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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Seed priming with mepiquat chloride and foliar applications of salicylic acid and proline improve the adverse effects of water deficit in cotton (*Gossypium hirsutum* L.)

Mepiquat chloride ile tohum ön uygulaması, salisilik asit ve prolinin yaprak uygulamaları pamukta (*Gossypium hirsutum* L.) kısıntılı sulamanın olumsuz etkilerini iyileştirir

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ABSTRACT

We aimed to investigate the effects of some seed priming and foliar applications on stress prevention in cotton under deficit irrigation conditions. Seed priming with mepiquat chloride (PIX) and foliar applications of salicylic acid (SA) and proline (PRO) were tested at three levels of irrigation at 25, 50, and 100% of field capacity. Plant height, boll number, fiber length and fiber strength were significantly affected by the interaction of irrigation level × treatment. The effects of irrigation level and treatment were significant for boll weight, seed index, seed cotton yield and lint yield. When deficit irrigation conditions (25%) were compared with full irrigation, plant height decreased by 21.6 %, boll number by 18.1 %, boll weight by 26.0%, seed index by 5.8%, seed cotton yield by 25.6% and lint yield by 24.6%. Seed priming with PIX and foliar application of PRO produced significantly higher seed cotton and lint yields, whereas SA application had favourable fiber quality parameters under deficit irrigation conditions. PRO slightly increased fiber fineness. Foliar application of SA positively affected chlorophyll content (SPAD) and leaf area index (LAI) under deficit irrigation. In conclusion, it was recommended that all three practices could be successfully used to alleviate negative impacts under deficit irrigation conditions.

ÖZET

Pamukta su kısıntısı koşullarında bazı tohum ön uygulaması ve yaprak uygulamalarının stresi önleme üzerine etkilerinin araştırılması amaçlanmıştır. Mepiquat klorid (PİX) ile tohum ön uygulaması ve salisilik asit (SA) ile prolinin (PRO) yaprak uygulamaları tarla kapasitesine göre düzenlenen %100, %50 ve %25 sulama konularında test edildi. Bitki boyu, koza sayısı, lif uzunluğu ve lif dayanıklılığı özellikleri sulama seviyesi × uygulama etkileşiminden önemli ölçüde etkilenmiştir. Koza ağırlığı, tohum indeksi, kütlü pamuk verimi ve lif verimi için sulama düzeyi ve uygulamanın etkileri önemliydi. Kısıntılı sulama koşulları (%25) tam sulama ile karşılaştırıldığında, bitki boyu %21,6, koza sayısı %18,1, koza ağırlığı %26,0, tohum indeksi %5,8, kütlü pamuk verimi %25,6 ve lif verimi %24,6 oranında azalmıştır. PİX ile tohum ön uygulama ve PRO'nun yapraktan uygulanması önemli ölçüde daha yüksek kütlü pamuk ve lif verimi sağlarken, SA uygulaması kısıntılı sulama koşulları altında yüksek lif kalitesi parametrelerine sahip olmuştur. PRO'nun lif inceliğini az da olsa artırdığı tespit edilmiştir. SA'nın yapraktan uygulanması, kısıntılı sulama koşullarında klorofil içeriğini (SPAD) ve yaprak alan indeksini (LAI) olumlu yönde etkilemiştir. Sonuç olarak, her üç uygulamanın da kısıntılı sulama koşullarında olumsuz etkileri hafifletmek için başarıyla kullanılabileceği önerilmiştir.

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INTRODUCTION

Water deficiency is one of the most important abiotic stress factors encountered in the cotton cultivation areas of Türkiye and the world. The yield loss caused by drought is estimated to be 50% in the coming years (Mahdi et al., 2020; Anonymous, 2024). Water stress increases the accumulation of reactive oxygen species and adversely affects main processes such as photosynthesis, transpiration, stomatal conductance and growth of cotton (Cinar et al., 2022; Zafar et al., 2023; Hu et al., 2023; Lai et al., 2023). Therefore, it is essential to improve the tolerance of cotton to water deficit conditions for yield and quality stability.

