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Original Research

Impact of Different Levels of Drought Stress on Yield and Yield Components in Some Cotton (*Gossypium hirsutum* L.) Cultivars

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Abstract

This study aimed to assess the yield and yield components of various cotton cultivars under different levels of drought stress. In the experiment, three irrigation treatments (I-100, I-75, and I-50) and three cotton cultivars were included. Analysis of the two-year data showed that water treatments significantly affected all traits except the number of seeds per boll. Full irrigation treatment (I-100) had higher values for seed cotton yield, plant height, number of monopodial and sympodial branches, number of nodes of first fruiting branches, number of nodes, HNR, number of bolls, boll weight, seed cotton weight per boll, and 100-seed weight than those of other water stress applications. Depending on the water stress applied, yield losses of 25.60% in I-75 and 54% in I-50 were observed compared to full irrigation. As a result of the application of water stress (I-75 and I-50), plant height, the numbers of monopodial branches, sympodial branches, first fruiting branches, nodes, and bolls were reduced, and boll weight (g), seed cotton weight per boll (g), and 100-seed weight decreased, while ginning percentage was increased; number of seeds per boll was not affected. These results also revealed that there were significant differences among cultivars (Kartanesi, Stoneville 468 and FiberMax 832) in terms of many investigated traits. The Stoneville 468 and Kartanesi cultivars were found to have superior values for yield and ginning percentage. According to the results of a two-year study, water stress negatively affected cotton yield and yield components. By demonstrating how specific cotton cultivars uniquely respond to deficit irrigation, this study offers novel baseline data and practical cultivar recommendations to mitigate agricultural productivity losses under climate change. Based on the results of the study, it was concluded that drought stress is a limiting factor for successful cotton production.

Keywords: cotton, water stress, yield, yield components

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Introduction

Water scarcity, increasing food demand, and climate change are interconnected global challenges. Global warming, driven by the greenhouse effect, contributes to significant and unpredictable shifts in the distribution of water resources.

Some regions will face excessive rainfall, while others will experience significant declines in precipitation. As a result, countries with already limited water resources are likely to enter a prolonged period of water scarcity. Mitigating the negative impacts of potential wet and dry extremes on agricultural production is only possible through the exploration and development of innovative solutions.

Therefore, understanding plant water needs, ensuring water efficiency, and designing proper irrigation programs are now critical [1]. One-third of the world's arable land is currently affected by water scarcity [2, 3]. According to the 2014 report prepared by the International Panel on Climate Change (IPCC), changes in the weather (temperature, precipitation) cause irregularities and fluctuations in agricultural production. It is predicted that water shortages and droughts will increase and agricultural productivity will decrease due to the impact of climate change.

It is widely recognized that plant development is closely linked to the water balance within plant tissues. When water becomes deficient, key physiological processes are disrupted, initially hindering plant growth and subsequently reducing yield. Water plays a vital and dominant role in nutrient uptake and transport, chemical and enzymatic reactions, cell growth and expansion, as well as physiological processes such as transpiration. Therefore, water deficiency negatively impacts plant development, morphology, and biochemical functions [4]. The effects of water stress on plants depend on the duration and severity of the stress, the developmental stage of the plant at the time of exposure, and the plant variety. Among the various growth stages, the reproductive phase following seed germination is known to be the most sensitive to water stress. Cotton, in particular, is considered highly susceptible to water stress during both the flowering stage and boll formation.

Drought stress adversely affects both vegetative growth and root development in plants. Li et al. [4] demonstrated that the effects of drought stress on cotton vary across different stages. They found that drought stress at the seedling stage leads to reductions in plant height, the number and length of fruit branches, root length, and the number of lateral roots. The structural and anatomical characteristics of plant roots are crucial for adaptation to drought stress. Studies have shown that moderate drought promotes root elongation, while severe drought inhibits normal root growth [5].

McMichael and Quisenberry [6] reported that under severe water stress conditions, the root-to-shoot length ratio decreases, dry matter accumulation is reduced, fewer nodes form on leaves and stems, and leaf area declines. In contrast, Malik et al. [7] found that, under drought stress, root development is less affected than shoot development. Pettigrew [8] stated that drought stress reduces the leaf area index, causes square and fruit drop, and accelerates the termination of both vegetative and reproductive development in plants. The adverse effects of drought stress on plant growth, development, and physiological phenomena were reflected in reduced fruit production and seed cotton yield [9].

This study was carried out to determine the effects of different levels of water stress on yield and yield components in three different cotton varieties (with okra and normal leaves). By identifying the distinct agronomic responses of these specific cultivars to deficit irrigation, this research provides novel baseline data for breeders. Practically, it guides producers in semi-arid environments to mitigate yield losses through optimal cultivar selection and efficient water management.

Materials and Methods

Experimental Area

Two-year field experiments were conducted at the research field of the GAP International Agricultural Research and Training Center (37°56'N Lat, 40°15'E Long and 677 m elevation) located in Diyarbakır, Türkiye. The climate in this region is semiarid with total annual precipitation of 549.1 mm. Long-term climate data results showed a total of 454 mm of precipitation and an average temperature of 15.8ºC.

Research soils are generally red-brown, have a clayey structure, are flat or close to being flat and therefore have very little erosion, and are zoned soils that belong to the large soil group at deep or medium depth.

Soil samples were collected from a depth of 0-30 cm and analyzed at the soil analysis laboratory of the GAP International Agricultural Research and Training Center; the soil was found to have a loamy structure and to be slightly alkaline, calcareous and saline, insufficient in organic matter and phosphorus, and sufficient in potassium (Table 1).

Climate Data

Diyarbakır is one of the major provinces in the Southeastern Anatolia Region where a continental climate prevails. The climatic data for the years during which the study was conducted, as well as for the long-term period, are shown in Table 2.

Data show that precipitation in May (157.6 mm) and October 2018 (76.6 mm) significantly exceeded long-term averages, whereas relative humidity during July–September of both years fell below average. It is observed that the maximum temperature values in June, July and August in both years were above those of the long-term period.

Table 1. Soil properties of the research area.

