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Effect of Deficit Irrigation on Some Agronomic Traits of Cotton (*gossypium hirsutum* L.) Cultivar in Semi-Arid Conditions

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Abstract: In order to observe the effects of deficit irrigation on seed cotton yield, some agronomic and fiber quality parameters of Sahra cotton cultivars, a field trial was conducted in year of 2023 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. In the trials, irrigation water was applied to cotton cultivars using drip irrigation method as 100%, 67%, 33% and 0% of evaporation from Class A Pan corresponding to 7-day irrigation frequencies. The applications of water level significantly affected seed cotton yield, yield components (number of bolls per plant, boll weight, 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 168,5-506,0 kg/da. The highest yield and other components were obtained from treatment S1 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 (67%).

Keywords: Cotton; deficit irrigation; fiber quality; Aydın

1. Introduction

Cotton (*Gossypium hirsutum* L.) is the most significant fibre crop in the world, meeting the natural fibre needs of the textile industry [1]. Cotton is an industrial plant that directly concerns many countries around the world in terms of production and consumption. Nearly all of global cotton production (99.5%) is concentrated in a select group of countries that rank among the top ten cotton producers worldwide. These nations include China, India, the United States, Brazil, Australia, Türkiye, Pakistan, Uzbekistan, Argentina, and Greece. The top cotton producing countries are China (5,730,000 tonnes), India (5,366,000 tonnes) and the USA (3,815,000). In Türkiye, cotton cultivation occurs in an area of 480,000 hectares, and 833,000 tonnes of cotton fibre are produced [2]. Almost all cotton cultivation in Türkiye is carried out in the Aegean Region, Southeastern Anatolia Region, Çukurova and Antalya regions [3]. Cotton cultivation areas by region are given in Table 1. Accordingly, it is seen that the region with the highest cotton cultivation area in 2023 is the Southeastern Anatolia Region with an area of 2 million 998 thousand decares and a share of 60.27% [4] (Table 1).

Table 1: Cotton cultivation areas by regions (decares) (TUİK, 2024)

Regions	2020	2021	2022	2023	Average	%
Mediterranean	679.991	722.016	929.841	680.658	753.127	16,35
Aegean	1.011.626	979.762	1.211.686	1.093.400	1.074.119	23,32
Southeast Anatolia	1.895.537	2.619.897	3.587.358	2.998.800	2.775.398	60,27
Other regions	5.046	1.115	2.728	1.526	2.604	0,06
TÜRKİYE'S TOTAL	**3.592.200**	**4.322.790**	**5.731.613**	**4.774.384**	**4.605.247**	**100,00**

When cotton production amounts by regions are analyzed, the cotton production amount of the Southeastern Anatolia Region in 2023 is 1 million 293 thousand tons and ranks first in terms of production amount. In the average of 2020-2023, the Southeastern Anatolia Region (58.38%) is followed by the Aegean Region (24.53%) and the Mediterranean Region (17.05%) (Table 2).

Table 2: Amount of cotton production by regions (tonnes) (TUİK, 2024)

Regions	2020	2021	2022	2023	Average	%
Mediterranean	356.311	382.648	460.539	313.407	378.226	17,05
Aegean	527.244	542.832	613.729	492.581	544.097	24,53
Southeast Anatolia	888.035	1.324.004	1.674.630	1.293.458	1.295.032	58,38
Other regions	2.056	516	1.102	554	1.057	0,05
TÜRKİYE'S TOTAL	**1.773.646**	**2.250.000**	**2.750.000**	**2.100.000**	**2.218.412**	**100,00**

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 fiber 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 [5]. 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 [6]. 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 [6,7].

Water shortages are predicted in many areas as a result of climate change, and particularly in tropical and subtropical regions, including Türkiye 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 [8]. 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 [9].

Numerous studies have reported how cotton reproductive growth, yield, and fiber 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 [10]. 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 [11]. A study performed to determine the effect of five different irrigation levels on water use efficiency, yield, yield components and fiber 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 [12]. 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 kPa ve -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 irrigation levels [13].

The aim of this study was to create a suitable irrigation programme by the drip irrigation method for Sahra cultivars of cotton and to investigate the effects of irrigation treatments on yield and some agronomic components.