Strategies to overcome water deficit include developing tolerant/resistant varieties and using efficient fertilization and irrigation methods. In addition, exogenous plant growth regulators (PGRs) (Hu et al., 2020; Zhang et al., 2022; Mansour et al., 2023) and seed priming (Nasir et al., 2019; Alam et al., 2021) have been recognized as an effective tool to increase drought tolerance in plants. In order to alleviate water deficiency damage, natural antioxidants such as salicylic acid, proline and mepiquat chloride, and gibberellin inhibitors were focused (Rady et al., 2016; Semida et al., 2017). Mepiquat chloride (1,1-dimethylpiperidinium chloride, MC), an inhibitor of gibberellin biosynthesis, has been used as seed priming in cotton under different stress conditions (Wang et al., 2019; Qi et al., 2023). Mepiquat chloride increases root length and affected cell wall properties by decreasing gibberellin biosynthesis, which governs Ent- kaurene synthesis and thus increases drought tolerance (Iqbal et al., 2005; Gikloo & Elhami, 2012). Salicylic acid with foliar application increases photosynthesis parameters but decreases respiration by preserving the water content of tissues (Silva et al., 2011; Barros et al., 2019). The performance of salicylic acid on yield and fiber quality under water deficit conditions was found to be significant in cotton (Noreen et al., 2015; Mahdi et al., 2020; Heidaria et al., 2022). Proline is an osmoprotectant that plays a vital role in redox balance and ion homeostasis in plants and is a scavenger of free oxygen radicals (Loutfy et al., 2022; Drwish et al., 2023). Water stress increases endogenous proline content in cotton leaves (Yehia & El-Menshawie, 2008; Yehia, 2020; Pawar et al., 2020; Ibrahim et al., 2021; Ibrahim et al., 2023). Foliar application of proline was found to be successful in reducing the adverse effects of drought-induced in the early developmental stages of cotton (Kılınçoğlu et al., 2021) and maize (Ali et al., 2007).

Although foliar applications of osmo-regulators and various seed priming have been addressed to ameliorate the adverse effects of deficit irrigation in many studies, it is noteworthy that these studies were carried out during the early developmental stages of cotton. Therefore, we aimed to investigate the performance of seed priming and foliar applications at the reproductive stages under deficit irrigation in field conditions. In addition, this study provides the opportunity to see the effect of water deficiency on yield and fiber quality traits and the chances of the success of treatments.

MATERIALS and METHODS

Plant materials and growth conditions

This study was planned to investigate seed priming of plant growth regulator, Mepiquat chloride (PIX), and foliar application of some osmoregulators, salicylic acid (SA) and proline (PRO), performance for increasing water scarcity tolerance of cotton (*Gossypium hirsutum* L. cv. BA1010 cultivar). The experiment was conducted using a split-plot design within a Randomized Complete Block Design (RCBD) with three replications. The three irrigation regimes (25, 50, and 100% of soil field capacity) were allocated to the main plots, while PIX, SA, and PRO treatments were assigned to the sub-plots at the Cotton Research Institute experimental station, Nazilli-Aydın in 2023. All plots consisted of four rows with 6-m lengths. The inter-row and intra-row spaces were 0.70 and 0.10 m, respectively.

The climate data for the long term (1983 – 2022) and experimental year (2023) are presented comparatively in Figure 1. It was recorded that average, maximum and minimum temperatures increased, especially in July-September. It is observed that May and June are rainy during the cotton growing season, unlike in the long term.