Years	2017	2018
Texture	Clay-Loam(C-L)	Clay-Loam(C-L)
EC (dS m^{-1})	1.27	1.40
pH	8.10	8.20
$CaCO_3$ (%)	11.00	11.46
P_2O_5 (kg ha^{-1})	3.21	4.02
K_2O (kg ha^{-1})	243	250
Organic Matter (%)	0.98	1.15
Bulk Density (g/cm^3)	1.30	1.20
Field Capacity (%)	44.05	44.03
Permanent Wilting Point (%)	30.04	31.08

Plant Material, Experimental Design and Cultural Practices

In the study, three cotton cultivars (Stoneville 468, Fiber Max 832 and Kartanesi) were used as plant material. The experiments were set up in four blocks according to a split-plot design; the main plot consisted of irrigation levels and the subplot consisted of varieties.

Cotton planting was performed with a planting machine on 12 May 2017 and 19 April 2018. Each parcel consisted of four rows, each 12 m in length, with inter-row and intra-row spacings of 70 cm and 15-20 cm, respectively.

Water applications and repetitions were separated by 2 m. Soil water content was measured gravimetrically at 0-30, 30-60, and 60-90 cm soil layers at 15-day intervals before planting, after harvest, and during the plant development period, and moisture was monitored.

Plant Water Consumption: The water consumption of the experimental subjects was calculated using the water balance equation [10].

$$ET = I + P - R - D \pm \Delta S$$

In the equation,
ET: Plant water consumption (mm),
I: Amount of applied irrigation water (mm),
P: Rainfall (mm),
R: Surface runoff (mm), D: Deep infiltration (mm),
ΔS: Change of moisture in the soil (mm).

In the research, the irrigation water to be applied was calculated volumetrically using evaporation measurements collected from the Class A evaporation pan at 5-day irrigation intervals [11].

The entire amount of water measured from the evaporation pan was calculated and applied to the I-100 (full water) subject; 75% of the measured amount of water was calculated and applied to the I-75 (25% water reduction) irrigation subject, and 50% of the measured amount of water was calculated and applied to the I-50 (50% water reduction) irrigation subject. The equation given below was used in the irrigation water calculation.

$$I = A \times Ep \times Kpc \times P$$

In the equation,
I: Irrigation water to be applied to the parcel (L),
A: Parcel area (m^2),
Ep: Class A Pan evaporation amount (mm),
Kpc: Pan coefficient (pan coefficient is taken as 1),
P: Wetting area ratio (%).

The irrigation system consists of a control unit, main pipeline, manifold pipelines, lateral pipelines, and drippers. The irrigation system utilized 50 mm PE pipes for the pump connection and control unit outlet, 32 mm PE pipes for the main and manifold lines, and 16 mm pressure-regulating in-line drip pipes for the laterals. A lateral pipeline was installed in each row; the dripper intervals were 25 cm, and the drippers had a flow rate of 2 L/h. The analysis revealed that the electrical

Table 2. Climate data for the years in which the experiment was conducted and for the long-term period.

Month	Average Temperature (ºC)			Maximum Temperature (ºC)			Rainfall (mm)			Relative Humidity (%)		
	2017	2018	Long-term	2017	2018	Long-term	2017	2018	Long-term	2017	2018	Long-term
April	12.8	15.9	13.8	19.5	24	20.2	98.8	48.6	68.7	68.5	52.9	63
May	18.8	19.4	19.3	26.3	26.5	26.5	30.6	157.6	42.8	57.6	67.3	56
June	26.9	26.6	26.3	35	34.5	33.7	2.6	14.4	8	30	37.4	31
July	32.3	31.2	31.2	40.7	39.3	38.4	0	0	0.7	19.4	24.1	27
August	31.1	31.4	30.3	39.9	39.1	38.1	0	0.8	0.4	22.8	24.1	28
September	26.8	26.1	24.8	36.4	34.6	33.2	0	6.2	3.9	22.3	29.3	32
October	17.2	18.7	17.2	24.8	25.8	25.2	22	76.6	31.7	39.2	52.3	48
Mean	23.7	24.2	23.3	31.8	31.9	30.7	22.0	43.4	22.3	37.1	41.0	40.7

*Source: Turkish State Meteorological Service. Diyarbakır

conductivity (EC) of the irrigation water was 0.60 dS/m, with a pH of 7.6.

Considering the soil analysis results, 160 kg ha^{-1} pure nitrogen (N) and 80 kg ha^{-1} P_2O_5 were applied; approximately ¼ of the nitrogen and all of the phosphorus were applied in the form of DAP (Diammonium phosphate) compound fertilizer before planting, and ¾ of the nitrogen was applied in the form of urea in three periods (beginning of squaring, beginning of flowering and flowering period) until the peak flowering period. All other cultural practices, such as insect and weed control, have been performed on the cotton crop from sowing to harvest. Insecticides were applied once in both years against *Aphis gossypi*, *Thrips tabaci*, *Helicoverpa armigera* and *Empoasca* ssp.

The parcels were harvested twice by hand for yield determination on 10 October 2017 and 27 November 2017 in the first year, and on 1 October 2018 and 2 November 2018 in the second year. After the harvest was completed, the seed cotton weights were measured and used to calculate the seed cotton yield. Agronomic observations and measurements were taken from 10 randomly selected plants in each plot before the first harvest.

Statistical Analysis

The data obtained from the trial were analyzed. ANOVA (analysis of variance) was performed using the JMP 7.0.1 statistical software package (SAS Institute 2002). The treatment means were further compared.

Results

In the study, the results of the variance analysis for the investigated traits, combined year average values, and multiple comparison results based on the $LSD_{(0.05)}$ test are presented in Table 3 and Table 3a).

Seed Cotton Yield (kg ha^{-1})

According to the analysis of variance presented in Table 3, statistically significant differences at the 1% level were observed for the factors of year, water applications, and year x water application interaction. Varieties and the year × water × variety interaction were found to be non-significant.

When evaluated by years, the highest seed cotton yield was recorded in 2017, with a value of 3620.04 kg ha^{-1}, placing it in the first statistical group. In contrast, the yield obtained in 2018 was 3100.44 kg ha^{-1}, categorizing it into the second group (Table 4).

