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# The Effects of Different Levels of Irrigation Practices on Cotton: Yield and Quality Parameters

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**Abstract** This study was conducted to observe the effects of different drip irrigation levels and seed-coated techniques on seed cotton yield, yield component and fiber quality parameters produced from Esperia cotton variety in the Aegean Region of Turkey during the year of 2019. The trial was designated in randomized complete block design with two factors and three replications. In the study, four different irrigation levels (100, 75, 50 and 25%) and two different seed-coated techniques (delinted seed and Zinc coated with 9.2%) were investigated. In the trials, irrigation water was applied to cotton cultivars using drip irrigation method as 100%, 75%, 50% and 25% of evaporation from Class A Pan corresponding to 8-day irrigation frequencies. First irrigationwasappliedwhen~40% of available soil moisture was consumed in the 1.20-m effective root zone. The highest seed cotton yield was obtained from IL-100 treatment as averaging 5767 kg $ha^{-1}$, followed by IL-75 treatment as averaging 5573 kg $ha^{-1}$. The lowest yield was obtained from IL-25 treatment as averaging 3927 kg $ha^{-1}$. Regarding the some agronomic parameters (number of bolls per plant, boll raw cotton weight single plant yield, 100-seed weight and lint percentage) the difference between seed applications was found to be insignificant, while the difference between irrigation levels was significant at a level of $p<0.01$. According to the results of ANOVA of fiber quality parameters (fiber strength, fiber length, fiber fineness, uniformity and elongation), the difference between seed applications was found to be insignificant, while the difference between IL was found to be significant at a level of $p< 0.05$. 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 cotton yield and good fiber quality.

**Keywords** Cotton, drip irrigation, crop components, fiber quality

## 1. Introduction

Current trends indicate that several regions are facing water shortages, particularly in the Aegean region of Turkey, but also in a progressively large number of countries worldwide. In the semi-arid regions of the Aegean, for all the practical purposes, fresh water resources are inadequate. Nowadays limited availability of irrigation water requires fundamental changes in irrigation management and 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 [1]. However, the use of drip irrigation techniques is inevitable in the near future because of the salinity problem caused by traditional irrigation methods [2]. Thus, this creates the need for continuous improvement in irrigation practices, especially in the cotton production of the Aegean region. Water saving irrigation methods should be followed in order to save water and maximize yield. Due to the severe competition in urban and rural use and other sectors, the value of the water will most probably rise shortly [3]. Thus, appropriate irrigation scheduling is required for maximizing the yield and water use. In scheduling irrigation programs, methods based on gravimetric and pan evaporation have widespread usage due to their simple and easy application and low cost [4]. Thus, this creates the need for continuous improvement in irrigation practices, especially in the cotton production of the Aegean region. Turkey's seed cotton production meets approximately 44% of the needs of its domestic market. Turkey is among the top 11 cotton production countries in the world. In 2018/2019, seed cotton acreage and crop production of Turkey is 508 000 ha and 988 000 t, respectively. Average cotton lint yield is about 1944 kg $ha^{-1}$ [5].

[6] indicated that the period from square initiation to first flower represents the most critical development period in terms of water supply affecting yield components. The peak flowering period was the most sensitive to drought and at this time water stress led to the greatest decrease in yield. Under water stress, decrease in seed cotton yield is primarily due to the reduction in number of bolls. Water stress affect lint quality; fiber length, strength and micronaire reading as well [7]. In this respect, [2] applied irrigation at five different rates (full irrigation and four deficit rates) to cotton and found that the highest application of water regime producing the highest yield, while [8] reported that no yield reduction in cotton with the deficit water.

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 [7, 9, 10, 11]. 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 [7]. 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 [12, 13].

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 [14]. 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. Besides different drip irrigation levels, with proper management such as seed-coated techniques should be studied by the researchers. Therefore, limited availability of irrigation water requires fundamental changes in irrigation management or urges the application of water saving methods. The aim of this study was to investigate to research the effects of irrigation treatments on yield, yield components, and on fiber quality characteristics for Carismacultivar of cotton, which are widely grown in Aydın province.