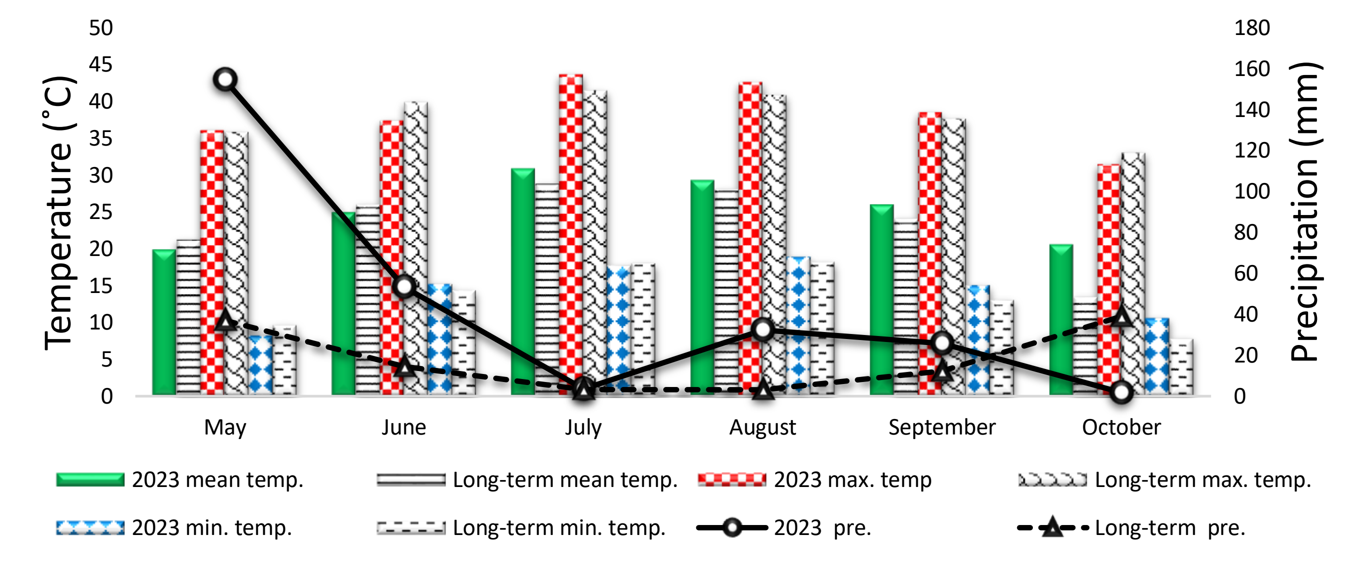

Figure 1. Temperature and precipitation data of the experimental site

Şekil 1. Deneme alanının sıcaklık ve yağış verileri

Some chemical and physical properties of soil layers of the experimental area are given in Table 1. The results of soil analysis showed that the first 60 cm of the experimental area is generally composed of soils with high loam content, low salinity and alkaline pH value. The lime and sodium contents are high, whereas the percentage of organic matter, total nitrogen and potassium contents are low. In addition, phosphorus content is sufficient, and calcium content is moderate.

Table 1. Some chemical and physical properties of the soil layers of the experimental area

Çizelge 1. Deney alanı toprak katmanlarının bazı kimyasal ve fiziksel özellikleri

Depth (cm)	**Field Capacity (%)**	**Fading Point (%)**	**Volume Weight (m^3 kg^{-1})**	**Composition Class**
0 – 30	17.73	6.14	1.67	silty – loam
30 – 60	22.46	12.20	1.43	clay – loam
60 – 90	28.13	19.68	1.48	clay
90 – 120	25.60	11.40	1.48	silty – clay – loam

Treatments

Each treatment was applied on four rows in each replicate of three different irrigation conditions. For priming, at first, cotton seeds were treated at concentrations of 8.0 g L^{-1} of PIX for 5 hours at 25° C (Niakan et al., 2012), and then these seeds were dried in a shady place. These seeds were then sown in 4 rows on May 16th, 2023. The other treatments, SA (200 ppm; Sigma-Aldrich, St. Louis, MO) and PRO (300 ppm) were applied as a foliar spray with a back-mounted pressurized sprayer to completely cover the plant foliage in the morning before sunrise in cool and windless weather conditions after the first application of deficit irrigation at the peak of flowering (August 5th). Control plants were sprayed with water at a dose of 300 L ha^{-1}.

Irrigations

Irrigation water was taken from the Cotton Research Institute water tank with the help of a water pump and brought to the experimental area with 63 mm outer diameter PVC pipes. Polyethylene (PE) laterals with an outer diameter of 16 mm were laid in the experimental plots, with one lateral per row in each plot. Lateral drip irrigation pipes had a 2 L h^{-1} flow rate, and dripper spacing was selected as 25 cm. Valves with a diameter of 16 mm were installed at each lateral line to ensure controlled irrigation (İsotçu & Başal, 2016). Irrigation was stopped when 10% of the cotton bolls opened (Ektiren & Değirmenci, 2018).

