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Full Length Research Paper

Effect of different irrigation water level on cotton yield and yield components

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Effects of different water level on yield and yield components of the drip irrigated cotton were evaluated in Amik Plain in the East Mediterranean Region of Turkey. Four levels of irrigation water were tested in 2003 and 2004. Treatments were 25 (I_{25}), 50 (I_{50}), 75% (I_{75}) of the full irrigation treatment (I_{100}) which received 100% class-A pan evaporation. Numbers of irrigation events were 5 and 8 in 2003 and 2004, respectively. Under I_{25}, I_{50} and I_{75} treatment conditions, evapotranspiration, total cotton seed yield, boll weight, lint percentage, number of sympodial branches and leaf area index decreased while some boll parameters such as boll weights and opened boll numbers increased. Increase of boll number per plant under water stress condition showed that cotton had high ability for adapting water stress conditions. The highest yield was obtained in the I_{100} treatment. A second degree polynomial relation could adequately describe the cotton seed yield response to the irrigation water amount. The highest irrigation water use efficiency (IWUE) was obtained with the I_{50} treatment.

Key words: Drip irrigation, seed yield, water use efficiency (WUE), cotton.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is grown as an irrigated main crop in the Mediterranean, Aegean and South-eastern Anatolia regions of Turkey. The cotton production is very important for not only its economic benefits but also for its socio-economic value in the country. Irrigation among other cultural practices is the most important input ensuring high and good quality cotton production. Although cotton is known to be drought tolerant, its yield could significantly be increased with appropriate irrigation management (Tekinel and Kanber, 1989). While excessive irrigation could promote vegetative growth and decrease yield, inadequate and infrequent irrigation can increase shedding ratio.

The most commonly used irrigation methods in Turkey are furrow and border irrigations. However, in recent years, sprinkler and especially drip irrigation methods for cotton irrigation are being used owing to shortage of irrigation water resources. Mateos et al. (1992) determined that drip irrigation method was more advantageous than furrow irrigation method. Fereres et al. (1985) indicated that drip irrigation promoted an early yield and increased the total yield. Cetin and Bilgel (2002) reported that the drip irrigation increased seed cotton yield by 21 and 30% over furrow and sprinkler irrigation, respectively, in the Harran Plain. With drip irrigation of cotton, 18 - 42% of the irrigation water was saved compared to furrow irrigation in Uzbekistan (Ibragimov et al., 2007).

In the arid southeastern part of Turkey, the highest cotton yield was obtained from the full irrigation treatment (100% of cumulative class A pan evaporation) under the trickle-irrigated plots (Yazar et al., 2002). Ertek and Kanber (2003) reported that cotton yield, boll number and shedding percentage increased linearly with irrigation water amount. However, Karam et al. (2006) showed that cotton lint yield was inversely related to irrigation amount. Mert (2005) reported that nonirrigation condition water stress reduced some cotton yield components in the Amik Plain. Similar results were reported by Pettigrew (2004), Aujla et al. (2005), Jalota et al. (2006), and Chun-yan et al. (2007).

In most parts of Turkey, precipitation level is not

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Table 1. Some climatological data for experimental area.

Month	Year	Max Temp. (°C)	Min Temp. (°C)	Average Temp. (°C)	Relative Humidity (%)	Wind Speed (m/s)	Total Rainfall (mm)	Epan (mm)
April	2003	21.8	13.0	16.8	71	2.4	45.4	131.9
	2004	23.7	12.0	17.3	61	2.2	70.6	103.0
	Long term	37.5	1.5	17.1	68	3.4	101.0	186.0
May	2003	30.6	17.7	23.7	55	2.5	46.8	174.8
	2004	24.8	16.8	20.4	70	3.4	106.4	192.8
	Long term	42.5	7.7	21.1	67	4.1	82.0	174.4
June	2003	29.7	21.8	25.4	68	4.0	10.8	221.1
	2004	28.7	21.4	24.7	70	4.3	0.0	196.9
	Long term	41.5	11.6	24.6	67	5.4	21.3	206.5
July	2003	31.7	24.7	27.7	70	4.6	18.9	244.7
	2004	31.9	24.6	27.7	72	4.5	0.0	224.6
	Long term	43.4	15.9	26.9	70	6.1	6.8	231.8
August	2003	32.7	25.9	28.6	70	4.6	0.0	234.1
	2004	31.6	25.2	27.8	73	4.5	0.0	232.4
	Long term	43.9	15.4	27.6	70	5.9	7.0	219.3
Sept.	2003	30.8	21.5	25.4	62	3.2	8.4	181.7
	2004	31.5	21.4	25.8	68	3.2	0.0	192.5
	Long term	42.6	7.9	25.4	66	4.1	30.0	162.2
Oct.	2003	28.1	18.2	22.3	67	2.5	3.1	125.0
	2004	30.1	18.0	23.4	58	1.7	12.8	130.2
	Long term	39.2	2.3	20.4	65	2.5	81.4	109.5
Annual Mean	2003	23.4	14.8	18.5	70	2.7	1168.7	1313.3
	2004	23.3	14.7	18.5	69	2.7	1053.2	1272.4
	Long term	23.0	13.8	18.1	69	3.7	1109.3	1289.8

enough for high crop yields. Moreover the existing water resources are at risk of near depletion and being heavily degraded. It should further be noted that there are strong evidences for climate change which would result even further decrease of annual rainfall year by year (Kimura, 2007). It is believed that research work studying agricultural production under deficit irrigation conditions may help to develop irrigation programs for minimizing future yield reductions when water scarcity becomes wide spread. This work was under taken to determine the effects of different water levels (water stress) on yield and yield components of drip irrigated cotton in the Amik Plain. This study was first research about cotton irrigation on different water level in this plain.