## 2. Materials and Methods

Field experiments was carried out 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 2019 growing season. Climate in this region is semi-arid with total annual precipitation of 644.3 mm. Average seasonal rainfall is 644.3 mm, with 90% of the rain occurring between November and March. Typical Mediterranean climate prevails in the experimental area. Table 1 summarizes the monthly mean climatic data compared with the long-term mean climatic data for Aydın [15]. The growing season temperatures were typical of long term-means (1983-2018) for Aydın located in the western Aegean region of Turkey.

**Table 1:** Weather conditions prevailed during the experiments compared to the long- run at the experimental site

| 1983-2018 | | | | |
|---|---|---|---|---|
| **Month** | **Temperature (°C)** | **Relative Humidity (%)** | **Avg. Total Rainfall (mm)** | **Avg. Total Evaporation (mm)** |
| **January** | 8.2 | 71.7 | 107.1 | 25.0 |
| **February** | 9.3 | 68.9 | 89.2 | 30.6 |
| **March** | 12.0 | 65.6 | 74.6 | 64.9 |
| **April** | 16.1 | 62.3 | 51.8 | 104.2 |
| **May** | 21.0 | 57.3 | 39.9 | 162.3 |
| **June** | 25.9 | 49.9 | 13.6 | 221.5 |

| | | | | |
|---|---|---|---|---|
| **July** | 28.5 | 49.1 | 5.9 | 258.7 |
| **August** | 27.9 | 53.5 | 6.5 | 230.9 |
| **September** | 23.8 | 56.1 | 16.3 | 162.9 |
| **October** | 18.7 | 62.8 | 40.5 | 98.1 |
| **November** | 13.3 | 69.1 | 88.2 | 47.3 |
| **December** | 9.3 | 73.5 | 110.7 | 25.5 |
| **Annual average** | **17.8** | **61.7** | **644.3** | **1431.9** |
| | | **2019** | | |
| **Month** | **Temperature (°C)** | **Relative Humidity (%)** | **Total Rainfall (mm)** | **Total Evaporation (mm)** |
| **January** | 8.5 | 80.1 | 206 | 88.3 |
| **February** | 10.6 | 72.0 | 58.3 | 75.8 |
| **March** | 13.3 | 62.7 | 28.6 | 112.8 |
| **April** | 16.0 | 60.6 | 56.9 | 139.4 |
| **May** | 21.6 | 56.2 | 11.9 | 223.1 |
| **June** | 26.9 | 54.3 | 26.9 | 296.7 |
| **July** | 28.4 | 46.6 | 1.2 | 345.9 |
| **August** | 29.3 | 46.4 | 0 | 360.4 |
| **September** | 24.4 | 58.7 | 16.6 | 239.7 |
| **October** | 21.4 | 64.8 | 29.4 | 167.7 |
| **November** | 16.5 | 71.9 | 65.1 | 121.1 |
| **December** | 10.5 | 77.7 | 117.7 | 64.6 |
| **Average** | **18.9** | **62.6** | **618.6** | **2235.5** |

The soil series in the research area was Büyük Menderes Basin developed on aluvial materials [16]. The soil of the experimental site is classified as Entisols and Fluvisols-Regosols sandy-loam with relatively high water holding capacity. For the experiment area, water content at field capacity varied from 18.4 to 23.1% and wilting point varied from 7.2 to 10.1% on dry weight basis. Research area soils contain high percentages of sand (49.7-68.2%), followed by clay (13.6-17.5%) and loam (19.2-32.0%) 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 Carisma cotton variety was planted on 24 April 2019, with 0.70 × 0.20 m spacing. A compound fertilizer of (15%, 15%, and 15% composite) was applied at a rate of 45 kg ha$^{-1}$ pure N, P and K before planting. The required remaining portion of nitrogen was followed by 25 kg ha$^{-1}$before first irrigation.

The trial was designated in randomized complete block design with twofactorsandthreereplications. In the study, four different irrigation levels (100, 75, 50 and 25%) and two different seed-coated techniques (zinc coated with 9.2% anddelintedseed) were investigated. There were 3 m between each plot. Each experimental plot had four cotton rows at 0.7 m spacing and 5 m in length. In the trials, irrigation water was applied to cotton cultivar using drip irrigation method as 100%, 75%, 50% and 25% of evaporation from Class A Pan corresponding to 8-day irrigation frequencies. First irrigationwasappliedwhen~40% of available soil moisture was consumed in the 1.20-m effective root zone. Irrigation water was used from a deep well located near the experimental site. The control unit consisted of screen filter with 10 l s$^{-1}$ capacity, control valves, manometers mounted on the inlet and outlet of each unit. Distribution lines consisted of PVC pipe manifolds for each plot. The diameters of the laterals were 16 mm PE and each lateral irrigated one plant row. The inline emitters were used with a discharge rate of 4 L h$^{-1}$ above 10 m operating pressure. In the system, emitter and the lateral spacing were chosen as 0.20 and 0.70 m, respectively.

