et al*., 1994; Farre and Faci, 2006).

Several experimenters have subjected maize to a water deficit during different developmental stages. It was found that both the time and the degree of stress are important in determining the final grain yield. It is well established that a water deficit in the period which includes anthesis can have a disastrous effects on the maize grain yield, whereas the effects of moisture stress are less drastic at other growth stages (Moser *et al*., 2006). Irrigating a crop with the required quantity of water during the moisture sensitive period of flowering and yield formation stages, yet allowing moderate stress at vegetative and maturity stages produce the optimum yield with maximum water use efficiency and water economy in most crops (Panda *et al*., 2004; Shaozhong *et al*., 2000).

Many studies have shown that the relationship between maize yield and seasonal crop water use is linear (Dagdelen *et al*., 2006; Payero *et al*., 2006; Cetin, 1996; Howell *et al*., 1995; Cosulluela and Faci, 1992). On the other hand, predicting the yield response of maize to water use is important in developing strategies and decision-making for farmers and their advisors and research for irrigation management under limited water conditions.

The objective of this study was to determine water-yield relations of maize and the effects of limited water on yield, yield response factor, water use efficiency, irrigation water use efficiency, dry matter and leaf area index. The results of this study will provide a guideline to regional growers and irrigation agencies on water-saving irrigation and optimum water management programs for maize in the Aegean region of Turkey.

MATERIALS AND METHODS

Site and climate: Field data for this study were collected in 1999 and 2000 at the Agricultural Research Station of Aegean University, Izmir, Turkey (latitude 38° 28' N, longitude 27° 15' E, altitude 27 m).

The soil of the experimental site is Sandy Clay Loam (SCL) with water content at field capacity varying from 18.81 to 22.94% and wilting point varying from 8.45 to 10.72% on a dry weight basis. The physical and chemical properties of the soil in the experimental crop field are given in Table 1 and 2.

Table 1: Physical properties of the soils of experimental field

Soil depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})
0-30	48.24	25.28	26.48	22.94	10.72	1.13
30-60	58.24	17.28	24.48	20.58	9.66	1.52
60-90	61.24	17.28	21.48	18.81	8.45	1.62
90-120	63.24	15.28	21.48	18.66	8.58	1.57

The climatic variables for the experimental years were recorded at a weather station located close to the experimental site. These variables and the long-term trends for the growing season (June-November) are shown in Table 3. The experimental area has favourable soil and climate conditions for maize production.

Irrigation water applied during the experimental years was also analysed (EC:1.2 dS m^{-1}; pH: 6.79; SAR:1.01) and classified C_3S_1. According the EC, pH and SAR values, it can be concluded that the water used in irrigation is proper for maize production.

Crop agronomy: In 1999, maize was planted on July 20 and harvested on November 11 (Day of Year, DOY:201). In 2000, it was planted on July 10 and harvested on November 1 (Day of Year, DOY:193). Maize plants were thinned to a spacing of 0.70 m (row width)*0.20 m. Weeds, pests and diseases were controlled. Maize plots were fertilized with 50 kg day^{-1} pure NPK (20:20:0) before sowing and first irrigation. Plant density is 7.1 plant m^{-2}.

Irrigation treatments: The experiment was conducted using a randomized complete block design with three replications. Each experimental plot was designed as 10 m long by 5.0 m wide. There was a 2.0 m space between each plot in order to minimize water movement between treatments.

In this study, five irrigation treatments, differing in irrigation rate, were evaluated at ten day intervals. Irrigation treatments were tested with 100, 70, 50, 30 and 0% replenishment of water depleted at 120 cm soil profile from 100% replenishment treatment. Each year, treatments included a dryland treatment (I_0) which received no irrigation. This many treatments were included to obtain enough data points and a wide enough range of water stress levels to be able to develop meaningful quantitative relationships between irrigation, yield and other parameters. Also, irrigation was applied when approximately 50% of the available soil moisture was consumed in the effective root zone at the control treatments, called I_{100}. The measured soil moisture level in the I_{100} treatment was used to initiate irrigation of maize during the growing season. In treatments, I_{70}, I_{50}, I_{30} and I_0 irrigations were applied at the rates of 70, 50, 30 and 0%

