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The Effects of Water Stress on Yield, Yield Component and Quality Parameters of Drip Irrigated Cotton in Aydın Province

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Abstract In order to observe the effects of water stress on seed cotton yield, some agronomic and fiber quality parameters of Gloria cotton cultivars, a field trial was conducted in year of 2018 at the Research and Application Farm of the Agriculture Faculty of Aydın Adnan Menderes University.

The trial was designated in randomized complete block design with three replications. Irrigation was begun in the control plots (S_1) with 40% of usable water holding capacity of the soil at a depth of 1.20 m taken up, and 75%, 50% and 25% of the water applied to the control plots was applied to the other plots. The applications of water level significantly affected seed cotton yield, yield components (number of bolls per plant, boll weight, number of sympodias, single plant yield, 100-seed weight and lint percentage) and cotton fiber quality parameters (fiber length, fiber fineness, fiber strength, uniformity percentage and fiber elongation. Average seed cotton yield varied between 1685 and 5985 kg ha^{-1}. The highest yield and other components were obtained from treatment S_1 where there was no water restriction. In the case of water scarcity, second highest seed cotton yield was obtained from S_2 deficit irrigation treatment (75%).

Keywords Cotton, Fiber Quality, Drip Irrigation, Semiarid Climate

Introduction

Turkey's cotton production meets approximately 44% of the needs of its domestic market. Present cotton production in Turkey is about 852.000 tons of lint cotton from 462.000 ha. The Aegean region of western Turkey produce 41.2 % of the national cotton production of the country [1]. 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 (*Gossypium hirsutum L.*) 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% [2].

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. The reason for a fall in growth rate, defined as a slowing in growth or development, is a reduction in size of the leaves of the plant which is under water stress, and a decline in photosynthesis. As a result of this, the first reactions of the plant to water stress are a shortening in height and a reduction in the size of the leaves, which result in a loss of yield and quality. This loss in yield in cotton caused by water stress varies according to the timing and the severity of the drought. 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 early vegetative and when the first flowers appear, has the greatest effect on yield [3]. The most important reason for the loss of yield seen in cotton when a drought occurs is a decline in the numbers of bolls per unit area [4]. 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 [5,4]. Drought not only affects yield but also fibre quality. It is reported that drought in the period when the cotton fibre is beginning to grow affects fibre length, strength and maturity [6, 7, 8, 9]. It has been found that drought in the end of the flowering period affects the development of the bolls, and thus increases the proportion of low-strength and immature fibres [8]. At the head of other factors determining the yield potential of cotton in drought conditions comes the length of the growth period (early or late) of the cotton cultivar. In drought conditions, the long growth period of late cultivars may give them an advantage over early cultivars in terms of yield potential. But on the other hand, in conditions of acute or excessive drought, the yield of early cultivars may be low, but it is nevertheless higher than that of late cultivars [10, 11].
The use of drip irrigation techniques is inevitable in the near feature because of the salinity problem caused by traditional irrigation methods [12]. Also, drip irrigation have been suggested as a means of supplying most types of crops with frequent and uniform applications of water, adaptable over a wide range of topographic and soil conditions [13]. Under good management practices, deficit irrigation with drip system can result in substantial water savings with little impact on the quality and quantity of the harvested yield Water stress occurring during the cotton growing season may reduce final lint yield. Cotton yield is dependent on the production and retention of bolls, and both can be decreased by water stress [4]. The Aegean region is one of the most important agricultural and industrial region in Turkey. All cotton production areas of western Turkey receive inadequate amounts or inadequate distribution of rainfall. The dependence of crop yields on water supply is a critical issue due to the increasingly limited water resources for irrigation in the Aegean region and its semi-arid climate. The aim of this study was to investigate to research the effects of irrigation treatments on yield, yield components, and on fibre quality characteristics for Gloria cultivar of cotton, which are widely grown in this area.

Materials and Methods

Field experiments of drip-irrigated cotton were conducted at the Agricultural Research Station of Aydın Adnan Menderes University, Aydin-Turkey at 37° 51’ N latitude, 27°51’ E longitude and 56 m altitude during the 2018 growing season. Climate in this region is semi-arid with total annual precipitation of 657 mm. The Lower Büyük Menderes Basin has a Mediterranean climate of hot and dry summers and cool wet winters. The some climatic variables for experimental year for May-September are given in Table 1 [14].