Seasonal crop evapotranspiration (ET) of cotton plants under varying irrigation levels were calculated with the water balance equation (Eq. 1) [17].

$$ET = I + P \pm \Delta SW - Dp - Rf \quad (1)$$

where; ET is actual crop evapotranspiration (mm), I the amount of irrigation water applied (mm), P the precipitation (mm), ΔSW changes in the soil water content (mm), Dp the deep percolation (mm), and Rf amount of runoff (mm). Since the amount of irrigation water was controlled, deep percolation and run off were assumed to be negligible.

Eq. (2) [18] was used to calculate the amount of irrigation water,

$I = P \times A \times IL$ (2)

Where I is the volume of irrigation water (L), P wetting percentage (taken as 100 % for row crops), A is plot area ($m^2$), IL represents irrigation levels (IL-100, IL-75, IL-50 and IL-25).

Cotton was collected by hand harvesting in each plot on 23 October 2019. 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 Fiber Quality Laboratory of the Nazilli Cotton Research Institute-Aydın/TURKEY for determination of fiber strength, fiber length, fiber fineness, uniformity and elongation. Fiber characteristics were determined using an HVI (High Volume Instrument) from fiber taken from each plot. The yield components examined in this study are; number of bolls per plant (no plant$^{-1}$), boll rawweight (g), single plant yield (g plant$^{-1}$), 100-seed weight (g) and 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 [19].

## 3. Results & Discussion

The total irrigation water amounts applied, seasonal water use and seed cotton yield values were presented in Table 2. The first treatment irrigation was applied on July 08, and irrigations were terminated on September 2, in 2019. Seasonal amount of irrigation water applied for different drip treatment ranged from 124.2 to 496.8 mm in growing season. Seasonal water use varied from 254.9 to 635.3 mm in growing season. Irrigation water was applied 8 times to the treatments over the growing season (Table 2).

**Table 2:** Seed cotton yield and water use efficiency values as influenced by seed applications and irrigation levels

| Seed coated-applications | Irrigation Levels | Seed yield (kg ha$^{-1}$) | Irrigation water applied (mm) | Water use (mm) | Water use efficiency (WUE) (kg m$^{-3}$) | Irrigation water use efficiency (IWUE) (kg m$^{-3}$) |
|---|---|---|---|---|---|---|
| **Zinc coated with 9.2%** | $K_{100}$ | 5662 | 496.8 | 635.3 | 0.89 | 1.13 |
| | $K_{75}$ | 5478 | 372.6 | 514.5 | 1.06 | 1.47 |
| | $K_{50}$ | 4595 | 248.4 | 372.8 | 1.23 | 1.85 |
| | $K_{25}$ | 3900 | 124.2 | 259.3 | 1.50 | 3.14 |
| **Delinted seed** | $D_{100}$ | 5872 | 496.8 | 606.9 | 0.96 | 1.18 |
| | $D_{75}$ | 5679 | 372.6 | 492.0 | 1.15 | 1.52 |
| | $D_{50}$ | 4705 | 248.4 | 391.4 | 1.20 | 1.89 |
| | $D_{25}$ | 3955 | 124.2 | 254.9 | 1.55 | 3.18 |

Data obtained from the growing season showed that seed cotton yield was significantly affected ($P < 0.01$) by seed applications and irrigation levels (Table 3). No interactions between treatments (T) and irrigation levels (IL) were observed. The delinted seed application resulted in higher yield than the zinc coated with 9.2% applications. As the IL increased, increment was observed in cotton yield in all seed applications. The highest average yield was obtained from IL-100 treatment as averaging 5767 kg ha$^{-1}$ and the lowest yield was obtained from IL-25 treatment as averaging 3927 kg ha$^{-1}$. Examining these results from the point of view of irrigation levels (IL), four groups formed in 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 75 % level were second, and treatments which had received water at the 25 % level formed the last group. On the other hand, in terms of seed applications (T), delinted seed application was the first group and zinc coated applications was the last group.