Table 2: Chemical properties of the soils of experimental field

Soil depth (cm)	Total salinity (dS m^{-1})	$CaCO_3$ (%)	Total N (%)	Organic matter (%)	Available micro elements (ppm) P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
0-30	1.03	7.31	0.129	2.18	0.82	260	4700	30	159.1	6.41	3.50	7.95	21.76
30-60	0.84	7.32	0.081	1.45	0.62	170	3700	30	163.0	6.89	1.64	0.56	19.07
60-90	0.84	7.35	0.059	1.08	0.87	130	3200	20	186.2	6.79	10.74	0.84	16.38
90-120	0.76	7.40	0.036	0.68	1.24	110	3100	30	211.5	8.18	9.74	0.41	19.46

Table 3: Long-term monthly climatic data for the growing season at the experimental site

		Month					
Year	Climatic data	June	July	August	September	October	November
Long term	T_{min} (°C)	17.3	20.7	20.6	16.7	12.7	8.8
	T_{max} (°C)	31.4	34.0	33.5	29.7	25.8	18.6
	$T_{average}$ (°C)	25.1	27.7	27.0	22.6	18.0	13.2
	RH (%)	50.0	47.0	50.0	56.0	63.0	68.0
	Rainfall (mm)	7.8	3.6	2.0	17.1	47.5	82.1
	Wind speed (m sec^{-1})	2.0	2.7	2.5	2.2	2.0	1.8
1999	T_{min} (°C)	18.8	22.5	21.9	17.2	13.5	9.9
	T_{max} (°C)	32.7	35.1	34.7	30.8	25.6	18.9
	$T_{average}$ (°C)	26.5	29.2	28.3	23.5	18.9	14.2
	RH (%)	50.4	49.8	50.0	55.6	58.8	56.6
	Rainfall (mm)	0.9	1.3	-	0.3	25.7	44.3
	Wind speed (m sec^{-1})	1.9	2.3	2.1	1.5	1.9	1.9
2000	T_{min} (°C)	18.8	21.0	22.6	16.5	12.7	8.6
	T_{max} (°C)	32.8	37.8	35.0	30.9	23.7	22.1
	$T_{average}$ (°C)	26.2	29.7	28.6	23.3	17.5	14.0
	RH (%)	45.4	41.5	47.3	52.2	61.3	63.6
	Rainfall (mm)	-	3.0	-	-	63.0	115.4
	Wind speed (m sec^{-1})	2.9	2.0	3.5	2.4	1.8	0.9

of control treatments (I_{100}) on the same day, respectively. The closed-end furrow irrigation method was used in all treatments. Water applied to each experiment plot was measured with water metered connected to an irrigation pipe. Irrigation was started on 13 August 1999 and 11 August 2000.

Soil and crop measurements: Soil water content was monitored gravimetrically in each 0.3 m layer down to a depth of 1.20 m for each treatment before each irrigation water application.

Crop evapotranspiration (ET) was calculated using the soil water balance equation for the growing season as follows (Heermann, 1985):

$$ET = R + I - D \pm \Delta W \quad (1)$$

Where:

- ET = Evapotranspiration (mm)
- R = Rainfall (mm)
- I = Irrigation application (mm)
- D = Drainage (mm) and
- ΔW = The change of soil water storage at the measured soil depth. Runoff and drainage were considered negligible in the water balance.

The effect on yield of water stress during the growing season was calculated as follows (Doorenbos and Kassam, 1979):

$$\left(1-\frac{Y_a}{Y_m}\right) = k_y\left(1-\frac{ET_a}{ET_m}\right) \quad (2)$$

Where:

- Y_a = Actual harvested yield (kg ha^{-1})
- Y_m = Maximum harvested yield (kg ha^{-1})
- ky = Yield response factor
- ET_a = Actual evapotranspiration (mm)
- ET_m = Maximum evapotranspiration (mm)
- $(1-Y_a/Y_m)$ = Relative yield decrease
- $(1-ET_a/ET_m)$ = Relative evapotranspiration deficit