The two-year combined ANOVA revealed significant treatment effects on seed cotton yield: I-100 (full irrigation) ranked in the first statistical group with 4570.38 kg ha^{-1}, followed by I-75 in the second (3400.45 kg ha^{-1}) and I-50 in the third (2100.88 kg ha^{-1}). It was observed that the applied water stress caused a decrease in seed cotton yield. When the study was examined in terms of varieties, significant statistical differences were found among them. The Kartanesi variety, with a yield of 3410.26 kg ha^{-1}, and the Stoneville 468 variety, with 3600.91 kg ha^{-1}, were classified in the first group, while the FM 832 variety, yielding 3060.55 kg ha^{-1}, belonged to the second group.

Plant Height

According to the variance analysis of plant height values (Table 5), statistically significant differences were observed among water treatments and varieties at the $p \leq 0.01$ level, as well as a significant three-way

Table 3. Variance analysis for the traits examined at different irrigation levels.

Source of Variation	D.F.	Seed Cotton Yield	Plant Height	Monopodial Branches	Sympodial Branches	Node of First Fruiting Branches	Number of Nodes	Height/Node (HNR)
Year (Y)	1	47926.40**	265.78	9.80**	92.93**	10.33**	1215.24**	117.70**
Replication	6	738.00	29.30	1.07	4.74	1.00	2.85	0.69
Water Treat (W)	2	364887.00**	3809.96**	2.07**	151.54**	4.97**	52.54**	1.85*
Year x Water	2	16018.30**	10.78	0.08	52.20**	0.25	3.42	0.33
Error 1	12	2347.82	122.61	0.29	4.83	0.39	3.29	0.47
Variety (V)	2	18180.70**	148.05**	0.70**	2.05	0.17	9.39**	0.14
Year × Variety	2	2714.28	56.46	0.31	26.30**	1.17**	2.68	0.04
Water × Variety	4	1933.72	30.68	0.23	7.90**	0.33*	0.60	0.16
Y × W × V	4	12182.00**	56.27*	0.17	11.12**	0.10	5.69**	0.46*
Error 2	36	2724.10	23.31	0.15	1.55	0.13	1.17	0.20
General	71							

* and ** indicate significance at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Table 3a). Variance analysis for the traits examined at different irrigation levels.

Source of Variation	D.F.	Number of Bolls	Boll Weight	Seed Cotton Boll Weight	Number of Seeds in the Boll	100-seed Weight	Ginning percentage
Year (Y)	1	149.65**	57.44**	5.87**	0.89	0.07	3.38
Replication	6	17.19	1.16	0.17	3.00	1.12	2.46
Water Treat (W)	2	352.74**	3.86**	8.69**	10.66	7.85**	21.46*
Year × Water	2	28.67	0.04	0.06	1.60	0.08	1.56
Error 1	12	16.46	0.80	0.37	3.70	0.73	5.24
Variety (V)	2	2.94	16.60**	4.93**	118.11**	4.31**	109.88**
Year × Variety	2	32.31**	0.40	0.00	1.33	0.07	3.53
Water × Variety	4	21.14**	0.88*	0.57*	4.46	0.82	2.61
Y × W × V	4	12.70**	0.51	0.08	0.74	0.71	1.88
Error 2	36	2.38	0.34	0.18	4.22	0.58	4.93
General	71						

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

Table 4. Average values and groupings of applications in terms of seed cotton yield.

Variety	Seed Cotton Yield											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	5590.67 a	3800.83 cd	1740.85 g	3710.78	3970.42 b	3070.31 c	2270.50 d	3100.74	4780.54	3440.07	2010.18	3410.26 a
Stv 468	4870.99 ab	3590.45 cd	2760.15 ef	3740.53	4720.72 a	3540.61 bc	2140.52 de	3470.28	4800.36	3570.03	2450.33	3600.91 a
FM 832	4910.33 ab	3110.19 de	2160.90 fg	3390.81	3350.17 bc	3290.33 c	1550.39 e	2730.30	4130.25	3200.26	1860.15	3060.55 b
Mean	5130.00 a	3500.49 b	2220.63 c		4010.77 a	3300.42 b	1990.14 c		4570.38 a	3400.45 b	2100.8 c	
Average	3620.04 a				3100.44 b				3360.24			

* Means followed by the same letter(s) in each column are not significantly different at p<0.01

interaction between year × water treatment × variety at the p≤0.05 level. Conversely, no significant differences were found for the main effect of year or the two-way interactions of year × water treatment, year × variety, and water treatment × variety.

The combined analysis over the two years (Table 5) reveals that water treatments had a significant impact on plant height. The highest plant height was recorded with the I-100 full irrigation treatment, averaging 111.58 cm, placing it in the first statistical group. This was followed by the I-75 water-stressed treatment, with a height of 99.51 cm, in the second group, while the lowest height was observed under I-50, with 85.10 cm, placing it in the third group.

The results indicate that the applied water stress led to a reduction in plant height. When analyzed by variety, statistically significant differences were observed. The Kartanesi and FM 832 varieties produced the tallest plants, with average heights of 100.09 cm and 101.08 cm, respectively, placing them in the first statistical group. In contrast, Stoneville 468 recorded a significantly lower average plant height of 96.37 cm, placing it in the second group.

Additionally, a significant three-way interaction (year × water treatment × variety) was detected. The highest plant height value of 118.67 cm was observed in 2017 under the I-100 full irrigation treatment for the FM 832 variety. Conversely, the lowest plant height of 82.50 cm was recorded in 2018 under the I-50 water stress treatment for the Stoneville 468 variety.

Number of Monopodial Branches

The analysis of variance showed significant differences at the 1% level among years, water treatments, and varieties. When the study was examined

Table 5. Average values and groupings of applications in terms of plant height.