Table 3 shows variance analysis and the LSD test results values relating to various agronomic characteristics obtained from the study. Regarding the number of bolls, the difference between seed treatments was found to be insignificant, while the difference between irrigation levels was significant at a level of $p<0.01$ (Table 3). 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 25% and 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 [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 and between 15 and 21 in relation to the cultivars and irrigation programmes [23, 24, 25, 26].

Considering boll raw cotton weight, the difference between seed application treatments and irrigation levels were found to be significant at a level of $p<0.01$(Table 3). Examining the results 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 all seed applications from treatments to which irrigation water had been applied at a proportion of 50% and25%. 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; between 4.6 and 6.0 g according to different irrigation applications and cotton varieties, respectively [24, 26, 27]. The single plant yield values varied from 54.98 to 80.71 g/plant in relation to the seed applications and irrigation levels. Examining single plant yield values in the Table 3, it is seen that both the seed applications and irrigation levels were significant at a level of $p<0.01$. Examining the results 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%). 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 [25, 26, 27]. Examining 100-seed weight in Table 3, it is seen that the difference between seed applications were insignificant, while the difference between irrigation levels were significant at the $p<0.01$ level. The highest value was 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 [28]; 9.31-11.20 g by [18]; and 9.91-13.13 g by [29] in connection with different irrigation methods and irrigation programmes. Examining lint percentage values, it is seen that there were a nonsignificant difference between seed applications and irrigation levels (Table 3). These values varied from 43.11 to 44.08 % in growing season. 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 [30]. In the same way, values of 43-44% reported by [31]. In a study applying surface irrigation methods values of 44-45% and 41.6-44.3% were reported by [32] and [33]. In another study in the same region, using the drip irrigation method lint percentage values of 39.96-40.02% were determined by [29]. Also, in a study under restricted irrigation conditions, lint percentage values varied between 43% and 45% according to irrigation levels [34]. Another researcher in the same region reported these values as 39.8-41.7% [28].

**Table 3:** Some agronomic traits of cotton influenced by different seed applications and irrigation levels

| | | **Seed cotton yield (kg ha$^{-1}$)** | **Number of bolls (number)** | **Boll raw weight (g)** | **Single plant yield (g)** | **100-seedweight (g)** | **Lint percentage (%)** |
|---|---|---|---|---|---|---|---|
| **Seed Applications (T)** | **Delinted seed** | 4967a | 13.91 | 5.01a | 70.728a | 9.47 | 43.80 |
| | **Zinc coated with 9.2%** | 4741b | 13.91 | 4.88b | 68.716b | 9.52 | 43.73 |
| **LSD$_{\%5}$** | | 8.68 | | 0.094 | 1.193 | | |
| **Irrigation Level (IL)** | **100%** | 5767a | 14.66a | 5.43a | 80.717a | 9.67a | 43.11 |
| | **75%** | 5573b | 14.66a | 5.25b | 78.087b | 9.56b | 44.08 |
| | **50%** | 4650c | 14.00b | 4.64c | 65.100c | 9.45c | 44.01 |
| | **25%** | 3927d | 12.33c | 4.45d | 54.983d | 9.32d | 43.85 |
| **LSD$_{\%5}$** | | 12.27 | 0.655 | 0.133 | 1.687 | 0.086 | |
| | **T** | ** | ns | ** | ** | ns | ns |
| | **IL** | ** | ** | ** | ** | ** | ns |
| | **T x IL** | ns | ns | ns | ns | ns | ns |

*P< 0.05; **P< 0.01; ns: not significant; In a column values with a common letter are not significantly differ from one another using LSD$_{\%5}$