Water Use Efficiency (WUE) and Irrigation Water Use Efficiency (IWUE) were calculated as follows (Howell *et al.*, 1995):

$$WUE = \frac{Y}{ET} \quad (3)$$

$$IWUE = \frac{Y_i - Y_o}{I_i - I_o} \quad (4)$$

Where:

- Y = Grain yield (kg ha^{-1})
- ET = Evapotranspiration (mm)
- Y_i = Grain yield for irrigation level i
- Y_o = Grain yield for equivalent dry land
- I_i = Amount of irrigation applied for level i. In most cases, I_o would be zero

Crop development stages in maize were recorded in all treatments. A phenological stage was defined as 50% of the plants reaching that stage. Regular observations were made of leaf area index and dry matter. Collections of maize plant samples were started after first irrigation and continued until harvest. Maize leaves were separated from the stem and the leaf area of plants was measured using a scanner with FLAECHE packing programme. Maize leaves and the rest of the plants were cut into pieces and then oven dried at 65°C to a constant weight (Gardner *et al*., 1985; Koksal, 1995).

Analysis of variance (ANOVA) was used to evaluate the effects of the treatments on the yield, LAI and DM components. Mean comparisons were made by the LSD (least significant difference) method with $p<0.05$. The analyses were conducted using the TARIST program (Acikgoz *et al*., 1994).

RESULTS AND DISCUSSION

Water-yield relationship: A total of six irrigations were applied to maize in all treatments during the growing season. As shown in Table 4, the amount of irrigation water applied varied from 96.8 to 323.2 mm in 1999 and from 139.9 to 466.6 mm in 2000. The seasonal values of crop water use per treatment ranged from 142.1 to 481.9 mm in 1999 and from 136.2 to 599.4 mm in 2000. The highest seasonal crop water use occurred in the full irrigation treatment (I_{100}) owing to an adequate soil water supply during the growing season and the lowest crop water use occurred in the non-irrigated treatment (I_0). Crop water use values were affected by irrigation treatments and years. These differences can be attributed to climatic factors and irrigation scheduling practices. Seasonal crop water use of maize obtained by Kanber *et al*. (1990) was 474.2-605.8 mm in the Cukurova region, while Istanbulluoglu and Kocaman (1996) obtained 353-586 mm in the Thrace region. In addition, Tolk *et al*. (1998) obtained 357-587 mm, Katerji *et al*. (1996) 494-644 mm, Dagdelen *et al*. (2006) 169-547 mm and Igbadun *et al*. (2006) 385.4-537.1 mm. Also, crop water use for maize without water deficit was reported by Pandey *et al*. (2000) as 641-668 mm, while Stegman (1986) reported 432-514 mm. The results observed in this research were in agreement with that given above.

Irrigation treatments also resulted in differences in grain yield as shown in Table 4. This ranged from 3750 to 10639 kg ha^{-1} in 1999 and from 2136 to 10383 kg ha^{-1} in 2000 for the different irrigation regimes. Increased water amounts resulted in a relatively higher yield, since water deficit was the main yield-limiting factor in both years. The maximum yield was obtained at I_{100} and the minimum yield at I_0 in both 1999 and 2000. Grain yields from the experiments were considered adequate as they compared well with the world average grain yield of maize of 2004 of 4907 kg ha^{-1} (Fao, 2006).

Table 4: Amount of irrigation water, crop water use and grain yield for the years 1999 and 2000

Year	Treatment	Irrigation water applied (mm)	Crop water use (mm)	Grain yield (kg ha^{-1})	Relative yield (%)
1999	I_{100}	323.2	481.9	10639	100.0
	I_{70}	226.1	384.9	9517	89.5
	I_{50}	161.5	335.8	6469	60.8
	I_{30}	96.8	214.8	5833	54.8
	I_0	-	142.1	3750	35.2
2000	I_{100}	466.6	599.4	10383	100.0
	I_{70}	326.6	444.4	7541	72.6
	I_{50}	233.3	361.7	5497	52.9
	I_{30}	139.9	282.2	4201	40.5
	I_0	-	136.2	2136	20.6