Variety	Plant Height (cm)											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	110.33 b	98.33 ef	92.13 fg	100.27	112.20 ab	102.30 cde	85.25 gh	99.92	111.27	100.32	88.69	100.09 a
Stv 468	108.93 bc	101.33 de	86.47 gh	98.91	106.85 bcd	92.15 fg	82.50 h	93.83	107.89	96.74	84.48	96.37 b
FM 832	118.67 a	107.07 bcd	86.67 gh	104.13	111.85 ab	97.50 ef	84.75 h	98.03	115.26	102.28	85.71	101.08 a
Mean	112.64	102.24	88.42		110.30	97.32	84.17		111.58 a	99.51 b	85.10 c	
Average	101.10				97.26				98.73			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

Table 6. Average values and groupings of applications in terms of number of monopodial branches.

Variety	Number of Monopodial Branches											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	3.13	3.45	3.07	3.22	2.88	3.00	2.30	2.73	3.00	3.23	2.68	2.97 b
Stv 468	3.47	3.53	2.85	3.28	3.00	2.45	2.05	2.50	3.23	2.99	2.45	2.89 b
FM 832	4.08	3.53	3.45	3.69	2.95	2.85	2.45	2.75	3.52	3.19	2.95	3.22 a
Mean	3.56	3.51	3.12		2.94	2.77	2.27		3.25 a	3.14 a	2.69 b	
Average	3.40 a				2.66 b				3.03			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

by year, the number of monopodial branches recorded in 2017 was in the first group at 3.40 branches plant^{-1}, and the value obtained in 2018 was in the second group with 2.66 number plant^{-1} (Table 6). Considering the results of the two-year combined variance analysis, it was found that the water treatments were significant. The values from the I-100 full water application and the I-75 water stress treatment were placed in the first group, with 3.25 and 3.14 plants per unit, respectively. The I-50 water stress treatment, with 2.69 plants per unit, was placed in the second group. It was observed that the applied water stress caused a decrease in the number of monopodial branches.

Highly significant differences were observed among varieties. The FM 832 variety was in the first group with 3.22; Kartanesi and Stoneville 468 varieties were in the second group with 2.97 and 2.89 branches plant^{-1}, respectively.

Number of Sympodial Branches

A significant difference was observed at the p≤0.01 level for year, water treatment, year × water treatment, year × variety, water treatment × variety, and year × water treatment × variety interactions. However, no significant differences were found between the varieties (Table 7). When the study was evaluated by years, it was found that the number of sympodial branches recorded in 2018 was higher than that recorded in 2017.

The results of the combined variance analysis over two years revealed that water treatments had a significant effect. Specifically, the I-100 full irrigation resulted in the highest number of sympodial branches (18.85 number plant^{-1}), followed by I-75 water stress with 16.12, and I-50 water stress with 13.83 number plant^{-1}, indicating a clear decline in the number of sympodial branches under water stress conditions. A significant year x water treatment interaction was also observed. The maximum number of sympodial branches (21.55 number plant^{-1}) was obtained in 2018 under the I-100 full irrigation treatment, whereas the minimum value (13.60 number plant^{-1}) was recorded in the same year under the I-50 water stress treatment. Regarding the year x variety interaction, significant differences were detected as well. The highest number of sympodial branches (18.66) was recorded in 2018 for the Stoneville 468 variety, while the lowest value (14.56) was observed in 2017 for the same variety. In terms of water treatment × variety interaction, the Stoneville 468 variety under I-100 full irrigation

Table 7. Average values and groupings of applications in terms of number of sympodial branches.

Variety	Number of Sympodial Branches											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	15.73 d-g	14.00 g-u	14.46f-u	14.73 d	21.90 b	15.92 d-f	14.55 f-u	17.46 b	18.81 ab	14.96 e	14.50 ef	16.10
Stv 468	15.00 e-h	14.86 f-ı	13.80 hu	14.56 d	24.60 a	18.32 c	13.05 j	18.66 a	19.80 a	16.59 d	13.42 f	16.61
FM 832	17.73 c	16.66 c-e	13.93 hu	16.11 c	18.15 c	16.95 cd	13.20 ıj	16.10 c	17.94 bc	16.80 cd	13.56 f	16.11
Mean	16.16 b	15.18 bc	14.07 c		21.55 a	17.07 b	13.60 c		18.85 a	16.12 b	13.83 c	
Average	15.13 b				17.41 a				16.27			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

produced the highest number of sympodial branches (19.80 number plant^{-1}), whereas the lowest value (13.42 number plant^{-1}) was also recorded for Stoneville 468 under I-50 water stress.

It was observed that there were significant statistical differences in terms of year × water treatment × variety interactions. The highest value of 24.60 was observed in 2018 under I-100 full irrigation for the Stoneville 468 variety, while the lowest value (13.05) was obtained from the Kartanesi variety under I-50 water stress in the same year.

Number of Nodes of First Fruiting Branches

Upon examining the variance analysis of the number of nodes on the first fruiting branches, a significant difference was observed at the 1% level for years, water treatments, and the year × variety interaction, and at the 5% level for the water treatment × variety interaction. When the study was examined in terms of year, it was determined that the number of nodes on the first fruiting branches obtained in 2017 was in the first group with 6.24 number plant^{-1}, and the value obtained in 2018 was in the second group with 5.48. When the two-year combined variance analysis results were taken into consideration, it was determined that the applications were significant. The I-100 full irrigation treatment ranked in the first statistical group with 6.33 plants per unit, followed by I-75 in the second (5.83) and I-50 in the third (5.42). It is seen from Table 8 that the applied water stress caused the number of nodes of first fruiting branches to decrease. A significant year × variety interaction was observed: the highest first fruiting branch node number occurred in FM 832 in 2017 (6.47 nodes plant^{-1}), while the lowest was in both FM 832 and Stoneville 468 in 2018 (5.33 nodes plant^{-1}). It was determined that significant statistical differences at the 5% level occurred in terms of water treatment × variety interactions. The highest number of nodes of first fruiting branches was obtained from Stoneville 468 in I-100 full irrigation with 6.43, and the lowest value was obtained from the Stoneville 468 variety in I-50 water stress with 5.31 number plant^{-1}.

Number of Nodes

A highly statistically significant difference was observed at the 1% level (p≤0.01) for the main effects of year, water treatments, and varieties, as well as for the three-way interaction of year × water treatment

Table 8. Average values and groupings of applications in terms of number of nodes of first fruiting branches.

