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Effect of DeficitIrrigation on Some Agronomic Traits of Cotton (GossypiumhirsutumL.)Cultivars Differing in Maturity

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Abstract:*This field trial was carried out on the Carmen (late-maturing) and Özbek (early-maturing) cotton cultivars in 2010 and 2011 at the Research and Application Farm of the Agriculture Faculty of Adnan Menderes University. The applications of water significantly affected raw cotton yield and various agronomic parameters as; number of bolls per plant, boll weight, number of fruit branches, single plant yield, 100-seed weight and lint percentage. The study was conducted according to a randomized complete block design was used with three replications and two factors. Irrigation treatments were designated as full irrigation level (IL-100, which received 100 % of the soil water depletion) and those that received 75 %, 50 % and 25 % of the amount received by treatment IL-100 on the same day. The highest yield was obtained from Carmen (late-maturing) under full-irrigation treatment. According to the research results, irrigation treatments significantly influenced the cotton yield and the agronomic components evaluated in this study.*

Keywords:*Cotton, drip irrigation, deficit irrigation, agronomic components*

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I. INTRODUCTİON

Turkey's cotton production meets approximately 44% of the needs of its domestic market. In 2003, an area of 721 000 ha was used for cotton production, and in 2013 this figure was reduced up to 450 000 ha. Reductions in the areas planted, while at the same time an increase in consumption and a reduction in yield because of drought, have necessitated the development of high-yield drought-resistant cultivars of cotton [1].

A reduction of groundwater resources connected to global climate change, a rise in energy prices, and an increase in industrial and domestic water consumption have led to a reduction in the amount of water available for agricultural production. In addition to this, the effects of global warming are more and more being felt, and one of the most important of these is drought. This has a negative effect on crop production. Thus although cotton has relatively high drought resistance when compared with other crop plants, the length of a drought and its occurrence in the growing season can cause reductions in yield by as much as 70-80%.

In cultivated crops including cotton, drought (water stress) is among the abiotic stress factors which most limit productivity. Previous studies have demonstrated the negative effects of water stress on yield and fibre quality in cotton. It has been reported that drought in the growing period, when the cotton plant is most sensitive to water stress, in the period at the start of squaring and when the first white flowers appear, has the greatest effect on yield [2]. The most important reason for the loss of yield in cotton when a drought occurs is a decline in the numbers of bolls per unit area [3]. At the same time, water stress affects the distribution of the bolls on the fruiting branches. Under normal irrigation conditions, not only bolls in the second and third position but also those on the tenth branches or more contribute to the cotton yield, but in drought conditions these bolls fall, and only those in the first position are productive [3,4].

Water shortages are predicted in many areas as a result of climate change, and particularly in tropical and subtropical regions, including Turkey and the Mediterranean basin, a reduction in the availability of water is expected. The areas of Turkey most affected by this drying trend are the Aegean, Mediterranean, Marmara and Southeast Anatolian regions [5]. In addition to this, the effects of global warming are more and more being felt, and one of the most important of these is drought. This has a negative effect on crop production. Limited availability of irrigation water requires fundamental changes in irrigation management or urges the application of water saving methods. Common irrigation methods practiced for cotton production in this region are wild flooding, basin and furrow methods. In general, the farmers over irrigate, resulting in high water losses and low water use efficiencies and thus creating drainage and salinity problems [6].

Numerous studies have reported how cotton reproductive growth, yield, and fibre quality are affected by moisture deficits. Reductions in the number of bolls as a result of water stress have an adverse effect on the yield of raw cotton. Water stress in the late flowering period of cotton slows the growth of the bolls forming in this period, and reduces their strength [7]. In a study carried out to determine the effect of different irrigation intervals (5 and 10 days) on cotton yield under Çukurova conditions, it was found out that as the irrigation level and interval increased, the number of bolls increased, and as a result of this, cotton yield increased[8]. A study performed to determine the effect of five different irrigation levels on water use efficiency, yield, yield components and fibre quality characteristics, found that raw cotton yield, the number of bolls and the weight of cotton per boll fell with the reduction in irrigation water level[9].In a study conducted in the west of China in 2008-2009, cotton plant was irrigated under five different soil matrix potential irrigation conditions (-10 kPa, -20 kPa, -30 kPa, -40 kPave -50 kPa). Researchers concluded that as the amount of water which could be taken up by the roots in the soil increased, yield and number of bolls increased at a lower negative value, while boll cotton weight showed an irregular reaction to irrigationlevels[10].

The aim of this study was to investigate the effects of different irrigation treatments on yield and some agronomic components of the early-maturingÖzbek and the late maturing Carmen cultivars of cotton.