MATERIALS AND METHODS

The experiment was conducted at Telkalis experimental field at Agricultural Faculty of Mustafa Kemal University in the Amik Plain of Hatay in Turkey (latitude 36°39′ N, longitude 36°40′ E, and altitude 93 msl) in 2003 and 2004. Amik Plain is an important cotton production center in the East Mediterranean region of Turkey. Besides, this plain might be one of the places that will be affected the most from the scarcity of water in the future. A typical Mediterranean climate prevails in the Amik Plain with hot-dry summers and mild-rainy winters. Some climatic data of the experimental site during the experimental periods is given in Table 1. The average temperature is 18.1°C and average annual rainfall is 1109 mm. The relative humidity is about 69%. Daily wind speeds (at 2.0 m) ranged from 3.0 to 6.1 ms^{-1} over the summer months. In 2003, the rainfall and free water surface evaporations (Epan) during the growing season were 76 and 1102 mm, respectively. In 2004, the corresponding totals were 106 and 1078 mm.

Soil in the experimental site is deep clayey with high levels of clay contents varying from 66.6 to 73.1% and organic matter varying from 4.5 to 5.1% (Table 2). The soil salinity content was slightly increasing with depth. However, the experimental soil had no water table and salinity problem. Total available water capacity was 228 mm for a 0.9 m soil depth. The soil was classified as *Cromic haploxerert* (Dinc et al. 1997).

The cotton cultivar (c.v. Sure Grow125) was planted on May 1st, in 2003 (121 DOY: day of year) and April 30th, in 2004 (120 DOY) with 0.70 × 0.20 m spacing.

Four irrigation treatments designated as full irrigation (I_{100}) with no water stress and slight (I_{75}), mild (I_{50}), and severe water stress (I_{25}) treatments were tested. The irrigation requirement for the treatment I_{100} was so calculated that the plants under this treatment would experience no water stress. Irrigation water amount applied

Table 2. Soil characteristics of the experimental field.

Characteristics	0 - 0.3 m	0.3 - 0.6 m	0.6 - 0.9 m	0.9 - 1.2 m
Organic matter (%)	5.1	4.6	4.5	4.9
Sand (%)	15.9	15.5	16.1	17.1
Silt (%)	15.4	17.2	10.8	16.3
Clay (%)	68.7	67.3	73.1	66.6
Soil texture	C	C	C	C
Salinity (%)	0.09	0.06	0.07	0.11
pH (in paste, 1:1)	8.0	8.1	8.1	8.3
Bulk density (g cm^{-3})	1.37	1.42	1.47	1.47
M.C. at FC (%, v v^{-1})	56.0	47.0	54.0	48.0
M.C. at PWP (%, v v^{-1})	28.0	24.0	28.0	25.0

Table 3. Amount of irrigation water (mm) for irrigation treatments and crop coefficients.

Year	2003*					2004**							
Irr. no	1	2	3	4	5	1	2	3	4	5	6	7	8
Irr. date	7/11	7/24	8/01	8/10	8/26	7/23	7/30	8/06	8/13	8/20	8/27	9/03	9/10
I_{100}	36	62	36	52	109	32	30	37	41	44	47	32	23
I_{75}	27	47	27	39	82	24	22	28	31	33	35	24	17
I_{50}	18	31	18	26	55	16	15	19	21	22	23	16	12
I_{25}	9	16	9	13	27	8	7	9	10	11	12	8	6
Kc	**0.6**	**0.8**	**0.8**	**1.0**	**1.2**	**0.6**	**0.85**	**0.9**	**1.05**	**1.1**	**1.2**	**0.85**	**0.65**

*At the beginning of the irrigation season (DOY: 182), a total of 127 mm irrigation water was applied to all plots. ** Irrigation water for the initial event (DOY: 195) was 181 mm.

to the other treatments were decreased stepwise as 25, 50 and 75% of water applied to the treatment I_{100} (Table 3).

The amount of irrigation water for I_{100} treatment was calculated using the Equation 1

$$I = Kp \times Epan \times Kc \quad (1)$$

where I is the amount of irrigation water (mm), Epan is the cumulative evaporation during irrigation interval (mm). The water evaporation data was measured with a screened Class A pan located at the meteorological station near the experimental field. Kc is the crop coefficient which changed depending on crop growth stage and Kp is the pan coefficient (Table 3). Kp was taken 0.75 for the experimental area depend on different pan siting, environment, different levels of mean relative humidity and wind speed. Kc and Kp were both as recommended by Allen et al. (1998).

A randomized complete block design with three replications was used. Each plot had six cotton rows at 0.7 m spacing and 33 m in length. The plots were irrigated with drip irrigation method. The PE drip lines with 16 mm diameter with in-line drippers at 0.30 m intervals. The average discharge of the drippers was 1.1 L h^{-1} at 0.8 bars of pressure with one drip line for each crop row.

The irrigation water was used from a deep well located in the experimental station. Quality wise, irrigation water had no problem and its Electrical Conductivity (EC) value (0.72 dS m^{-1}) was far below the salinity tolerance level of cotton. The initial irrigation was initiated when crop covering percentage up to 30% level. Irrigation interval ranged from 7 to 16 days. During the experimental seasons in 2003, some irrigation applications were late due to electric power cut and consequently well pumping breakdowns unintentionally.