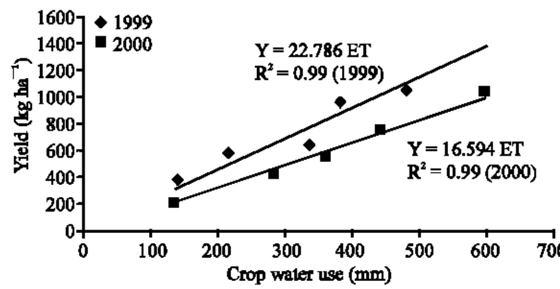

Fig. 1: Relationship between grain yield (Y) and seasonal crop water use (ET) for maize

Under the conditions of the Harran plain, Cetin (1996) reported the highest yield of 10150 kg ha^{-1} using the furrow irrigation method. Dagdelen *et al*. (2006) in Western Turkey found that the average maize yield varied from 2880-11340 kg ha^{-1} and that the highest average maize yield was obtained from full irrigation treatments. Cakir (2004) determined grain yield of maize as 3147-12438 kg ha^{-1} and Tolk *et al*. (1998) found it to be 4110-8480 kg ha^{-1}. When the water saving in this study was 30% (I_{70}), 50% (I_{50}), 70% (I_{30}) and 0% (I_0) of I_{100}, the rates of decrease in maize grain yield were found to be 10.5, 39.2, 45.2 and 64.8 of I_{100} in 1999 and 27.4, 47.1, 59.5 and 79.4 of the I_{100} in 2000, respectively. The results indicated that deficit irrigation affected grain yield significantly.

The relation between seasonal crop water use and grain yield have been evaluated for each year (Fig. 1)

The relationship between seasonal crop water use and grain yield was linear for each experimental year. Their

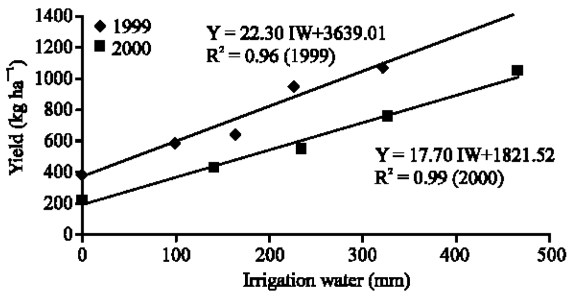

Fig. 2: Relationship between grain yield (Y) and irrigation water (IW) for maize

Table 5: Water use efficiency values for the experimental years

	WUE (kg m^{-3})		IWUE (kg m^{-3})	
Treatments	1999	2000	1999	2000
I_{100}	2.21	1.73	2.13	1.78
I_{70}	2.47	1.70	2.55	1.65
I_{50}	1.93	1.52	1.68	1.44
I_{30}	2.71	1.49	2.15	1.47
I_0	2.64	1.57	-	-

relationship was significant at $p<0.05$. A linear relationship between crop water use and yield for maize has been reported by other researchers (Payero *et al*., 2006; Dagdelen *et al*., 2006; Cetin, 1996; Howell *et al*., 1995; Cosulluela and Faci, 1992).

Also, the relation between grain yield and seasonal irrigation applied to maize was evaluated for each experimental year (Fig. 2). The relationship between grain yield and irrigation applied was also linear ($p<0.05$) in 1999 and 2000.

Farre and Faci (2006) also observed grain yield to be linearly related to seasonal irrigation applied to maize. The findings of their work showed that in the northeast of Spain and on a loam soil, the yield penalties of moderate or severe water deficit are more important in maize than in sorghum.

Water use efficiency and irrigation water use efficiency: Water Use Efficiency (WUE), expressed as the ratio of grain yield to seasonal crop water use, was affected by the irrigation treatments in maize (Table 5). WUE values ranged from 1.49 to 2.71 kg m^3 both years. In 1999, WUE for I_{30} treatments was the highest, while that for I_{50} treatment was the lowest. On the other hand, no significant difference was found between treatments I_{100} and I_{70} in either year. In 2000, I_{100} was the highest and I_{30} was the lowest. However, a wide range of WUE values have been found for maize in different studies (Farre and Faci, 2006; Yazar *et al*., 2002; Tolk *et al*., 1998; Steele *et al*., 1997; Koksal, 1995; Steele *et al*., 1994; Caldwell *et al*., 1994).