II. MATERİALS AND METHODS

This study was conducted under field conditions at the research and application farm of the Agriculture Faculty of Adnan Menderes University on its southern campus. The research area is located in the Büyük Menderes Lower Basin, ata latitude of 37° 51' North and a longitude of 27° 51' East [11].

The Lower Büyük Menderes Basin has a Mediterranean climate of hot and dry summers and cool wet winters. Monthly average temperatures vary between 9.5°C and 28.1°C, monthly relative humidity varies between 47% and 76%, average monthly wind speed is from 1.2 to 1.8 m/s, and monthly average precipitation varies from 2.2 to 135.1 mm [12]

The water content at field capacity varied from 18.4- 23.1 % and wilting point varied from 7.2-10.1 % on dry weight basis in the fieldwhere the experiment was conducted.The soils of the experimental area contain sand percentage between 49.7-68.2 %, which was followed by silt percentage 19.2-32.0 % and clay percentage 13.6-17.5 %. The soils could be classified as loam. Throughout the soil profile reaching up to 1.2 m depth, the dry soil bulk densities ranged from 1.35 to 1.52 g cm^{-3}. The available soil water content of the soil profile was 221 mm within the top 1.2 m depth.

The irrigation water needed to irrigate the experimental plots in the study was supplied from a deep-wellwithin the experiment area. Irrigation water was raised from the well with a motor pump, and transferred to the study area in 63 mm external diameter braided PVC pipes. The drip irrigation method was used in the study and 16 mm external diameter polyethylene laterals were arranged in the experimental plots in such a way that a single lateral came to each plot. Lateral drip irrigation pipes were chosen with drippers with a flow rate of 4 Lh^{-1} and a dripper spacing of 25 cm. Valves of 16 mm diameter were installed at the head of each lateral line in order to provide control over irrigation.

The cotton cultivars Carmen and Özbek were used as research material. The Carmen cultivar is a late-maturing variety which is productive and has good fibre quality characteristics. The plants are of medium height and conical in shape, and the stems are thick and strong. The Özbek cultivar is an early-maturing variety, productive, with high ginning productivity, and is resistant to wilting disease [13].Cotton plants were thinned to a spacing of 0.70 m × 0.25 m when the plants were about 0.15 m in height. A compound fertilizer (15 % N, 15 % K, and 15 % P) was applied at a rate of 40 kg da^{-1} pure N, P and K at planting. The required remaining portion of nitrogen 25 kg N kg da^{-1} was applied as 33 % ammonium nitrate before the first irrigation.Seeds were sown with a pneumatic seed drill with 70 cm between the rows.

A randomized complete block design was used with three replications with 3 m between each plot. Each experimental plot had a total area of 33.6 m² at sowing. Two different maturing cotton cultivars (C) (Carmen and Özbek) and four different irrigation levels (IL), 100 %, 75 %, 50 % and 25 %, were investigated in the experiment. The soil moisture was observed by gravimetric soil sampling method in order to determine irrigation time and irrigation was initiated when 40 % of the available water of the soil had been used up. Water was applied at 100 % of the water needed to reach field capacity to the plots which were to be fully irrigated, and at 75 %, 50%, and 25 % proportions of this amount to plots that were to receive deficit irrigation.

At harvesting, the plants in the two middle rows were harvested by hand and weighed, and the cotton yield of the plots weredetermined (kg ha^{-1}).The agronomic components examined in this study are; raw cotton yield per plant ($gplant^{-1}$), number of bolls per plant($numberplant^{-1}$), boll raw cotton weight (g), number of fruiting branches per plant ($numberplant^{-1}$), single plant yield, 100-seed weight (g) andlint percentage (%). The raw cotton yield per plant ($gplant^{-1}$) was determined by dividingthe weight of raw cotton harvested from each plot by the number of plants.Number of bolls per plant ($numberplant^{-1}$) was calculated from the number of opened bolls on ten plants collected at random from each plot at harvest time.Boll raw cotton weight (g) was determined bydividing the weight of raw cotton of 25 bolls taken at random from the plants of each plot at harvest time by the number of bolls.Number of fruiting branches per plant ($numberplant^{-1}$) was obtained by counting the number of fruiting branches of ten plants taken at random from each plot at harvest time. 100-seed weight (g) was determined by weighing 100-seeds from a 20-boll sample taken at random from each plot. The lint percentagewas determined by passing the raw cotton obtained from the bolls through a roller gin experimental ginning machine. Then the ratio of the weight of the fibreto the weight of the raw cotton gives the lint percentage (%).Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on seed cotton yield (kg ha^{-1}). The Least Significant Differences (LSD) test was used for comparing and ranking the treatments. Differences were determined significant at $P < 0.05$.