Table 1: Some climatic data of region for the experimental year (2018)

Month	Average temperature (^{0}C)	Average relative humidity (%)	Evaporation (mm)	Average sunshine duration (h)	Rainfall (mm)
May	23.2	57.1	173.3	8.2	71.0
June	25.8	57.1	194.6	7.8	28.5
July	29.2	49.4	255.1	9.2	5.8
August	28.5	56.4	210.4	8.4	16.3
September	25.3	55.2	168.8	8.0	32.9

For the experiment area, water content at field capacity varied from 20.3 to 23.1 % and wilting point varied from 7.2 to 10.1 % on dry weight basis. Research area soil contain high percentages of sand (49.7-68.2 %), followed by silt (19.2-32.0 %) and clay (13.6-17.5 %) and could be classified as Sandy-loam. The dry soil bulk densities ranged from 1.35 to 1.52 g cm^{-3} throughout the 1.2 m deep profile. The total available soil water content within the top 1.2 m of the soil profile was 221.0 mm. (Table 2).

Table 2: Some physical characteristics of soils at the experimental site

Soil depth (cm)	Soil texture	Bulk density (g/cm^3)	Field capacity (%)*	Wilting point (%)*	Available water holding capacity (mm)
0-30	Sandy-Loam	1.35	23.1	10.1	52.6
30-60	Sandy-Loam	1.45	22.9	9.4	58.8
60-90	Sandy-Loam	1.52	18.4	7.3	50.6
90-120	Sandy-Loam	1.50	20.3	7.2	59.0
0-120					221.0

*on dry weight basis

The Gloria cotton variety was planted on 20 April 2018. Cotton plants were thinned to a spacing of 0.70 m (row width) × 0.20 m when the plants were about 0.15 m in height. A compound fertilizer (each included 15 % composite) was applied at a rate of 40 kg ha^{-1} pure N, P and K at planting. The required remaining portion of nitrogen 25 kg N ha^{-1}, was applied as 33 % ammonium nitrate before the first irrigation.

The irrigation water needed to irrigate the experimental plots in the study was obtained from an underground water source within the farm. This 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 in each plot of the study where the drip irrigation method was used, 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 l h^{-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 experiment was set up in 2018 with a random block experimental design with three replications. The experimental blocks in the study were in four rows and had dimensions of 5.0 x 2.8 m, with a total area of 14.0 m^2. In order to prevent leakage, 3 m was left between blocks and 2 m between plots.

Five irrigation levels, 100%, 75%, 50%, 25% and 0% were applied in the experiment. The gravimetric method was used to determine irrigation time. The treatments were irrigated using the drip irrigation method and irrigation was started when 40% of the usable water retention capacity 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%, 25% and 0% proportions of this amount to plots that were to receive partial irrigation. The fully (100%) irrigated plot was designated as the control plot, and the other plots were irrigated in the proportions mentioned above. Cotton was collected by hand harvesting in each plot on 10 October 2018. At harvest time, the plants in the two middle rows were harvested by hand and weighed, and the cotton yield of the plot was found. At the first harvest, a sample of 500 g of raw cotton was taken from each plot and sent to the Fibre Quality Laboratory of the Nazilli Cotton Research Institute-Aydın/TURKEY for determination of ginning yield, fibre strength, fibre length, fibre fineness, uniformity and elongation. Fibre characteristics were determined using an HVI (High Volume Instrument) from fibre taken from each plot. The yield components examined in this study are; number of bolls per plant (no plant^{-1}), boll raw cotton weight (g), number of sympodia per plant (no plant^{-1}), single plant yield (g plant^{-1}), 100-seed weight (g) and lint percentage (%). Number of bolls per plant (no plant^{-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 by dividing 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 sympodia per plant (no plant^{-1}) was obtained by counting the number of sympodia of ten plants taken at random from each plot at harvest time. The raw cotton yield per plant (g plant^{-1}) was determined by dividing the weight of raw cotton harvested from each plot by the number of plants.100-seed weight (g) was determined by weighing 100-seeds from a 20-boll sample taken at random from each plot. The lint percentage was 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 fibre to the weight of the raw cotton gives the lint percentage (%). In order to determine the differences between irrigation treatments, the data relating to all the parameters described above were subjected to variance analysis. The Least Significant Differences (LSD) test was used for comparing and ranking the treatments. Differences were determined significant at $P < 0.05$. Variance analysis and LSD tests were carried out with the use of the TARİST program, which was developed for this purpose [15].