The amount of irrigation water was measured using a flow-meter. Total crop evapotranspiration (ET) under each treatment was calculated using water balance approach shown by Equation 2 (James, 1988).

$$ET = (P + I) \pm \Delta S - Dp - Ro \quad (2)$$

where P is the rainfall, I is the irrigation amount, ΔS is change in the soil water storage in a period, Dp is deep percolation, and Ro is run-off amount. The units of all parameters in this equation were millimeters. In this study, Ro was assumed to be zero because the earth bunds between adjacent sub-plots also prevented the run-off and run-on. Deep percolation was calculated from the difference between the field capacity moisture depth and total of soil moisture depth plus (P + I) at 0.90 m soil depth in the observed period. The soil water measurements with gravimetric sampling were done just before sowing, and before each irrigation events and lastly at the harvest. Soil samples were taken at 0.30 m increments over 0.90 m depth at mid way over a centrally located row of plants of every plot.

Guard rows were constructed between the plots, thus no runoff losses or gains from plots to the plots occurred. Deep percolation was likely only during spring season because of high rainfall.

Total water use efficiency (TWUE) was computed by dividing the cotton yield by water use. The irrigation water use efficiency (IWUE) was determined as the ratio of cotton yield to the applied irrigation water for a particular treatment (Howell et al., 1990).

Yield was determined by hand-harvesting from 29 m center section of the middle two rows in each plot on October 3, 2003 (276 DOY) and October 8, 2004 (281 DOY). Seed cotton yield, the number of bolls and boll weight per plot were determined at harvesting. Time variation of plant height, number of sympodial branch per plant, green boll number, opened boll number, and leaf

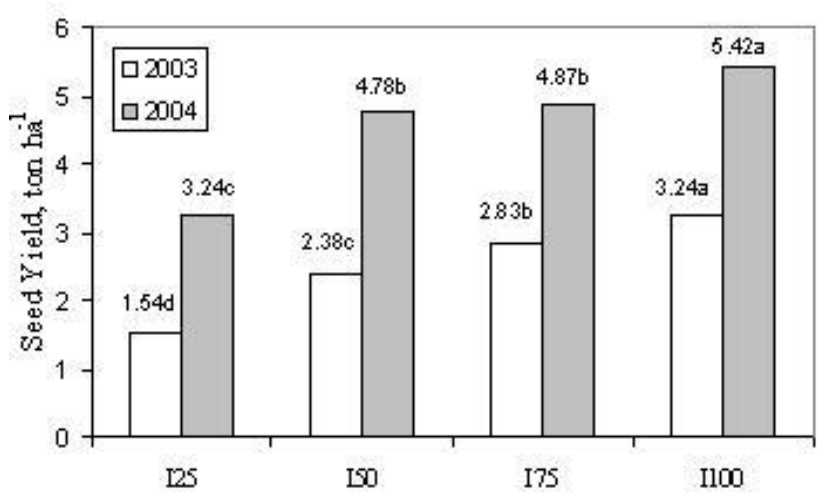

Figure 1. Cotton seed yield for irrigation treatments in two experimental years.

Table 4. Irrigation water amount and other evapotranspiration components.

ET Components	2003				2004			
	I_{100}	I_{75}	I_{50}	I_{25}	I_{100}	I_{75}	I_{50}	I_{25}
I, Irrigation water (mm)	423	349	275	201	467	395	324	252
ΔS, Soil water storage (mm)	125	128	143	181	155	196	230	243
Pe, Effective rainfall (mm)	76	76	76	76	106	106	106	106
Dp, Deep percolation (mm).	45	46	45	48	76	68	60	52
ET, Evapotranspiration (mm)	579	507	449	410	652	629	600	549

area index value were assessed for all treatments during both growing periods in 2003 and 2004.

The sensitivity of cotton seed yield to the ET deficit for the whole growing season was determined by using a model developed Stewart et al. (1977).

Analysis of Variance (ANOVA) was used to evaluate the effects of different irrigation treatments on the yield and yield components of cotton. The least significant differences (LSD) test was used for comparing and ranking of the treatments.

RESULTS

In both years, the full irrigation treatment (I_{100}) gave the highest yield (Figure 1). There were statistically significant differences ($P \leq 0.05$) among the treatments for seed cotton yields.

Five and eight irrigations were realized in the first and second years, respectively. The total amount of irrigation water varied from 201 to 423 mm in 2003; and 252 to 467 mm in 2004 (Table 4).

In both years, the cotton seed yield (Yc, in kg ha^{-1}) was strongly associated to the irrigation water (I, in mm) applied. The following linear and polynomial relations were obtained (Equation 3):