III. RESULTS AND DİSCUSSİONS

Effect of different irrigation levels on yield of cultivars

Table1 shows the cotton yields obtained from the experimental treatments and the results of the variance analysis. The highest cotton yields were obtained from IL-100 treatments in which no water restrictions were applied in the growing season for both cultivars of cotton. The lowest raw cotton yield was obtained from treatments IL-25, in which water was applied at a level of 25%. Raw cotton yields from other irrigation treatments varied between these values. Variance analysis was used to determine the differences between the irrigation treatments according to the raw cotton yields obtained. Examining Table 1, it can be seen that cultivars and irrigation levels in each year were found to be significant at the $p<0.01$ level. On the other hand, the C x IL interaction was found not to be significant in either year. The LSD test was performed to establish the difference in raw cotton yield between cultivars and irrigation levels.

Examining these results from the point of view of cultivars, it is seen that Carmen formed the first group and Özbek the second group. In terms of water level, four groups formed in each year. The first group consisted of the IL-100 treatments where no water restriction had been applied in the whole growing season, treatments in which water had been applied at the 75% level (IL-75) were second, and treatments which had received water at the 25% (IL-25) level formed the last group.

Table 1. Seed cotton yield as influenced by cotton cultivars and irrigation levels

Treatment		**2010**	**2011**
Cultivar	Carmen	5640.7a	5680.0a
	Özbek	5094.0b	520.61b
F Value (C)		**	**
LSD %5		20.404	14.348
Irrigation Level (IL)	% 100	6250.2a	6319.0a
	% 75	5590.1b	5690.0b
	% 50	5180.0c	5291.0c
	%25	4459.0d	4462.0d
F Value (IL)		**	**
LSD %5		28.855	20.291
CxIL		ns	ns

*P< 0.05; **P< 0.01; ns: not significant

Values with a common letter are not significantly different from one another using $LSD_{0.05}$

At the same time, making a general assessment, it was found that the findings in relation to yield were similar to the findings of researchers performing studies on different irrigation programmes. According to the results of a study conducted on cotton irrigated by drip irrigation in the Aydın area, the highest yield of cotton was achievedwith irrigation at eight-day intervals from a treatment in which 100% of the amount of evaporation from a class A evaporation pan was applied [14]. In a study conducted in Çukurova, cotton plant irrigated by drip irrigation, it was reported that raw cotton yield varied between 1970 and 4220 $kgha^{-1}$[15]. On Harran plain, the applicability of LEPA and drip irrigation systems with cottonwas researched. They concluded that LEPA and drip irrigation could be used more effectively than surface irrigation, and that they could prevent irrigation water losses[6]. Different irrigation methods (furrow, sprinkler and drip) were compared with cotton on the Harran plain and according to the results of the study, the highest raw cotton yield was obtained with drip irrigation. It was 30% higher than that obtained by sprinkler irrigation and 21% higher than that of furrow irrigation [16].

In evaluations conducted previously, it has been found that both cultivar and the level of irrigation applied are important in increasing raw cotton yield. It has been concluded that the most suitable irrigation programme in terms of raw cotton yield would be using the Carmen cultivar, in conditions where there was no irrigation water restriction in the area under IL-100 treatment.

Results concerning various agronomic characteristics

Table 2 shows values relating to various agronomic characteristics obtained from the study, and Table 3 shows variance analysis and the LSD test results of these findings.

Table 2. Results of some agronomic traits of different cultivars under different irrigation levels

Treatments		Number of bolls (number $plant^{-1}$)	Boll raw cotton weight (g)	Number of fruit branches (number $plant^{-1}$)	Single plant yield (g $plant^{-1}$)	100-seed weight (g)	Lint percentage (%)
2010							
Carmen	IL-100	19	5.90	15	111.7	10.42	40.9
	IL-75	19	5.69	11	103.1	10.79	40.4
	IL-50	18	5.43	11	97.0	10.42	39.3
	IL-25	17	5.38	10	80.2	9.62	39.1
Özbek	IL-100	21	4.95	16	105.5	10.80	40.0
	IL-75	18	5.23	14	90.1	10.50	39.3
	IL-50	18	4.78	11	82.6	10.63	39.0
	IL-25	18	4.64	10	74.7	9.49	38.4
2011							
Carmen	IL-100	18	5.49	17	112.1	10.73	41.7
	IL-75	18	5.27	13	103.8	10.52	40.8
	IL-50	17	5.12	14	98.7	10.39	39.8
	IL-25	15	4.59	13	79.9	9.36	39.3
Özbek	IL-100	20	5.05	17	107.6	10.56	40.5
	IL-75	17	4.83	16	93.4	10.48	39.9
	IL-50	17	4.58	12	85.4	10.34	39.6
	IL-25	16	4.21	11	75.0	9.47	38.8