The first irrigation started when moisture in the 0-90 cm soil depth dropped to 50%, and enough irrigation water was applied to bring the available water to the field capacity. According to the subjects of the experiment, full irrigation plots were given all of the water required to reach the field capacity (100%), while ½ (50%) and ¼ of this water (25%) were given to the plots with deficit irrigation. When the irrigation time of the first irrigation according to the determined criterion came, the amount of water that would bring each soil layer to the field capacity was calculated using the moisture values obtained from the observation plots containing the full irrigation (100%) subject. The irrigation water calculated separately for 0-30 cm, 30-60 cm and 60-90 cm soil layers was applied to each plot by drip irrigation method. Monitoring of soil moisture in the experimental plots; soil samples taken from 0-30 cm, 30-60 cm, and 60-90 cm soil layers were placed in aluminium containers to be tared, and their wet weights were weighed, then their dry weights were weighed after drying in an oven at 105 °C for 24 hours. Thus, the moisture content of the soil was calculated as % by using the formula PW (moisture content) = (Wet – Tare) - (Dry – Tare) / (Dry – Tare) × 100. The amount of water to be given to the soil layers at 0-30, 30-60 and 60-90 cm depths where soil samples were taken was calculated using the following equation (Güngör et al., 1996).

$$d = ((FC - AW) / 100) \times Ɣt \times DP \qquad \textbf{Eq.(1)}$$

In the equation; d: Amount of irrigation water required to bring the available soil moisture to field capacity (mm), FC: Field capacity (%), AW: Available soil moisture (%), Ɣt: Volume weight of soil (g cm^{-3}), DP: Soil depth (mm).

Dağdelen et al. (2005), according to the results of their research regarding cotton irrigated with drip irrigation in the Aydın region, the highest cotton yield was obtained from the subject where 100% of the evaporation amount from the class A evaporation container was applied at 8-day irrigation intervals. For this reason, the Pan evaporation coefficients considered for irrigation were determined based on the results of scientific research conducted in the region, and subsequent irrigations were made at 8-day intervals.

In the calculation of the amount of irrigation water, according to the principles stated by Kanber (1984), the open-water surface evaporation method and the following equation were used.

$$V = P \times A \times E_{pan} \times kpc \qquad \textbf{Eq.(2)}$$

In the equation, V is the irrigation water applied to the plot (L), A is the plot area (m^2), E_{pan} is the cumulative Class A Pan evaporation amount (mm) at the 8-day irrigation interval, kpc is the selected pan coefficient, P is the % wetted area. In the study, 3 different irrigation levels kpc-1: 1.00 (full water-100%), kpc-2: 0.50 (deficit irrigation-50%) and kpc-3: 0.25 (deficit irrigation-25%) were examined. In this study, according to Sezen et al. (2011), the percentage of wetted area value (P) was taken as 100% for hoe crops planted in rows. In the experiment, the first irrigation was made when 50% of the available water-holding capacity of the plant at the effective root depth (90 cm) was consumed, and irrigation water was applied to the plots to cover the moisture deficit. Successive irrigations were made by considering the total evaporation values in the 8-day irrigation interval.

A class A evaporation container was used to measure the daily evaporation amount. For this purpose, the daily evaporation amount was determined by measuring at 09:00 every day by using a micrometer caliper to make up the missing water (Güngör & Yıldırım, 1987). The amount of water applied during the experiment and irrigation dates are given in Table 2.

Table 2. Amount of irrigation water applied to full and deficit irrigation plots per unit area
Çizelge 2. Birim alan başına tam ve kısıntılı sulama yapılan parsellere uygulanan sulama suyu miktarı

Irrigation Date	Amount of Water Applied		
	Full Irrigation (100%)	**Deficit Irrigation (50%)**	**Deficit Irrigation (25%)**
25.07.2023	26.13 m^3	26.13 m^3	26.13 m^3
02.08.2023	56.00 m^3	28.00 m^3	14.00 m^3
10.08.2023	64.83 m^3	32.40 m^3	16.20 m^3
18.08.2023	66.17 m^3	33.18 m^3	16.54 m^3
26.08.2023	61.17 m^3	30.58 m^3	15.29 m^3
04.09.2023	51.81 m^3	25.90 m^3	12.95 m^3
Total	***326.11 m^3***	***176.19 m^3***	***101.11 m^3***