Table 6: The relationship between relative yield decrease and relative evapotranspiration deficit for growing season

	1999			2000		
Treatment	1-(ET_a/ ET_m)	1-(Y_a/ Y_m)	ky	1-(ET_a/ ET_m)	1-(Y_a/ Y_m)	ky
I_0	0.705	0.647	0.92	0.773	0.794	1.03
I_{30}	0.554	0.452	0.82	0.529	0.595	1.12
I_{50}	0.303	0.392	1.29	0.396	0.471	1.19
I_{70}	0.201	0.105	0.52	0.258	0.274	1.06
I_{100}	-	-	-	-	-	-

Irrigation Water Use Efficiency (IWUE) values, expressed as the ratio of grain yield to total irrigation water applied, varied from 1.44-2.55 kg m^{-3}. In 1999 the IWUE of treatment I_{70} was the highest and the lowest IWUE occurred with treatment I_{50}. Similarly in 2000, the highest IWUE was obtained from I_{100} treatment and the lowest IWUE was obtained from I_{50} treatment. These results were similar to other values reported for maize. Musick and Dusek (1980) reported IWUE for maize between 2.44-2.70 kg m^{-3}; Howell *et al.* (1995) found that IWUE was between 1.51-2.48 kg m^{-3}; Caldwell *et al.* (1994) determined these values as 2.07-2.76 kg m^{-3}.

Relative yield decrease-relative evapotranspiration deficit relationship and yield response factor (k_y): The relationship between relative yield decrease and relative evapotranspiration deficit is shown in Table 6 and yield response factor (ky) is shown in Fig. 3. The slope of the fitted regressions represents ky.

The ky values of maize to water deficit for the entire growing season were 0.90 in 1999 and 1.07 in 2000. When the values of the two experimental years were combined, the coefficient of determination (r^2) was 0.939. According to the regression equations, ky was 0.99. Generally, the ky value obtained in this study was consistent with those reported by Koksal and Kanber (1998) as 1.03, by Gencoglan (1996) as 1.23, by Cakir (2004) as 1.29, by Dagdelen *et al.* (2006) as 1.04 and by Karam *et al.* (2003) as 0.81. Some differences could be explained by the high relative humidity and different precipitation characteristic of the coastal areas. On the other hand, Igbadun *et al.* (2006) reported the ky value to be 1.90. The high value for ky obtained in their study is an indication of severe moisture stresses or low resistance to moisture stress. It implies that the rate of relative yield decrease resulting from moisture stress is proportionally higher than the relative evapotranspiration deficit.

Above-ground dry matter (DM): Above-ground Dry Matter (DM) was also significantly affected ($p<0.05$) by water deficit in both 1999 and 2000 (Fig. 4, 5).

The highest level of dry matter of maize, obtained from I_{100} treatment, was 3.375 and 3.015 kg m^{-2} and