As Table 2 shows, the number of bolls varied from 15 to 21 in relation to the cultivars and irrigation programmes. Regarding the number of bolls, the difference between cultivars was found to be insignificant, while the difference between irrigation levels was at a level of $p<0.01$(Table 3). The number of bolls decreased in relation to a reduction in irrigation water applied. Generally, fewer bolls were obtained from both cultivars in treatments irrigated at 25% (IL-25) and 50% (IL-50).A study conducted in different soil series with lysimeters in Çukurova conditions, it was found that boll numbers varied between 4.5 and 10.4 under the effects of the irrigation programme applied and the soil series [17]. In a study in which the furrow irrigation method was applied under Harran plain conditions, the number of bolls varied between 10 and 20 according to different irrigation applications [18], while these values varied on average between 14.1 and 14.8 under Nazilli conditions [19]. Under Aydın conditions, the average number of bolls per plant varied between 6.1 and 15.6 and between 5.9 and 16.6 [10,15]. Considering boll raw cotton weight, variance analysis showed a difference between the cultivars of $p<0.01$ for both years, while the difference between irrigation levels was found to be significant at levels of $p<0.01$ and $p<0.05$ (Table 3). Examining the results from the point of view of cultivars, it is seen that the highest boll raw cotton weight was obtained from the Carmen cultivar. When results are scrutinized from the point of view of irrigation levels, the first group consisted of the treatments which received full irrigation (IL-100). Generally, a lower boll raw cotton weight was obtained in both cultivars from treatments to which irrigation water had been applied at a proportion of 50% and 25% (IL-50 and IL-25). In a study in which the drip irrigation method was applied under Aydın plain conditions, boll weights varied on average between 3.51 and 6.18 g according to different irrigation applications [10].

Table 3 shows that according to variance analysis, the difference between cultivars and irrigation levels was at the level of $p<0.01$ and was significant in both years.

Table 3. Some agronomic traits of cotton influenced by different cotton cultivars and irrigation levels

		Number of bolls (number plant^{-1})		Boll raw cotton weight (g)		Number of fruit branches (number plant^{-1})		Single plant yield (g)		100-seed weight (g)		Lint percentage (%)	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Cultivar	Carmen	18.8	17.32	5.61a	5.12a	12.8a	14.1	98.05a	98.65a	10.36	10.25	39.97a	40.44a
	Özbek	18.7	17.70	4.90b	4.67b	11.9b	14.0	88.25b	90.38b	10,31	10.21	39.20b	39.72b
$LSD_{0.05}$				0.214	0.154	0.561		3.372	2.311			0.370	0.352
Irrigation Level	% 100	20.1a	19.5a	5.44a	5.27a	15.8a	16.8a	108.6a	109.8a	10.61a	10.64a	40.50a	41.15a
	% 75	19.0ab	17.7b	5.46a	5.05b	12.6b	14.6b	96.65b	98.65b	10.65a	10.5ab	39.88b	40.38b
	% 50	18.4bc	17.3b	5.10b	4.85b	11.0c	12.8c	89.86c	92.08c	10.52a	10.36b	39.16c	39.73c
	%25	17.5c	15.5c	5.01b	4.,40c	10.0d	12.1c	77.48d	77.48d	9.55b	9.41c	38.81c	39.06d
$LSD_{0.05}$		1.271	1.329	0.302	0.217	0.794	1.279	4.768	3.268	0.480	0.236	0.523	0.498
	C	ns	ns	**	**	**	ns	**	**	ns	ns	**	**
	IL	**	**	*	**	**	**	**	**	**	**	**	**
	Cx IL	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

*P< 0.05; **P< 0.01; ns: not significant

Values with a common letter are not significantly different from one another using $LSD_{0.05}$