$$Yc=7.102(I)+317.88 \quad R^2=0.94 \text{(for 2003)} \tag{3a}$$

$$Yc = 0.024\,(I)^2 + 22.09\,(I) - 1832.7 \quad R^2 = 0.98 \tag{3b}$$

$$Yc = 9.256\,(I) + 1250.7 \quad R^2 = 0.84 \text{ (for 2004)} \tag{3c}$$

$$Yc = 0.048\,(I)^2 + 43.81\,(I) - 4651.7 \quad R^2 = 0.93 \tag{3d}$$

The seasonal evapotranspiration (ET) for the study periods ranged from 410 to 579 mm in 2003 and from 549 to 652 mm in 2004, depending on the level of water deficit imposed (Table 4). Compared to I_{100} treatment, reductions in the yield were 0.41 (13%), 0.86 (27%) and 1.7 ton ha^{-1} (53%) for I_{75}, I_{50} and I_{25} treatments, respectively. Similar results were noted in the second year when total water applied decreased from 467 to 252 mm, for the I_{100} and I_{25} treatments, respectively. The over all ET decreased by 103 mm (16%), 169 mm (29%) in the I_{25} treatment in 2003 and 2004, respectively. Yield losses in 2004 were 2.18 (40%) in I_{25}, 0.64 (12%) in I_{50} and 0.55 ton ha^{-1} (10%) in the I_{75} treatment compared to full irrigation treatment. The cotton seed yield (Yc) was linearly related to evapotranspiration (ET, in mm) as shown (Equation 4):

$$Yc = 14.4(ET) - 4325 \qquad (R^2 = 0.87) \tag{4}$$

These relations indicate that plant water consumption of

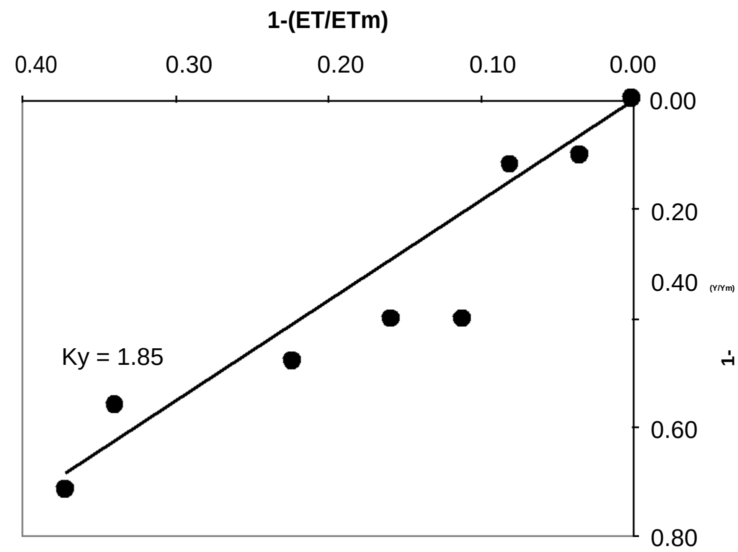

Figure 2. Relative yield decrease of cotton as a function of relative ET deficiency.

Table 5. Irrigation water use efficiency (WUE) and total water use efficiency (TWUE) for irrigation treatments.

Irrigation treatments	IWUE (kg $ha^{-1}mm^{-1}$)			TWUE (kg $ha^{-1}mm^{-1}$)		
	2003	2004	Mean	2003	2004	Mean
I_{100}	10.2	11.6	10.9	7.5	8.3	7.9
I_{75}	11.1	12.3	11.7	7.6	7.7	7.7
I_{50}	13.9	14.8	14.3	8.3	8.0	8.1
I_{25}	12.1	12.8	12.5	5.8	5.9	5.9

300.3 mm gives a minimum seed-cotton yield in Amik Plain soils.

The results of this work showed that the cotton-seed yield and plant water consumption (ET) can be described better with polynomial model than with simple linear model (Equation 5). This behavior may be attributed to regional climate, soil properties and irrigation regimes.

$$Yc = 0.0416\,(ET)^2 - 29.45\,(ET) + 6946.1 \quad R^2=0.93 \text{ (polynomial)} \qquad (5)$$

The relation between relative ET deficiency and relative yield decrease from Stewart Equation as shown in Figure 2, with yield response factor (Ky) of 1.85 for the whole growing season.

Water use efficiency (WUE)

The irrigation water use efficiency (IWUE) and total water use efficiency (TWUE) for both years were given in Table 5. The mean IWUE and TWUE values ranged from 10.9 to 14.3 and from 5.9 to 8.1 kg ha^{-1} mm^{-1}, respectively.

The relationship between two parameters, the percent reduction of irrigation water (Ip) as to full irrigation treatment of I_{100} and irrigation water use efficiency percent reduction (IWUEp) values was shown with equation 6.

$$IWUEp = -9.379\,(Ip)^2 + 9.18\,(Ip) + 11.05 \quad R^2= 0.48 \qquad (6)$$

The regression curve estimates that the maximum IWUEp that occurs at Ip of 49%. It can therefore be concluded that water deficit more than 50% of the irrigation requirement should be considered for the study region.

Yield components

As shown in Table 6, as water stress increased, seed cotton weight per boll decreased in spite of decreasing number of bolls remaining per plant. The range of seed-cotton weight was 3.7 to 4.9 g per boll in 2003, and 4.6 to 6.0 g per boll in 2004.

Table 6. Mean values of some yield components of cotton.