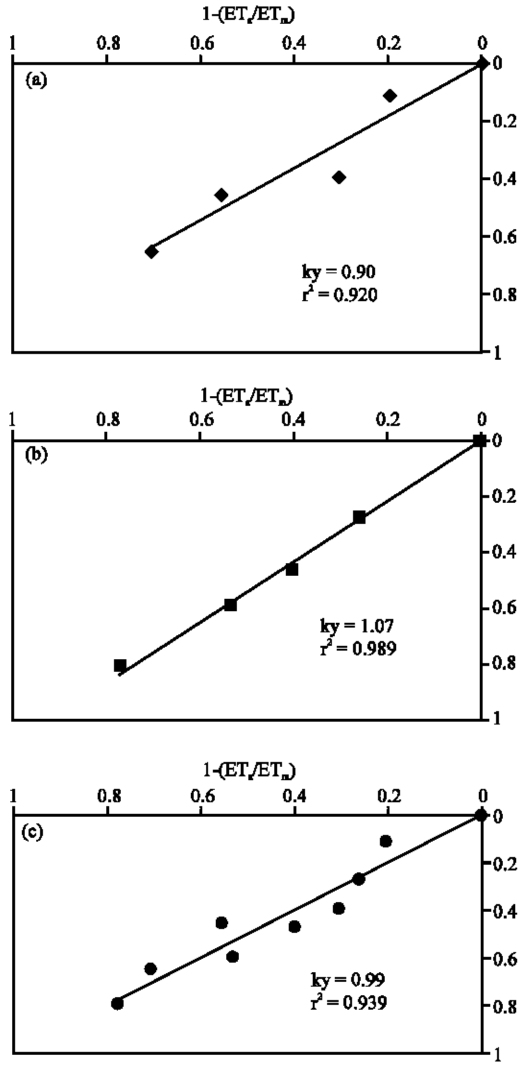

Fig. 3: Yield response factor, ky, for maize in 1999 (a), 2000 (b) the two experiments combined (c).

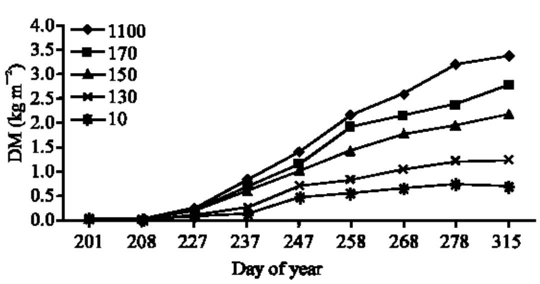

Fig. 4: Dry matter (DM) for maize in 1999

the lowest, obtained from I0 treatment, was 0.709 and 0.573 kg m^{-2} in 1999 and 2000 respectively. A significant difference was found between all treatments ($p<0.05$).

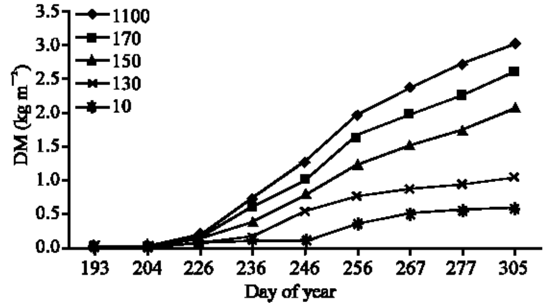

Fig. 5: Dry matter (DM) for maize in 2000

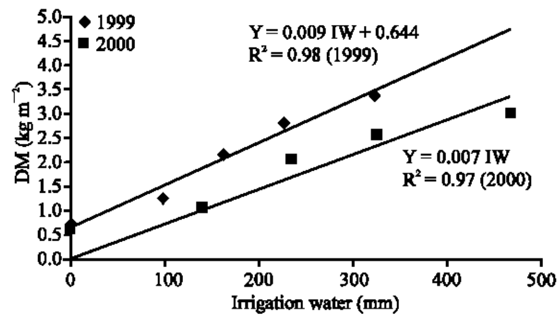

Fig. 6: The relationship between dry matter yield (Y) and irrigation water (IW)

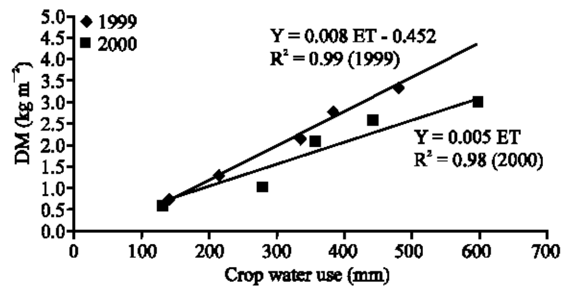

Fig. 7: The relationship between dry matter yield (Y) and crop water use (ET)

Increasing the amount of irrigation appeared to increase DM. That is, water deficit reduced dry matter. The results were consistent with those of Farre and Faci (2006). In addition, DM was found to be 2.5 kg m^{-2} by Karam *et al.* (2003) and 3.25-3.45 kg m^{-2} by Dagdelen *et al.* (2006). There was also a significant linear relationship between DM and irrigation applied and DM and crop water use obtained for maize, as shown in Fig. 6 and 7.