Results and Discussions

Irrigation treatments significantly ($P<0.01$) affected seed cotton yield (Table 3). Highest yield averaging 5985 kg ha^{-1} was obtained from S_1 treatment. Minimum yield was obtained from S_5 treatment with averaging 1685 kg ha^{-1}. Seed cotton yields from other irrigation treatments varied between these values. As the irrigation level increased, seed cotton yield were significantly increased. Therefore, well irrigation treatment could be suitable for drip irrigated cotton in the region. Under this conditions, total number of irrigation applications was seven in total growing season for S_1 treatment. Therefore, it was observed that the ratio of decreases in seed cotton yield for each percent deficit rate was not constant.

Table 3: Total number of irrigations and seed cotton yield in growing season

Treatments*	**Irrigation levels**	**Number of irrigations**	**Seed cotton yield (kg ha^{-1})**	**Relative yield (%)**
S_1	100%	7	5985a	100.0
S_2	75%	7	5750b	96.0
S_3	50%	7	4994c	83.4
S_4	25%	7	3856d	64.4
S_5	0%	-	1685e	28.1
Treatments (S)			**	
$LSD_{0.05}$			13.765	

** significant at *P*< 0.01

Different letters indicate significant differences at *P*< 0.05 using LSD test.

Table 4 shows values relating to various yield components obtained from the study, and shows variance analysis and the LSD test results of these.

Table 4: Results of some yield components of cotton cultivar under different irrigation levels

Treatments	**Number of bolls (number)**	**Boll raw cotton weight (g)**	**Number of sympodia branches (number)**	**Single plant yield (g/plant)**	**100-seed weight (g)**	**Lint percentage (%)**
S_1	14.0a	6,0a	13.2a	84,0a	9.66a	44.0a
S_2	13.0a	5,9ab	12.6b	77,0b	9.52a	43.2ab
S_3	12.0ab	5,7b	11.1c	68,0c	9.22b	42.0bc
S_4	10.0b	5,4c	10.2d	54,0d	8.92c	41.5c
S_5	5.0c	4,6d	8.1e	23,0e	8.38d	41.0c
Treatments	**	**	**	**	**	**
$LSD_{0.05}$	2.148	0.227	0.978	4.858	0.277	1.364

** significant at *P*< 0.01

Different letters indicate significant differences at *P*< 0.05 using LSD test.

As Table 4 shows, the number of bolls varied from 5 to 14 in relation to the irrigation treatments. Regarding the number of bolls, the difference between irrigation levels was at a level of p<0.01. The number of bolls fell in relation to a reduction in irrigation water applied. Generally, fewer bolls were obtained from cultivar in treatments irrigated at 25% and 50% (Table 4). The most important reason for the loss of yield seen in cotton when a drought occurs is a decline in the numbers of bolls per unit area [4, 16]. 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 [17] while these values varied on average between 14.1 and 14.8 under Nazilli conditions [18]. Under Aydın conditions, the average number of bolls per plant varied between 6.1 and 15.6 and between 5.9 and 16.6 and between 15 and 21 in relation to the cultivars and irrigation programmes [19, 20, 2]. Considering boll raw cotton weight, variance analysis showed a difference between irrigation levels was found to be significant at levels of p<0.01. The highest boll raw cotton weight from the treatments which received full and 75% level of irrigation (S_1 and S_2). 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%. 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; between 5.4 and 6.6 g according to different irrigation applications and cotton varieties [20, 21].

Table 4 shows that according to variance analysis of number of sympodia, the difference between irrigation levels was significant at the level of p<0.01. The number of sympodia fell in relation to reduction in irrigation water applied. Number of sympodias were determined between 8.1 and 13.2 for treatments. The first group consisted of treatments receiving full irrigation, and the last group consisted of the treatments to which the no water was applied. [22] found an average of 13.1 sympodias on the Nazilli-84 cultivar under Antalya conditions using furrow irrigation. In a study under Aydın plain conditions, drip irrigation and different cotton cultivars, the average number of sympodias varied from 8.1 to 12.4; and varied from 10 to 17 according to different irrigation applications [21, 2]. In a study in which the Nazilli-84 cultivar was used under Nazilli conditions, these values varied on average between 15.1 and 15.7 [18]. Examining single plant yield values, it is seen that the difference irrigation levels was significant at a level of $p<0.01$. The highest single plant yield was obtained from S_1 treatment as 84 g. First group was formed from treatments which received full (100%) irrigation water, and the last group was formed from the treatments which no irrigation wate received (S_5; 0%). Under Aydın conditions, the average single plant yields varied between 75 and 111 g and between 58 and 82 g in relation to the cultivars and irrigation programmes [21, 2]. Examining 100-seed weight in Table 4, it is seen that the difference between irrigation levels was significant at the $p<0.01$ level. 100 seed weight values were determined between 8.3 and 9.6 g for treatments. The highest values were obtained from the treatments which received the full amount of water (S_1). Similar to the other quality characteristics, 100-seed weight values in all irrigation treatments showed a decline in relation to irrigation water restriction. [23] a variation of 100-seed weight values of an average of 9.80-11.24 g in connection with different irrigation methods and irrigation programmes under Aydın conditions; [19] found values of 9.31-11.20 g, and [24] determined 9.91-13.13 g. On the other hand, [2] obtained the same values as 9.36-10.8 g in Aydın plain conditions from different cultivars and irrigation levels. Examining ginning efficiency values, it is seen that there was a significant difference at the $p<0.01$ level between irrigation treatments. 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 (S_1). In studies on this topic, [22] carried out a study on the Nazilli 84 cultivar of cotton under Antalya conditions using furrow and drip irrigation methods, and reported ginning efficiency of 41.42% with furrow irrigation and 42.06% with drip irrigation. In the same way, [2, 21] reported values of 38-41% and 41-42% in a study applying drip irrigation methods in Aydın plain conditions. In another study in the same region, [24] found values of 39.96-40.02% in a programme using the drip irrigation method.