Irrigation treatment	Seed cotton weight per boll (g)		Lint percentage (%)		Plant height (cm)		Leaf area index		Number of sympodial branch per plant		Number of green boll per plant		Number of opened boll per plant	
	2003*	2004*	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
I_{25}	3.7 cd	4.6 b	38.5 ab	44.0	9.3	12.3	46.3 b	77.5 c	0.7 b	3.8 b	9.3	19.0 b	5.7	4.8
I_{50}	4.2 bc	5.2 ab	37.2 bc	43.4	10.7	13.0	55.1 a	88.5 b	1.0 b	3.7 b	13.4	19.5b	3.7	3.5
I_{75}	4.6 ab	5.6 ab	37.6 bc	43.6	11.0	13.3	56.0 a	89.8 b	0.7 b	4.1 b	13.6	21.5 b	1.5	3.8
I_{100}	4.9 a	6.0 a	36.8 c	43.0	12.5	14.0	57.1 a	103.3 a	2.3 a	5.3 a	16.8	30.8 a	2.5	2.5
LSD (5%)	0.6	1.0	1.1	n.s	n.s	n.s	7.1	2.8	1.2	0.7	n.s	5.8	n.s	n.s

*Rows of data within a column, followed with different letters, are significantly different at $P \leq 0.05$, based on LSD mean range test.

Time variances of plant height and leaf area index for the different treatments are shown in Figure 3. The resulting relations for both parameters in two years were sigmoidal shape. The crop growth rate decreased as the stress increased. The maximum plant height in all treatments were measured over the time period of 220 to 240 DOY. The plant heights, measured at harvest, were between 46.3 and 57.1 cm in 2003 and 77.5 and 103.3 cm in 2004, and they were statistically different ($P \leq 0.05$) among the treatments (Table 6). Variations of LAI over the growing seasons were similar to the time variance of plant heights. The time period when maximum LAI observed was same as the plant height and it occurred at about 220 - 240 DOY.

Number of the sympodial branches increased from the treatment I_{25} to the treatment I_{100} in 2003 and 2004 (Table 6). The maximum number of sympodial branches observed under I_{25} was lower compared to other treatments. The time variance of branch numbers over the two years period (Figure 4) was similar and the maximum number in all treatments was measured at 218 in 2003 and 238 DOY in 2004.

The green boll numbers per plant were between 9.3 and 16.8 in 2003 and 19.0 and 30.8 in 2004 (Table 6). The boll numbers were not affected with irrigation treatments in 2003; however, they differed significantly ($P \leq 0.05$) among treatments in 2004. The highest values were observed under the I_{100} treatment. The variation of boll number with time (Figure 4) shows that there were sigmoidal relationships, and the maximum boll number was attained at about 220 to 240 DOY for both years. Towards the end of season, the boll numbers decreased in the I_{25} and I_{50} treatments, due to boll shedding.

The maximum lint percentage was obtained under I_{25} treatment, whereas the minimum lint percentage was noted under I_{100} (Table 6).

The highest number of opened bolls per plant were noted under the treatment I_{25} in both 2003 (5.7 per plant) and 2004 (4.8 per plant). The lowest number of the opened bolls was observed with I_{100} (2.5) in both years (Table 6). The results therefore suggest that there is an adverse effect of high irrigation level on number of opened bolls per plant.

DISCUSSION

The irrigation water amounts causing water stress and significant yield reduction of cotton were comparatively lower than the amounts reported by others in similar climatic regions in Turkey (Kanber et al., 1993; Yavuz, 1993; Cetin and Bilgel, 2002; Yazar et al., 2002; Ertek and Kanber, 2003). This may indicate different irrigation pro-grams of researches. The cotton seed yield (Yc) and irrigation water (I) relations show that seed-cotton yield increased polynomialy with increasing irrigation water amount applied. The range of change in determination coefficients was from 0.98 to 0.93 with second order polynomial relationship. The linear relations gave rather poor fit with determination coefficients of 0.94 to 0.84 (Equation 3a and 3c). Similar results were given by Kanber et al. (1993) and Jalota et al. (2006). They found that a second degree polynomial relation could adequately describe yield response of cotton to irrigation water amount.

The seasonal evapotranspiration (ET) measured for nearly all the irrigation treatments was more or less within the range reported by others in the different regions of Turkey (Kanber, 1977; Kanber et al., 1993; Cetin and Bilgel, 2002; Yazar et al., 2002; Ertek and Kanber, 2003), and elsewhere (Howell et al., 1984a,b; Phene et al., 1984; Aujla et al., 2005). Irrigation water and evapotran-