Table 4 shows the values relating to cotton fiber quality obtained in the study, and also same table gives the results of variance and the LSD tests of this research. In the growing year, the fiber fineness values (mic.) among the seed applications and irrigation levels were not statistically significant. The effect of water deficit on fiber fineness was not consistent throughout the year. Fiber fineness values varied from 5.04 to 5.28 mic. These results were in agreement with the results reported by [2]; [24] and [35]. On the other hand, in Aydın conditions, reported fiber fineness values varied from 4.28 to 4.76 micronaire [26]. Examining fiber length in Table 4, it is seen that the difference between seed applications were insignificant, while the difference between irrigation levels were significant at the $p<0.05$ level. The highest fiber length (29.46 mm) was obtained from the IL-100 irrigation level and occurred in the first group (a) (Table 4). IL-100 treatment resulted in highest fiber length in the study and followed by IL-75 and IL-50 as shown in Table 4. The findings obtained in the study were similar to most of the previous research into determining the effects of different irrigation level on cotton cultivars [2, 24, 35, 36]. Examining fiber strength in Table 4, the fiber strength values (g/tex) among the seed applications and irrigation levels were not statistically significant. Fiber strength values varied from 28.43 to 29.98 g/tex. However, almost the same fiber strength was detected between treatments in experiment year. Studies of gene action suggest that, within upland cotton genotypes there is little non-additive gene action in fiber strength [29]; that is, genes determine fiber strength. These results were in agreement with the results reported by [2, 24, 35, 36]. In addition, under Aydın conditions fibre strength values varied between 29.96 and 31.2 $gtex^{-1}$ in 2018 according to drip irrigation treatments [26]. The effects on fiber elongation and uniformity of the study treatments, from the point of view of the irrigation levels and seed applications were found to be insignificant. In the year of the study, these values varied from 7.08% to 7.41% and varied from 83.90% to 84.70%. These results were in agreement with the results reported by [26] in Aydın province.

**Table 4:** Cotton fiber quality as influenced by different seed applications and irrigation levels

| | | Fiber fineness (micronaire) | Fiber length (mm) | Fiber strength (g/tex) | Uniformity percentage (%) | Fiber elongation (%) |
|---|---|---|---|---|---|---|
| **Seed Applications (T)** | **Delinted seed** | 5.24 | 28.28 | 29.29 | 84.35 | 7.18 |
| | **Zinc coated with 9.2%** | 5.11 | 29.02 | 29.19 | 84.20 | 7.25 |
| **$LSD_{\%5}$** | | | | | | |
| **Irrigation Level (IL)** | **100%** | 5.04 | 29.46a | 29.30 | 84.70 | 7.41 |
| | **75%** | 5.20 | 29.24ab | 29.25 | 84.13 | 7.21 |
| | **50%** | 5.28 | 28.46bc | 28.43 | 84.38 | 7.08 |
| | **25%** | 5.20 | 28.63c | 29.98 | 83.90 | 7.16 |
| **$LSD_{\%5}$** | | | 0.752 | | | |
| | **T** | ns | ns | ns | ns | ns |
| | **IL** | ns | * | ns | ns | ns |
| | **T x IL** | ns | ns | ns | ns | ns |

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

In a column values with a common letter are not significantly differ from one another using $LSD_{\%5}$

## 4. Conclusion

According to the results obtained from the study, the highest seasonal plant water use value was obtained from IL-100 irrigation treatment for all seed applications. Seasonal water use varied from 254.90 to 635.30 mm in growing season. Both seed applications (T) and irrigation levels (IL) had significant effects on the yield of cotton at a $p<0.01$ level. The highest average yield was obtained from IL-100 as averaging 5767 kg $ha^{-1}$, followed by IL-75 as averaging 5736 kg $ha^{-1}$. The lowest yield was obtained from IL-25 as averaging 3927 kg $ha^{-1}$.

Regarding the some agronomic parameters (number of bolls per plant, boll raw cotton weight, single plant yield, 100-seed weight and lint percentage) the difference between seed applications was found to be insignificant, while the difference between irrigation levels was significant at a level of $p<0.01$. According to the results of ANOVA of fiber quality parameters (fiber strength, fiber length, fiber fineness, uniformity and elongation), the difference between seed applications were found to be insignificant, while the difference between IL was found to be significant at a level of $p< 0.05$. 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 good fiber quality. However, if water resources in the area are limited, then restricting water to a level of only 25% may produce acceptable results. In this regard, it was concluded that the most suitable irrigation programme from the point of view of cotton yield in a region without irrigation water restrictions, was the treatment (IL-100) in which water was fully applied.

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