Variety	Number of nodes of first fruiting branches											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	6.30	6.00	5.87	6.06 bc	6.00	6.05	5.30	5.78 c	6.15 ab	6.03 b	5.58 c	5.92
Stv 468	6.87	5.87	5.87	6.20 ab	6.00	5.25	4.75	5.33 d	6.43 a	5.56 cd	5.31 d	5.77
FM 832	7.13	6.40	5.87	6.47 a	5.70	5.40	4.90	5.33 d	6.42 a	5.90 bc	5.38 d	5.90
Mean	6.77	6.09	5.87		5.90	5.57	4.98		6.33 a	5.83 b	5.42 c	
Average	6.24 a				5.48 b				5.86			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

× variety. When analyzed by year, the highest number of nodes was recorded in 2017, with an average of 21.77 nodes per plant, placing it in the first statistical group. In contrast, the 2018 growing season yielded a significantly lower value of 13.55 nodes per plant, placing it in the second group (Table 9).

Based on the two-year combined analysis, water treatments were significant; I-100 (19.16 plant^{-1}) and I-75 (17.62 plant^{-1}) formed the first statistical group, while I-50 (16.20 plant^{-1}) fell into the second. It was observed that the applied water stress caused the number of nodes to decrease. When the study was examined in terms of cultivars, it was determined that there were significant statistical differences between them. Kartanesi and FM 832 varieties were in the first group with 18.01 and 18.03 number plant^{-1}, respectively, and the Stoneville 468 variety was in the second group with 16.94 number plant^{-1}.

A significant year × water treatment × variety interaction was observed; the highest node number (24.67 nodes plant^{-1}) occurred in 2017 with I-100 and FM 832, while the lowest (11.25 nodes plant^{-1}) was in 2018 with I-50 and Stoneville 468.

Height/Node Ratio (HNR)

A statistically significant difference was observed at the 1% level ($p \leq 0.01$) between years, and at the 5% level ($p \leq 0.05$) for the year × water treatment × variety interaction. However, no significant differences were found for the year × water treatment, variety, year × variety, and water treatment × variety interactions.

When evaluated by year, the height-to-node ratio was found to be significantly higher in 2018, with a value of 7.20, placing it in the first statistical group. In comparison, 2017 recorded a lower value of 4.64, classified in the second group (Table 10).

According to the combined two-year variance analysis, water treatments had a significant impact. The I-100 full irrigation treatment resulted in the highest height/node ratio (6.19), followed closely by I-75 water stress with 5.94, both of which were grouped statistically. The lowest ratio (5.64) was observed under the I-50 water stress treatment, which was placed in a separate group. These results indicated that increasing water stress led to a decrease in the height-to-node ratio, emphasizing the influence of irrigation level on plant morphological development.

It was determined that there were significant statistical differences in terms of year × water treatment

Table 9. Average values and groupings of applications in terms of number of nodes.

Variety	Number of nodes											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	24.56 a	20.53 cd	20.47 cd	20.53	14.80 e	14.90 e	12.90 fg	14.20	19.68	17.72	16.68	18.03 a
Stv 468	21.86 bc	21.00 cd	20.00 d	21.00	14.75 e	12.75 f-h	11.25 h	12.92	18.31	16.88	15.63	16.94 b
FM 832	24.67 a	22.87 b	19.93 d	22.87	14.30 ef	13.65 e-g	12.65 gh	13.53	19.48	18.26	16.29	18.01 a
Mean	23.70	21.47	20.13		14.62	13.77	12.27		19.16 a	17.62 b	16.20 c	
Average	21.77 a				13.55 b				17.66			

* and ** indicate significance at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Table 10. Average values and groupings of applications in terms of height/node ratio.

Variety	Height/Node											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	4.53 ef	4.78 ef	4.50 ef	4.61	7.66 ab	6.94 cd	6.62 d	7.07	6.10	5.86	5.56	5.84
Stv 468	4.98 e	4.82 ef	4.32 f	4.70	7.25 a-d	7.25 a-d	7.34 a-c	7.28	6.12	6.03	5.83	5.99
FM 832	4.83 ef	4.68 ef	4.35 ef	4.62	7.89 a	7.17 b-d	6.69 d	7.25	6.36	5.93	5.52	5.94
Mean	4.78	4.76	4.39		7.60	7.12	6.88		6.19 a	5.94 ab	5.64 b	
Average	4.64 b				7.20 a				5.92			

* and ** indicate significance at $p \leq 0.05$ and $p \leq 0.01$, respectively.

× variety interactions; the highest HNR, with a value of 7.89, was obtained in 2018 under the I-100 full water application for the FM 832 variety, and the lowest value, 4.32, was obtained in 2017 under the I-50 water stress application for the Stoneville 468 variety.

Number of Bolls

Upon examining the variance analysis of the number of bolls, a significant difference was observed at the 1% level for years, water treatments, year × variety, water treatment × variety, and the year × water treatment × variety interactions. When the study was examined by year, it was found that the highest boll number was obtained in 2017, with 20.29, placing it in the first group, while the lowest value was recorded in 2018, with 17.41, placing it in the second group (Table 11). When the two-year combined variance analysis result was considered, it was determined that the water treatments were significant; the values obtained from I-100 full water application and I-75 water stress application were in the first group with 22.15 and 19.74, respectively, and the value obtained from I-50 water stress was in the second group with 14.64 number plant^{-1}.

It was determined that significant statistical differences occurred in terms of water treatment × variety interactions. The highest boll number was obtained from the FM 832 variety in 2017, with 21.60, while the lowest value was recorded for the FM 832 variety in 2018, with 16.10 bolls per plant. It has been determined that significant statistical differences have occurred in terms of water treatment × variety interactions, and it can be observed that the highest boll number was obtained from the Stoneville 468 variety in I-100 full irrigation with 23.06, and the lowest value was obtained from the Stoneville 468 variety in I-50 water stress with 13.63 number plant^{-1}.