Examined from the angle of irrigation levels, the first group consisted of treatments receiving full irrigation, and the last group consisted of the treatments to which the least irrigation water was applied. The number of fruiting branches fell in relation to reduction in irrigation water applied.In a study conducted under Çukurova conditions, it was reported that the average number of fruiting branches varied between 10.8 and 17.8 with different water applications [17].In a study carried on with Nazilli-84 cultivar under Antalya conditions using furrow irrigation an average of 13.1 fruiting branches were determined [20]. In a study under Harran plain conditions, furrow irrigation and the Sayar-314 cultivar, the average number of fruiting branches varied from 6 to 24 according to different irrigation applications [18]. Another study in which the Nazilli-84 cultivar was used under Nazilli conditions, these values varied on average between 15.1 and 15.7 [19]. Examining single plant yield values in the Table 3, it is seen that the difference between variety and irrigation levels in both years were significant at a level of $p<0.01$. Examining the results from the point of view of cultivars, it is seen that the highest plant yield was obtained in both years from the Carmen cultivar. From the point of view of irrigation levels, the first group was formed from treatments which received full (100%) irrigation water, and the last group was formed from the treatments which received the least irrigation water (25%).

Examining 100-seed weight in Table 3, it is seen that the difference between cultivars was insignificant in both years, while the difference between irrigation levels was significant at the $p<0.01$ level. At both irrigation levels, the highest values were obtained from the treatments which received the full amount of water (IL-100). Similar to the other quality characteristics, 100-seed weight values in all irrigation treatments showed a decline in relation to irrigation water restriction. In three different experiments in Aydın conditions, researchers determined different 100-seed weight values with an average of 9.80-11.24 g by[21];9.31-11.20 g by [15];and9.91-13.13 g by [22]in connection with different irrigation methods and irrigation programmes.

Examining ginning efficiency values for the years 2010 and 2011, it is seen that there was a significant difference at the $p<0.01$ level from the point of view of both factors (Table 3). From the point of view of cultivars, the highest value was obtained from the Carmen cultivar, while when the results were examined from the point of view of irrigation levels; it was found that the highest values were obtained from the treatments without water restrictions, where the full amount of irrigation had been applied. In studies on this topic, a study carried out on the Nazilli 84 cultivar of cotton under Antalya conditions using furrow and drip irrigation methods, and reportedof 41.42% with furrow irrigation and 42.06% with drip irrigation [20]. In the same way, values of 43-44% reported by [23].In a study applying surface irrigation methodsvalues of 44-45% and 41.6-44.3% were reported by [24] and [15]. In another study in the same region,using the drip irrigation methodlint percentagevalues of 39.96-40.02%were determined by [22]. Also, in a study under restricted irrigation conditions, lint percentage values varied between 43% and 45% according to irrigation levels [25].Another researcher in the same region reported these values as 39.8-41.7% [21]. In studies in our region, differences in lint percentage values may be related to climatic differences between the years or to differences in methods and programmes applied.

IV. CONCLUSIONS

The conclusions of the study performed in 2010 and 2011 on cotton growninBüyük Menderes plain conditions with the purpose of determining the effects of different drip irrigation treatments on cotton yield and agronomic characteristics are evaluated in this study.

For both cultivars, the highest raw cotton yields were obtained from IL-100 treatments. In 2010 the highest yield, in treatments IL-100 in which water restriction was not applied during the growing season were 6405 $kgha^{-1}$ and 6100 $kgha^{-1}$, while in 2011 these values were 6448 $kgha^{-1}$ and 6190 $kgha^{-1}$. The lowest raw cotton yields were obtained from treatments IL-25, to which water was applied at a rate of 25%. Raw cotton yields for the other irrigation treatments varied between these values.

The number of bolls varied between 15 and 21 according to the different cultivars and irrigation programmes. Regarding the number of bolls, the difference between cultivars was found to be insignificant, while the difference between irrigation levels was at a level of $p<0.01$. Examining the results from the point of view of cultivars, the greatest boll raw cotton weight was seen in the Carmen cultivar.Thelint percentage values in 2010 and 2011 have a significant difference which was found for each factor at a level of $p<0.01$. In terms of cultivars, the highest value was obtained from the Carmen cultivar and when the results are examined from the point of view of irrigation levels the highest values were still obtained from the fully irrigated treatments where no water restriction was applied.

Finally, it may be concluded that as cotton is a crop which is sensitive to shortages of moisture in the soil, it is necessary to fully meet its water needs throughout the growing season in order to obtain high raw cotton yield and good agronomic characteristics.However, if water resources in the area are limited, then restricting water to a level of only 50% may produce acceptable results. According to evaluations conducted until now, both cultivar and the irrigation level applied are important in increasing raw cotton yield.In this regard it was concluded that the most suitable irrigation programme from the point of view of raw cotton yield in a region without irrigation water restrictions was the treatment IL-100 in which water was fully applied, using the Carmen cultivar.

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