2. Materials and Methods

This study was conducted under field conditions at the research and application farm of the Agriculture Faculty of Aydın Adnan Menderes University on its southern campus during the growing seasons of 2023. The research area is located in the Büyük Menderes Lower Basin, at a latitude of 37o 51' North and a longitude of 27o 51' East [14].

The Lower Büyük Menderes Basin has a Mediterranean climate of hot and dry summers and cool wet winters. There was no waterlogging problem and the average annual rainfall was 644.7 mm with a mean monthly temperature of 17.8 oC according to long-term meteorological data (2014-2021) in the experimental area. Total rainfall during the growing periods was 127,4 mm in 2023 [15].

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 field where 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-well within the experiment area irrigation. 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 2 Lh-1 and a dripper spacing of 20 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 Sahra was used as research material. Cotton plants were thinned to a spacing of 0.70 m × 0.10 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 on 11 May 2023. At the same time, 40 kg da-1 of (15-15-15) NPK fertilizer was added to the experimental plots. At the second hoeing, 33% ammonium nitrate fertilizer was applied at a rate of 25 kg da-1.

The trial was designated in randomized complete block design with three replications. In the study, four different irrigation levels (IR-100, IR-67, IR-33 and IR-00) was investigated. Irrigation water quantity based on cumulative evaporation from class A pan at 7 day irrigation interval was applied through drip system. Full (IR-100) and traditional deficit irrigation (IR- 67, IR-33) treatments received 100, 67 and 33% of 7 day cumulative evaporation from Class A pan located at the experimental station, respectively.

At harvesting, the plants in the two middle rows were harvested on November 17, 2023 by hand and weighed, and the cotton yield of the plots (kg da-1) were determined. The agronomic components examined in this study are; raw cotton yield per plant (g plant-1), number of bolls per plant (no plant-1), boll raw cotton weight (g), single plant yield, 100-seed weight (g) and lint percentage (%). 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. 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. 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 fiber 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 [16].

3. Results & Discussion

Effect of different irrigation levels on yield of cotton cultivar

Table 3 shows the cotton yields obtained from the experimental treatments and the results of the variance analysis. Irrigation treatments significantly ($P<0.01$) affected seed cotton yield. The highest cotton yield was obtained from %100 treatments in which no water restrictions were applied in the growing season. The lowest raw cotton yield was obtained from treatments % 0, in which no water was applied. Raw cotton yields from other irrigation treatments varied between these values. The LSD test was performed to establish the difference in raw cotton yield between treatments. Examining these results from the point of view of water level, four groups formed in growing year. The first group consisted of the % 100 treatments where no water restriction had been applied in the whole growing season, treatments in which water had been applied at the % 67 level were second, and treatments which had received water at the % 33 level formed third group. In evaluations conducted previously, it has been found that treatments 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 Sahra cultivar, in conditions where there was no irrigation water restriction in the area under % 100 irrigation level treatment.

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

Treatments*	Irrigation levels	Number of irrigations	Seed cotton yield (kg da^{-1})
S_1	100%	8	506.0 a
S_2	67%	8	408.3 b
S_3	33%	8	307.7 c
S_4	0%	-	168.5 d
Treatments (S)			**
$LSD_{0.05}$			13.655

**significant at $P< 0.01$

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

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, achieved the highest yield of cotton with irrigation at eight-day intervals from a treatment in which 100% of the amount of evaporation from a class A evaporation pan was applied [17]. In a study conducted in Çukurova in cotton plant irrigated by drip irrigation, it was reported that, raw cotton yield varied between 1970 and 4220 kg ha-1 [18]. On Harran plain, the applicability of LEPA and drip irrigation systems with cotton was researched [9]. They concluded that LEPA and drip irrigation could be used more effectively than surface irrigation, and that they could prevent irrigation water losses. 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 [19].