A significant year × water treatment × variety interaction was observed: the highest boll number (24.60) occurred in both 2017 (I-75, FM 832) and 2018 (I-100, Stoneville 468), while the lowest (13.05) was in 2018 (I-50, Stoneville 468).

Boll Weight

Examination of the variance analysis table for boll weight revealed statistically significant differences at the 1% level ($p \leq 0.01$) for year, water treatments, and varieties, as well as a significant difference at the 5% level ($p \leq 0.05$) for the water treatment × variety interaction. However, no significant differences were detected for the year × treatment, year × variety, or year× treatment × variety interactions. When evaluated by year, the boll weight recorded in 2017 was significantly higher, with an average of 8.83 g, placing it in the first statistical group, while the 2018 value of 7.05 g fell into the second group (Table 12).

According to the combined two-year analysis, irrigation treatments had a significant impact on boll weight. The I-100 full irrigation treatment resulted in the highest boll weight (8.33 g), followed by the I-75 water stress treatment with 7.98 g, both placed in the same statistical group. In contrast, the I-50 water stress treatment resulted in the lowest boll weight (7.53 g), placed in a separate group. These results clearly indicate that increasing levels of water stress led to a reduction in boll weight, underscoring the sensitivity of this trait to irrigation levels. When the study was examined by variety, it was found that there were significant statistical differences among the varieties. The FM 832 variety was in the first group with 8.86 g, the Kartanesi variety in the second group with 7.72 g, and the Stoneville 468 variety in the third group with 7.25 g. It was determined that there were significant statistical differences in terms of water treatment x variety interactions; the highest boll weight value was obtained from the FM 832 cotton variety under the I-100 full irrigation treatment, with a value of 9.67 g, and the lowest value was obtained from the Stoneville 468 variety under the I-50 water stress treatment, with a value of 6.85 g.

Seed Cotton Boll Weight

Seed cotton boll weight varied significantly by year, water treatment, and variety at the 1% level, with

Table 11. Average values and groupings of applications in terms of number of bolls.

Variety	Number of bolls											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	22.13 b	19.20 c	17.27 c-e	19.53 b	21.90 b	15.93 ef	14.55 fg	17.46 c	22.02 ab	17.56 c	15.91 d	18.50
Stv 468	21.53 b	23.47 ab	14.20 fg	19.73 b	24.60 a	18.33 cd	13.05 g	18.66 bc	23.06 a	20.90 b	13.63 e	19.20
FM 832	24.60 a	24.60 a	15.60 ef	21.60 a	18.15 cd	16.95 de	13.20 g	16.10 d	21.38 b	20.78 b	14.40 de	18.85
Mean	22.76	22.42	15.69		21.55	17.07	13.60		22.15 a	19.74 a	14.64 b	
Average	20.29 a				17.41 b				18.84			

* and ** indicate significance at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Table 12. Average values and groupings of applications in terms of boll weight.

Variety	Boll weight											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	8.27	8.87	8.33	8.49	7.33	6.67	6.86	6.95	7.80 cd	7.86 cd	7.50 d	7.72 b
Stv 468	8.47	8.33	7.60	8.13	6.55	6.10	6.43	6.36	7.51 d	7.38 de	6.85 e	7.25 c
FM 832	10.93	9.53	9.20	9.89	8.41	7.26	7.84	7.84	9.67 a	8.69 b	8.23 bc	8.86 a
Mean	9.22	8.91	8.37		7.43	6.68	7.05		8.33 a	7.98 ab	7.53 b	
Average	8.83 a				7.05 b				7.95			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

a significant treatment × variety interaction at the 5% level. However, no significant differences were observed for the interactions of year × treatment, year × variety, and year × treatment × variety.

Seed cotton boll weight was significantly higher in 2018 (5.13 g, first statistical group) compared to 2017 (4.56 g, second group). Considering the combined two-year variance analysis, the water applications were found to be significant. The full irrigation treatment (I-100) produced the highest boll weight at 5.47 g, placing it in the first group. The moderate water stress treatment (I-75) followed with 4.81 g in the second group, and the severe water stress treatment (I-50) yielded the lowest weight of 4.27 g, falling into the third group. These results indicate that increasing water stress led to a decrease in seed cotton boll weight (Table 13). Varieties differed significantly; FM 832 (5.33 g), Kartanesi (4.79 g), and Stoneville 468 (4.43 g) were placed in the first, second, and third statistical groups, respectively.

It was determined that significant statistical differences occurred in terms of water treatment × variety interactions; the highest value for boll seed weight, 6.22 g, was obtained from the FM 832 variety under I-100 full irrigation, and the lowest value, 4.05 g, was obtained from the Stoneville 468 variety under I-50 water stress.

Number of Seeds in the Boll

Upon examining the variance analysis table for the number of seeds per boll, a statistically significant difference at the 1% level was observed among the varieties. However, no significant differences were found for the effects of years, water treatments, or their interactions, namely, year × water treatment, year × variety, water treatment × variety, and year × water treatment × variety (Table 14). Based on the two-year combined analysis, seed number per boll varied significantly by variety, placing FM 832 (32.96) in the first group, and Kartanesi (31.80) and Stoneville 468 (28.68) in the second.

100-Seed Weight

Upon examining the variance analysis for 100-seed weight, significant differences at the 1% level were observed for both water treatments and varieties. However, no significant differences were found in relation to years or for the interactions of year × treatment, year × variety, treatment × variety, and year × treatment × variety (Table 15).

Considering the combined variance analysis over the two years, water treatments had a significant effect on 100-seed weight. The highest weight was obtained under the I-100 full irrigation treatment, which was placed in

Table 13. Average values and groupings of applications in terms of seed cotton boll weight.

Variety	Seed cotton boll weight											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	4.97	4.45	4.09	4.50	5.59	5.05	4.59	5.08	5.28 bc	4.75 de	4.34 ef	4.79 b
Stv 468	4.76	3.85	3.85	4.15	5.07	4.77	4.26	4.70	4.92 cd	4.31 f	4.05 f	4.43 c
FM 832	5.93	5.08	4.09	5.03	6.50	5.63	4.74	5.62	6.22 a	5.36 b	4.41 ef	5.33 a
Mean	5.22	4.46	4.01		5.72	5.15	4.53		5.47 a	4.81 b	4.27 c	
Average	4.56 b				5.13 a				4.85			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

the first group with 9.50 g. The I-75 and I-50 water stress treatments followed in the second group with weights of 8.83 g and 8.36 g, respectively. This indicates that reduced irrigation led to a decrease in 100-seed weight.