Table 5 shows fiber quality components for the irrigation treatments in the year of the experiment.

Table 5: Results of some fiber quality components of cotton cultivar under different irrigation levels

Treatments	Fiber fineness (micronaire)	Fiber length (mm)	Fiber strength (g/tex)	Fiber elongation (%)	Uniformity percentage (%)
S_1	4.76a	30.34a	31.20	6.70a	85.36a
S_2	4.73a	30.10a	30.46	6.43ab	84.76ab
S_3	4.59b	28.58b	29.96	6.20bc	83.60bc
S_4	4.46c	27.53bc	30.96	5.86cd	83.00c
S_5	4.28d	26.31c	30.16	5.70d	82.70c
Treatments	**	**	ns	**	**
$LSD_{0.05}$	0.113	1.232	-	0.483	1.200

ns not significant;** significant at $P< 0.01$

Different letters indicate significant differences at $P< 0.05$ using LSD test.

Drip irrigation treatments affected fibre fineness values in growing seasons (Table 5). It can be seen that there was difference between irrigation treatments in fibre fineness parameters and the effect of irrigation level was at a level of $p<0.01$. Fibre fineness values varied from 4.28 to 4.76 in 2018. [25] reported fibre fineness of 4.07-5.08 micronaire with the different drip irrigation levels. These results were in agreement with the results reported by [26]; [20] and [27]. Fiber length was generally shortened in response to deficit irrigation treatments. Fibre length values varied between 26.31 and 30.34 mm in 2018 according to irrigation treatments. Cotton cultivar produced longer fiber, 30.34 mm under full irrigation level (S_1) than all deficit irrigation levels. Different researchers reported that as irrigation increased, which implies higher soil moisture contents, fiber length increased [28,29]. In a different study, [19] and [24] in studies applying different irrigation methods and different cultivars under Aydın conditions, reported fibre length values of 26.4-30.0 mm and 27.0-29.0 mm respectively.

As can be seen in Table 5, according to the results of fibre strength variance analysis, the difference between irrigation levels was found to be insignificant. Fiber strength decreased as water deficit level increased during growing seasons in this study. Fibre strength values varied between 29.96 and 31.2 $gtex^{-1}$. [30, 4] reported that fibre strength was not affected by different irrigation levels, while [31] reported that fibre strength increased with a reduction in irrigation levels. [32] investigated the effects on cotton yield and quality of the drip and furrow irrigation methods, and found that fibre strength was not affected by the irrigation method. Although bolls in the first position generally stay in place in conditions of water stress, bolls on the second or higher sympodias fall. For this reason, values obtained from raw cotton taken from bolls in first position are naturally high. The effects on fiber elongation and uniformity of the study treatments, from the point of view of the irrigation levels were found to be significant (P<0.01). In the year of the study, these values varied from 5.7% to 6.7% and varied from 82.7% to 85.36%.

Conclusions

It is concluded that seed cotton yield components and fiber quality parameters were significantly (p<0.01) affected by drip irrigation application levels in 2018. The highest seed cotton yield was obtained from the S_1 treatment for growing season. 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 seed cotton yield and high quality fibre. However, if water sources in the area are limited, then restricting water to a level of only 25% may produce acceptable results. According to evaluations conducted until now, the drip irrigation level applied are important in increasing seed cotton yield. In this regard it was concluded that the most suitable irrigation programme from the point of view of seed cotton yield good fibre quality and yield components in a region under no water shortage was the treatment (S_1) in which water was fully applied.

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