Results concerning various agronomic characteristics

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

Table 4: Results of some agronomic characteristics of cotton cultivar under different irrigation levels

Treatments	Number of bolls (number)	Boll raw cotton weight (g)	Single plant yield (g/plant)	100-seed weight (g)	Lint percentage (%)
S_1	15.000a	5.033a	69.067a	9.820a	41.823a
S_2	12.333b	4.933a	57.533b	9.003a	41.067b
S_3	10.667bc	4.467a	49.567c	8.900a	40.733b
S_4	10.000c	3.267b	28.667d	8.640b	39.900c
Treatments	**	**	**	**	**
$LSD_{0.05}$	1.971	0.614	3.299	0.165	0.508

**significant at P< 0.01
Different letters indicate significant differences at P< 0.05 using LSD test.

Regarding the number of bolls, the difference between irrigation levels was at a level of p<0.01(Table 4). The number of bolls fell in relation to a reduction in irrigation water applied. Generally, fewer bolls were obtained from both cultivars in treatments irrigated at 33 % and 0 %. 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 [20]. 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 [21], while these values varied on average between 14.1 and 14.8 under Nazilli conditions [22]. Under Aydın conditions, the average number of bolls per plant varied between 6.1 and 15.6 and between 5.9 and 16.6 [13,18]. Considering boll raw cotton weight, variance analysis showed a difference between irrigation levels was found to be significant at levels of p<0.01 (Table 4). Examining the results from the point of view of treatments, it is seen that the highest boll raw cotton weight was obtained from the full irrigation. When results are scrutinized from the point of view of irrigation levels, the first group consisted of the treatments which received full irrigation (% 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 67% and 33%. 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 [13]. Examining single plant yield values in the Table 4, it is seen that the difference between treatments were significant at a level of p<0.01. Examining the results from the point of view of treatment, it is seen that the highest plant yield was obtained from the % 100 level. 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 no irrigation water (0 %). Examining 100-seed weight in Table 4, it is seen that the difference between treatments were 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 (% 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 [24]; 9.31-11.20 g by [18]; and 9.91-13.13 g by [19] in connection with different irrigation methods and irrigation programmes. Examining ginning efficiency values, it is seen that there was a significant difference at the p<0.01 level from the point of view of treatments (Table 4). From the point of view of treatments, 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 reported of 41.42% with furrow irrigation and 42.06% with drip irrigation [17]. In the same way, values of 43-44% reported by [26]. In a study applying surface irrigation methods values of 44-45% and 41.6-44.3% were reported by [27] and [18]. In another study in the same region, using the drip irrigation method lint percentage values of 39.96-40.02% were determined by [19]. Also, in a study under restricted irrigation conditions, lint percentage values varied between 43% and 45% according to irrigation levels [28]. Another researcher in the same region reported these values as 39.8-41.7% [18]. 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.

Results concerning various fiber quality components

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	5.693a	31.703a	34.567a	7.733a	87.033
S_2	5.423ab	30.530a	33.933a	7.433ab	85.967
S_3	5.223c	28.700b	33.033ab	7.300b	84.967

S_4	4.817c	28.197b	31.467b	7.233b	84.133
Treatments	**	**	*	*	ns
$LSD_{0.05}$	0.348	1.699	1.683	0.351	-

ns not significant; **significant at P< 0.01

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

Drip irrigation treatments affected fiber 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 4.81 to 5.69 in research year. [29] 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 [30]; [12] and [31]. Fiber length was generally shortened in response to deficit irrigation treatments. Fibre length values varied between 28.1 and 31.7 mm in 2023 according to irrigation treatments. Cotton cultivar produced longer fiber, 31.7 mm under full irrigation level (S1) than all deficit irrigation levels. Different researchers reported that as irrigation increased, which implies higher soil moisture contents, fiber length increased [32, 33]. In a different study, [34] and [25] 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 at a level of p<0.05. Fiber strength decreased as water deficit level increased during growing seasons in this study. Fiber strength values varied between 31.4 and 34.5 g/tex. [35, 6] reported that fiber strength was not affected by different irrigation levels, while [36] reported that fiber strength increased with a reduction in irrigation levels. [6] investigated the effects on cotton yield and quality of the drip and furrow irrigation methods, and found that fiber 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 of the study treatments, from the point of view of the irrigation levels were found to be significant (p<0.05). In the year of the study, these values varied from 7.2 % to 7.7 %

4. Conclusion

It is concluded that seed cotton yield, some agronomic characteristics and fiber quality parameters were significantly (p<0.01) affected by drip irrigation application levels in 2023. The highest seed cotton yield was obtained from the S1 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 fiber. However, if water sources in the area are limited, then restricting water to a level of only 67 % 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 fiber quality and yield components in a region under no water shortage was the treatment (S1) in which water was fully applied.

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