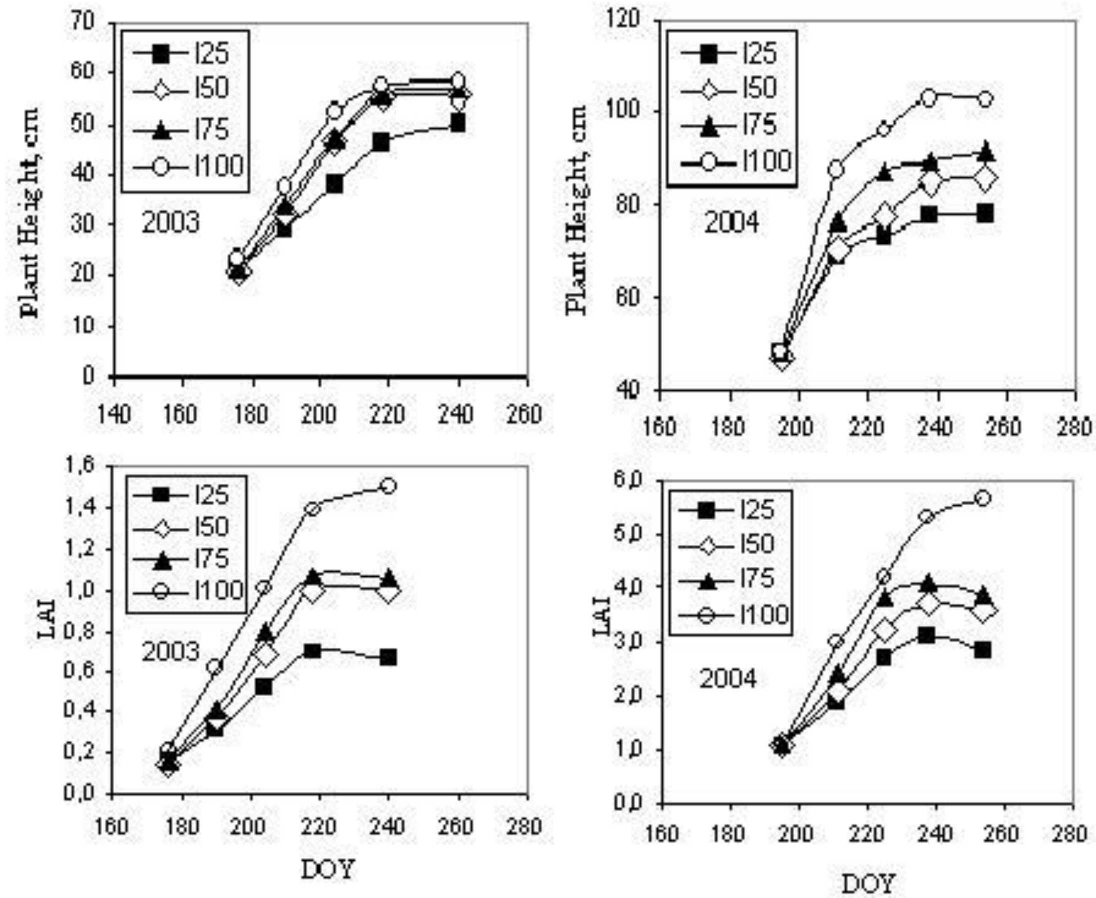

Figure 3. Changes in plant height and leaf area index among treatments.

spiration of cotton in the second experimental year was higher than those of the first year. The lower ET observed in 2003 should be attributed to somewhat lower irrigation water requirement realized because of short length of growing season and some climatic data as explained by Jensen et al. (1989).

In general, ET and yield of cotton reduced with decreasing irrigation water amount. For example, by reducing irrigation water from 423 to 201 mm (2003), ET was decreased by 169 mm (29%) in I_{25} treatment, compared to I_{100}. Yield reduction with decreasing irrigation water concurrently caused reductions in WUE and ET in all treatments. The relative yield reduction was proportionally was higher when compared with relative ET reduction in all treatments for the two years.

Sammis (1981) and Kanber et al. (1990) reported linear relationship between cotton yield and ETc. However, from long-term studies, Grimes and El-Zik (1982) sug-gested a slight curvature function considering the nature of cotton reproductive development and water relations. Jalota et al. (2006) recently explained that there was a close linear relationship between cotton seed yield and ET, and the polynomial relations for these variables did not show any improvement over the simple linear relation. Contrary of this, Vanjura et al. (2002) have reported that second-order polynomials provided the best approximation of irrigation-lint yield of cotton relationship for all years.

Doorenbos and Kassam (1986) reported that yield response factors (Ky) of cotton grown in deep and medium textured soils changed in a rather wide range from 0.85 to 0.50, respectively for seasonal water deficit. At the same time, Kanber et al. (1991) have found a high yield response factor (Ky: 1.2) for surface irrigated cotton for seasonal ET deficit. Recently, Yazar et al. (2002) reported that seasonal Ky factors are 0.50 to 0.75 for Harran Plain. However, Ertek and Kanber (2003) suggested Ky factors of 0.38 to 0.84 for seed cotton yield of the Seyhan Plain. Under Tashkent-Uzbekistan condi-tions, Kamilov et al. (2003) reported that same factor varied between 0.54 with 1.70. It was well documented that yield response factor varies, depending on ET, wetting depth during irrigation, irrigation program itself and crop yielding capacity (Hanks, 1983; Doorenbos and Kassam, 1986). Somewhat higher Ky observed in this work may be attributed to these factors mentioned above.