Varieties differed significantly in 100-seed weight; FM 832 ranked first (9.37 g), while Kartanesi (8.75 g) and Stoneville 468 (8.57 g) shared the second group.

Ginning Percentage

Upon examining the variance analysis table for ginning percentage, statistically significant differences were observed at the 5% level for water treatments and at the 1% level for varieties. No significant effects were found for years or for the interactions of year × treatment, year × variety, treatment × variety, and year × treatment × variety. Considering the combined data results over the two years, water treatments significantly influenced ginning percentage. As shown in Table 16, the I-75 and I-50 water stress treatments formed the first group with values of 41.51% and 41.56%, respectively, while the I-100 full irrigation treatment formed the second group, with a lower ginning percentage of 39.90%. In terms of varieties, significant statistical differences were also

Table 14. Average values and groupings of applications in terms of number of seeds in the boll.

Variety	Number of seeds in the boll											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	32.13	31.93	31.80	31.96	32.50	30.53	31.93	31.65	32.32	31.23	31.86	31.80 a
Stv 468	29.13	27.87	28.13	28.38	29.48	28.65	28.80	28.98	29.30	28.26	28.46	28.68 b
FM 832	33.67	33.67	31.00	32.78	34.40	33.18	31.88	33.15	34.03	33.42	31.44	32.96 a
Mean	31.64	31.16	30.31		32.13	30.78	30.87		31.88	30.97	30.59	
Average	31.04				31.26				31.14			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

Table 15. Average values and groupings of applications in terms of 100-seed weight.

Variety	100-Seed Weight											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	9.21	8.46	8.65	8.77	8.94	8.99	8.24	8.72	9.07	8.72	8.44	8.75 b
Stv 468	9.24	8.28	8.08	8.53	9.36	8.24	8.21	8.60	9.30	8.26	8.15	8.57 b
FM 832	9.77	9.83	8.27	9.29	10.46	9.21	8.70	9.46	10.12	9.52	8.48	9.37 a
Mean	9.41	8.85	8.33		9.59	8.81	8.38		9.50 a	8.83 b	8.36 b	
Average	8.86				8.93				8.89			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

Table 16. Average values and groupings of applications in terms of ginning percentage.

Variety	Ginning percentage											
	2017				2018				Combined Analysis			
	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean	I-100	I-75	I-50	Mean
Kartanesi	41.00	41.82	43.18	42.00	40.69	41.19	40.92	40.93	40.84	41.50	42.05	41.47 b
Stv 468	41.15	44.89	43.47	43.17	41.81	43.15	42.61	42.52	41.48	44.02	43.04	42.85 a
FM 832	37.32	38.73	39.26	38.44	37.41	39.25	39.92	38.86	37.37	38.99	39.59	38.65 c
Mean	39.82	41.82	41.97		39.97	41.20	41.15		39.90 b	41.51 a	41.56 a	
Average	41.20				40.77				40.99			

* and ** indicate significance at p≤0.05 and p≤0.01, respectively.

identified. The Stoneville 468 variety ranked first with a ginning percentage of 42.85%, followed by Kartanesi in the second group with 41.47%, and FM 832 in the third group with 38.65%.

Discussion

Analysis of the two-year study data revealed that the I-100 (full irrigation) water treatment consistently produced higher seed cotton yields compared to water-stressed conditions. Yield losses of 25.60% and 54.00% were recorded under the I-75 and I-50 water stress treatments, respectively. Significant differences were also found among the varieties in terms of seed cotton yield. The Stoneville 468 (3600.91 kg ha^{-1}) and Kartanesi (3410.26 kg ha^{-1}) varieties, both exhibiting a palmate leaf shape, produced higher yields than the FiberMax 832 variety (3060.55 kg ha^{-1}), which has an okra leaf shape. The findings are in line with Iqbal et al. [12] and Gao et al. [13], who emphasized that although a 50% water restriction applied via drip irrigation generally provided savings in the amount of irrigation water used, it caused a moderate decrease in seed cotton yield. However, they differ from Rehman et al. [14], who reported no decrease in seed cotton yield under water stress conditions, and Shani [15], who reported that the correlation between yields under water-stressed and non-stressed conditions across 10 cotton varieties grown in both irrigated and dry conditions was not significant.

This difference may be due to the high groundwater level in the cotton-growing areas, the presence of rainfall during the growing period, and the ability of the cotton plant to obtain the water it needs from the groundwater through its roots. The results also indicated that seed cotton yield varied significantly by year, with higher yields recorded in the first year of the study. This variation is likely attributed to differences in planting dates, soil temperature at sowing, and climatic factors, particularly the fluctuations in day and night temperatures between the two years.

Previous studies revealed that drought stress reduced cotton yield, probably because of the reduction in the number of bolls [8, 16]. The number of bolls per plant is an important yield component. In the study, the number of bolls per plant decreased as the level of water stress increased, and it was determined that the number of bolls per plant decreased by 34% at a 50% water stress level.

The findings of this study are consistent with those of Chen et al. [17], who reported that the number of bolls per plant decreased under water stress conditions in a study aimed at evaluating the responses of cotton genotypes to water stress and identifying tolerant varieties. Similar conclusions were drawn by Pettigrew [8], Rehman et al. [14], Wu et al. [18], Jia et al. [19], and Zare et al. [20], all of whom reported significant reductions in boll number under deficit irrigation. Additionally, Karademir et al. [21] emphasized that the number of bolls per plant could serve as a reliable selection criterion in breeding programs, based on their study involving 15 cotton genotypes subjected to high-temperature stress. Supporting this, Gao et al. [13], in a two-year investigation, found that water stress caused a 25% reduction in the number of bolls, affecting both yield and fiber quality traits of cotton. Furthermore, Sun et al. [22] highlighted that the boll number per plant is a critical trait that can be used as a selection criterion for improving cotton yield under drought conditions.