Leaf area index (LAI): Results obtained from the two experimental years showed a significant effect of irrigation application on LAI (Fig. 8). The highest LAI, obtained

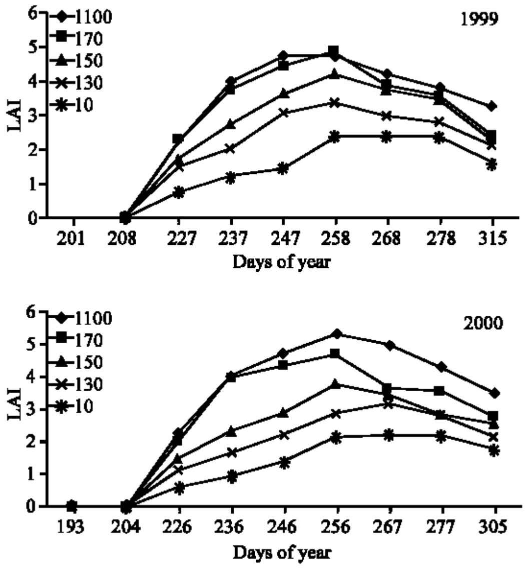

Fig. 8: Leaf area index for maize in 1999 and 2000

from I_{70} treatment, was 4.84 in 1999 and from I_{100} treatments, 5.31 in 2000. The lowest LAI was recorded from non-irrigated conditions, treatment I_0, in both years. These results showed that water deficit causes a decrease in LAI and reduction of yield. This result was consistent with the finding of İstanbulluoglu and Kocaman (1996) and Cosulluea and Faci (1992). Howell *et al.* (1995) determined that the highest LAI was 4-5.5 for maize under non-water stressed conditions. Maximum LAI of maize was reported to be 5.03-5.35 under well irrigated conditions and as 3.43-3.0 under non irrigated conditions, by Gencoglan (1996). Cakir (2004) reported that LAI increased under favourable soil moisture conditions until 70-80 days after emerge and then decreased as the older leaves died. In general the results obtained in this study are similar to those reported by other researchers. However, the slight differences could be due to differences in techniques used in the agronomic process, differences in climate between locations especially the amounts and distribution of precipitation, differences in crop varieties, cultural practices, irrigation methods and irrigation scheduling practices.

CONCLUSIONS

It was concluded from this study that maize grain yields were significantly affected by irrigation applied during the course of the growing season in 1999 and 2000. In both experimental years, grain yield ranged from 2136 to 10639 kg ha^{-1} with respect to the irrigation treatments and other components decreased according to the water deficit levels created.

Yield response factor (k_y) was estimated as 0.99 when the experimental years were considered together. k_y obtained for this study could be used for the purposes of irrigation management and water allocation scheduling over irrigation schemes under limited irrigation water supply. Water use efficiency values varied from 1.49 to 2.71 kg m^{-3} and irrigation water use efficiency values varied from 1.44 to 2.55 kg m^{-3}. Dry matter yield (DM) and Leaf Area Index (LAI) increased with increased water use in both experimental years. Maximum measured LAI was 4.84 for the treatment I_{70} in 1999 and 5.31 for the treatment I_{100} in 2000. Minimum LAI was obtained for treatment I_0 in 1999 and 2000. As the crop water stress increased, LAI values decreased due to a reduced size of the leaves. A positive linear relationships between crop water use and yield exists during the experimental years.

The finding of this study showed that treatment I_{100}, designated to receive 100% soil water depletion every ten days, could be used for maize grown in semi arid regions under no water scarcity. On the other hand, the treatment of 30% water saving (I_{70}) reduced maize yield by 18.96%. Thus, results obtained from treatment I_{70} could be used as a good basis for deficit irrigation strategy development in regions where irrigation water supplies are limited. However, severe deficit in irrigation water amounts will cause significant declines in crop yield.

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