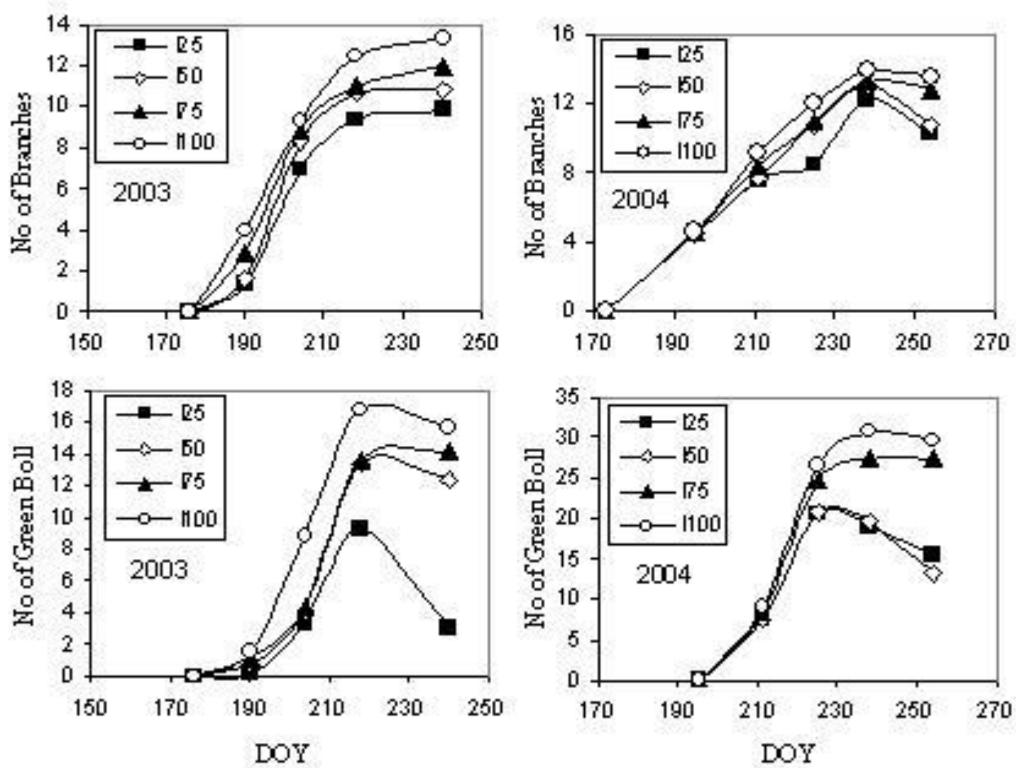

Figure 4. Changes in the some growth parameters among treatments.

Maximum IWUE was found in I_{50} treatment for both years. IWUE had higher values than TWUE since there was no rainfall during the irrigation season. Reports by Yavuz (1993), Yazar et al. (2002) and Ibragimov et al. (2007) showed similar IWUE values as found in our work. Similarly the TWUE values published by Grismer (2002), Yazar et al. (2002) and Karam et al. (2006) were in close agreement with our results.

There are numerous earlier works showing close response of cotton to water deficit on flowering, boll formation and its distribution and on other yield attributes (e.g., Gerik et al., 1996; Pettigrew, 2004). Boll weights per plant were significantly different among the irrigation treatments ($P \leq 0.05$). Gerik et al. (1996) found similarly smaller boll weights when water deficits were imposed. However, lint percentages were inversely affected with increased irrigation. The maximum lint percentage was obtained under I_{25} treatment, whereas the minimum lint percentage was noted under I_{100} (Table 6). However results by Kanber (1977) were reverse of what we observed.

Rate of increase of LAI was hindered with increase of water stress. The differences among treatments became larger as stress increased. The highest leaf area indexes were obtained under full irrigation treatment (I_{100}) in both 2003 and 2004. The applied irrigation water significantly affected the leaf area index. The results obtained were similar to earlier works by Yazar et al. (2002) and Karam et al. (2006).

The numbers of sympodial branches were directly affected with irrigation levels and they increased with increase amount of irrigation water application. However, the differences observed among the treatments were not significant in both years. Pettigrew (2004) also reported similar behaviour and found that higher was the applied amount of irrigation water, the higher was the number of sympodial branches.

The results on the number of bolls were similar to what Kanber (1977) and Cetin and Bilgel (2002) reported. Ertek and Kanber (2003) and later Mert (2005) also showed that the boll number per plant increases with applied irrigation water amount.

The seed cotton yield was directly related with plant height, the number of sympodial branches per plant, the number and weight of green bolls per plant. Ertek and Kanber (2003) showed that a strong association exists between yield and plant height and number of green bolls.

REFERENCES

Allen R, Pereira LS, Raes D, Smith M (1998). Crop Evapotranspiration. FAO Irrigation and Drainage Paper 56, Rome.