Plant height not only affects the size of cotton plants but also constitutes a crucial agronomic trait that affects the harvest index and yield potential [23]. In the study, it was determined that plant height decreased as the level of water stress increased. Our findings were in line with Rehman et al. [14], who reported that plant growth parameters, such as plant height, were significantly affected by water stress in their study on the effects of deficit irrigation conditions on agronomic and physiological parameters of cotton. This is consistent with the findings of Karademir et al. [24] and Satish [25], who stated that plant height had a direct effect on yield according to the results of path analysis in their drought stress study conducted with 20 cotton genotypes.

The number of monopodial and sympodial branches was affected by water stress when compared to well-watered conditions. The highest numbers of both branch types were observed under well-watered conditions and decreased progressively with increasing levels of water stress. These findings are consistent with those of Rehman et al. [14], who reported that deficit irrigation led to significant reductions in the number of monopodial branches, and Iqbal et al. [12], who found that monopodial branching was negatively affected under all water stress treatments except full irrigation (S-100). Similarly, Bakhsh et al. [26] reported an 18% reduction in the number of monopodial branches under water stress conditions. These findings also are in line with Karademir et al. [24], who reported that the number of sympodial branches has a direct effect on yield according to the results of path analysis in a drought stress study conducted with twenty cotton genotypes, and Rehman et al. [14], Satish [25], and Bakhsh et al. [26], who reported reductions in the number of sympodial branches under water stress conditions.

Water stress reduced the number of nodes, the number of first fruiting branches, and the height/node ratio (HNR), which are plant development indicators. The highest values for these traits were obtained from the I-100 treatment, and the values decreased as the level of water stress increased.

Satish [25] reported that the number of nodes decreased with water stress. It is reported by Oosterhuis and Kerby [27] that an average of 23 nodes can be formed in the plant under good irrigation conditions, and similar results were observed in the present study. Oosterhuis and Kerby [27] reported that a low HNR is related to stress conditions and is a trait sensitive to water stress and high-temperature stress.

The results of this study indicated that water restrictions led to a reduction in boll weight, seed cotton weight per boll, and 100-seed weight. Similar findings have been reported by Wu et al. [18], Jia et al. [19], and Bakhsh et al. [26]. In contrast, our results differ from those of Chen et al. [17], who found that deficit irrigation had no effect on seed cotton weight per boll. Our findings are in agreement with Campos et al. [28], who reported that different irrigation levels significantly influenced 100-seed weight. However, they again contrast with Chen et al. [17], who observed no effect of water restriction on 100-seed weight in a study evaluating cotton genotypes under drought stress.

It was determined that ginning percentage was influenced by irrigation levels; however, unlike other traits examined, ginning percentage increased with increasing water stress [29]. These findings are consistent with those of Campos et al. [28], who reported that different irrigation levels affected the ginning percentage in cotton under both full (100%) and deficit (50%) drip irrigation conditions. They also align with the results of Chen et al. [17] and Iqbal et al. [12], who observed that deficit irrigation improved ginning efficiency across various cotton genotypes. Karademir et al. [30] revealed that water stress had a negative effect on ginning percentage. However, our results contrast with those of Bai et al. [31], who reported that water stress had no significant effect on ginning efficiency.

The response of the number of seeds per boll to drought stress has received limited attention in the existing literature. In this study, it was observed that the number of seeds in the boll was not affected by water stress. Pettigrew [8] reported no significant effect of water deficit on the number of seeds per boll. McMichael and Esketh [32] found that the number of seeds per boll decreased only when drought stress was applied during the early stages of cotton development.

Overall, the study demonstrated that water stress significantly affected several agronomic traits, including plant height, number of monopodial and sympodial branches, number of nodes on the first fruiting branch, total number of nodes, number of bolls, boll weight, seed cotton boll weight, and 100-seed weight, a finding that is highly consistent with recent findings in the literature [33]. All of these traits showed a decreasing trend under water stress conditions. In this study, ginning percentage increased under water stress, while the number of seeds per boll remained unaffected. This increase in ginning outturn under deficit irrigation is likely due to a more pronounced reduction in seed weight compared to lint weight, proportionally increasing the lint percentage. Additionally, the stability of seed numbers per boll indicates that this trait is determined during early fertilization stages and is highly resilient to stress, which is consistent with recent agro-physiological findings [34].

In terms of varietal performance, significant differences were observed across many traits. The FM 832 variety excelled in plant height, number of monopodial branches, boll weight, seed cotton boll weight, number of seeds per boll, and 100-seed weight. The Stoneville 468 variety demonstrated superior performance in seed cotton yield and ginning efficiency, whereas the Kartanesi variety was distinguished by having the highest number of nodes.

Additionally, the interaction between irrigation treatments and varieties was found to be significant for traits such as number of fruiting branches, number of bolls, boll weight, and seed cotton boll weight. This suggests that these traits are influenced by both genotype and the level of water stress applied.

Year-to-year differences were found to be significant for all traits examined, except for plant height, number of seeds per boll, 100-seed weight, and ginning percentage.

Conclusions

The study revealed that water stress negatively impacted cotton yield and agronomic traits, with the most pronounced reductions observed under the 50% water stress level. The findings emphasized the critical importance of irrigation throughout the cotton growing season. Irrigation was found to significantly influence all the traits examined, highlighting that avoiding water restrictions during the plant's development is essential for achieving optimal yield. Notably, water limitation resulted in a 54% reduction in yield. Varietal selection also played a crucial role in yield performance. Among the varieties tested, Stoneville 468 and Kartanesi outperformed the okra-leafed FM 832 variety in terms of yield and can therefore be recommended for cultivation under similar conditions.

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AI Usage Disclosure Statement

The authors declare that no artificial intelligence (AI) tools or machine learning systems were used in the writing, translation, data analysis, or preparation of this manuscript. The entire work was conducted and prepared solely by the human authors.

Conflict of Interest

Authors declare no conflicts of interest.

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