Aujla MS, Thind HS, Butter GS (2005). Cotton yield and water use

efficiency at various levels of water and N through drip irrigation under two methods of planting. Agric. Water Manag. 71: 167-179.
Chun-yan W, Akihiroz I, Mao-song L, Dao-long W (2007). Growth and eco-physiological performance of cotton under water stress conditions. Agric. Sci. China. 6(8): 949-955.
Cetin O, Bilgel L (2002). Effects of different irrigation methods on shedding and yield of cotton. Agric. Water Manag. 54: 1-15.
Dinc U, Senol S, Aydın M, Akca E, Celik I, Dingil M, Oztekin E, Kılıc S, Günal H, Metin I, Nozoglu M (1997). Detailed soil survey and mapping of Hatay Agriculture Farming. Ankara, p. 67.
Doorenbos J, Kassam AH (1986). Cotton. In: Yield Response to Water. Irrigation and Drainage paper 33, Rome, pp. 88-92.
Ertek A, Kanber R (2003). Effects of different drip irrigation programs on the boll number and shedding percentage and yield of cotton. Agric . Water Manag. 60(1): 1-11.
Fereres E, Cuevas R, Orgaz F (1985). The crop irrigation of cotton in southern Spain. Proc.of the 3th Int.Drip Irr. Cong. ASAE, Fresno, CA, No.1, pp. 371-374.
Gerik TJ, Faver KL, Thaxton PM, El-Zik KM (1996). Late season water stress in cotton: I. Plant growth, water use and yield. Crop Sci. 36: 914-921.
Grimes DW, El-Zik KM (1982). Water Management of Cotton. Univ. California Div. Agric. Sci. Bull. p. 1904.
Grismer ME (2002). Regional cotton lint yield, ETc and water value in Arizona and California. Agric. Water Manag. 54(3): 227-242.
Hanks RJ, (1983). Yield and Water Use Relationships: on over view. In: Limitation to Efficient Use in Crop Production. (Ed. Taylor HM). ASEA, Madison, Wisconsin, USA. pp. 393-410.
Howell TA, Hatfield JL, Yamada H, Davis KR. (1984a). Evaluation of cotton canopy temperature to detect crop water stress. Transaction of ASAE. 27: 84-88.
Howell TA, Davis KR, McCormick RL, Yamada H, Walhood VT, Meek DW (1984b). Water use efficiency of narrow row cotton. Irrigation Sci. 5: 195-214.
Howell TA, Cuenca RH, Solomon KH (1990). Crop Yield Response. In: Management of Farm Irrigation Systems. (Eds.:G.J. Hoffman, T.A. Howell and K.H. Solomon). An ASAE Monog., St. Joseph, MI. pp. 93-124.
Ibragimov N, Evet SR, Esanbekov Y, Kamilov B, Mirzaev L, Lamers JPA (2007). Water use efficiency of irrigated cotton in Uzbekistan under drip and furrow irrigation. Agric. Water Manag. 90(1-2): 112-120.
Jalota SK, Sood A, Chahal GBS, Choudhury BU (2006). Crop water productivity of cotton (*Gossypium hirsutum* L.) wheat (*Triticum aestivum* L.) system as influenced by deficit irrigation, soil texture and precipitation. Agric. Water Manag. 84(1-2): 137-146.
James LG (1988). Priciples of Farm Irrigation Systems. (Ed. Jensen ME) ASAE monograph 3, St. Joseph, MI. pp. 3-9.
Jensen ME, Burman RD, (Ed.) Allen RG (1989). Evapotranspiration and irrigation water requirements. ASCE Manual Rep. Eng. Pract. No: 70, NY.
Kamilov B, Ibragimov N, Esanbekov Y, Evet S, Heng L (2003). Irrigation scheduling study of drip irrigated cotton by use of soil moisture neutron probe. In: Proceedings of the UNCGRI/IAEA. Workshop in Optimization of Water and Fertilizer Use for Major Crops of Cotton Rotation, Tashkent. pp. 13-18.
Kanber R (1977). A lyzimeter research on the effects of irrigation on cotton yield and water consumption at different moisture level of some soil series in Cukurova conditions. Soil and Water Research Institute. Gen.No.78, Report No: 85, Tarsus, p 169.
Kanber R, Bastug R, Koksal H, Baytorun N (1990). Yields and comperative performance of different crop production functions of cotton as influenced by deficit irrigation. Turkish J. Agric. Forest. 15(2): 533-547.
Kanber R, Tekinel O, Baytorun N, Kumova Y, Alagoz T, Onder S, Koksal H, Gencer, O, Koc MK, Diker K, Gencoglan C (1991). The opportunities of irrigation interval and water consumption of cotton in determining from water surface evaporation under Harran plain. Cuk. Univ. Agric. Faculty GAP research, rewiev and development project No: 5.3.1. Adana. p.38.
Kanber R, Tekinel O, Onder S, Koksal H (1993). Comparison of irrigation length of cotton under Cukurova climatic conditions. Turkish J. Agric. Forest. 18: 81-86.
Karam F, Lahoud R, Masaad R, Daccache A, Mounzer O, Rouphael Y (2006). Water use and lint yield response of drip irrigated cotton to the length of irrigation season. Agric. Water Manag. 85(3): 287-295.
Kimura F (2007). Downscaling of the Global Warming Projections to Turkey. In: The Final Report of the Research Project on the Impact of Climate Changes on Agricultural Production System in Arid Areas (ICCAP). pp. 21-37.
Mateos L, Berengena J, Orgaz F, Diz J, Fereres E (1992). Comparation between drip and furrow irrigation in cotton at two levels of water supply. Irrigation and Drainage Abstracts (018-04095).
Mert M (2005). Irrigation of cotton cultivars improves seed cotton yield, yield components and fibre properties in the Hatay region, Turkey. Acta Agriculturae Scandinavica. Section B, Soil Plant. 55: 44-50.
Pettigrew WT (2004). Moisture deficit effects on cotton lint yield, yield components, and boll distribution. Agron. J. 96: 377–383.
Phene CJ, Davis KR, Howell TA, McCornick RL, Nightengale HI, Meek DW (1984). Evapotranspiration and water use efficiency of trickle irrigated cotton. ASAE 84-2625. 1984 Winter Meetingof the ASAE, Florida. pp. 1-24.
Sammis TW (1981). Yield of alfalfa and cotton as influenced by irrigation. Agron. J. 73: 323-329.
Stewart JI, Cuenca RH, Pruitt WO, Hagan RM, Tosso J (1977). Determination and utilization of water production functions for principal California crops. W -67 Calif. Contrib. Proj. Rep. University of California.
Tekinel O, Kanber R (1989). The general rules of cotton irrigation. University of Cukurova, Agricultural Faculty Publication, No:18. Adana, Turkey. p. 56.
Vanjura DF, Upchurch DR, Mahan JR, Burke JJ (2002). Cotton yield and applied water relationships under drip irrigation. Agric. Water Manag. 55: 217-237.
Yavuz MY (1993). The effects of different irrigation methods on cotton yield and water use efficiency. PhD thesis. Cukurova University, Institute of Science and Technology, p. 120.
Yazar A, Sezen SM, Sesveren S (2002). LEPA and trickle irrigation of cotton in the Southeast Anatolia Project (GAP) area in Turkey. Agric. Water Manage. 54(3): 189-203.