Data collection

Physiological measurements were recorded in both flowering and boll opening periods. For estimating the relative water content (RLWC %), the method of Hayat et al. (2007) was used with the following formula: RLWC (%) = [(FW − DW) / (TW − DW)] × 100. Chlorophyll content (SPAD) was measured on ten randomly selected plants in each plot with a “SPAD 502 Plus Chlorophyll Meter (Konica Minolta Company, Japan)”. The newly opened and fully expanded top-fifth leaves of the plants were used for the measurements (Johnson & Sounders, 2003; Xie et al., 2016). The leaf area index (LAI) was determined by measuring three times per plot with an “AccuPAR model LP-80 ceptometer (METER Group, USA)”. Then, RLWC, SPAD and LAI values were averaged for statistical analysis.

Plant height (cm; PH), number of open bolls plant^{-1} (BN), 100-seed weight (g; SI), boll weight (g; BW), ginning out-turn (%; GOT) and seed cotton yield (t ha^{-1}; SCY), lint yield (t ha^{-1}; LY) were recorded at randomly selected ten plants at the harvesting time.

Fiber quality traits such as fiber length (mm), fiber fineness (mic.) and fiber strength (g tex^{-1}) were detected using Uster® High Volume Instrument (HVI) 1000 (USTER Technologies, Inc., Knoxville, TN, USA) at a 50 g fiber sample.

Data analysis

The recorded data were subjected to analysis of variance (Steel et al., 1997) according to the split-plot design in RCBD using the ‘agricolae’ package (Mendiburu & Mendiburu 2019) in R open-source, free software. When a main effect or interaction effect was significant ($p \leq 0.05$), the least significant difference (LSD) test was used to compare treatment means.

RESULTS and DISCUSSIONS

The interaction between irrigation levels and treatments for plant height, boll number, fiber length and fiber strength were significant (Tables 3 and 5). In full irrigation plot, SA and PRO treatments increased plant height compared with PIX and control, whereas non-significant differences among treatments were recorded in deficit irrigation (25%) (Table 4). Stunting in plant height is one of the most important morphological traits affected by abiotic stresses such as drought. Our results contradict the findings of Noreen et al. (2015) and Aziz et al. (2018), who reported that SA increased plant height under water-limited conditions. However, the same researchers emphasized that the varieties used in the study reacted differently to chemical treatments, application phases and frequency under drought conditions.

Table 3. ANOVA for yield components and yield

Çizelge 3. Verim ve verim bileşenleri için varyans analizi

Source of Variation	df	PH	BN	BW	GOT	SI	SCY	LY
Replications	2	4.30	12.19	0.34	0.54	0.01	0.03	0.01
Water Regime (WR)	2	981.65**	39.29**	6.77**	2.13*	1.17*	12.59**	2.17**
Error-1	4	0.88	2.01	0.35	0.19	0.06	0.07	0.01
Treatment (T)	3	77.39**	45.80**	1.09**	0.04	0.45**	1.20**	0.24**
WR × T	6	25.97**	5.94**	0.21	0.52	0.11	0.12	0.02
Error-2	18	0.66	1.34	0.14	0.29	0.05	0.10	0.03
General	35							

*: $p≤0.05$; **: $p≤0.01$. PH; Plant height (cm), BN; The number of open bolls plant^{-1}, BW; Boll weight (g), GOT; Ginning out-turn (%;), SI; 100-seed weight (g), SCY; Seed cotton yield (t ha^{-1}), LY; Lint yield (t ha^{-1})

The effect of PRO on boll weight was positive and significant at all three irrigation levels. The performance of SA followed PRO, and all three treatments produced more bolls than the control (Table 4). Similarly, the highest boll number values, seed cotton yield and lint yield under water stress were recorded in PRO treatment plots, while seed index values were found to increase in SA-treated plots. It has been emphasized in many studies that osmoregulatory applications improve yield and yield components in crops under drought (Ali and Ashraf, 2011; Noreen et al., 2015; Zhang et al., 2014).

Control plots exhibited the lowest fiber length values at all three irrigation levels, while SA and PRO had the highest lengths. Deficit irrigation was emphasized to reduce significantly fiber length (Lascano & Hicks, 1999; Balkcom et al., 2006; Başal et al., 2009), fiber fineness and fiber strength (Wang et al., 2016; Rehman & Farooq, 2019; Zhao et al., 2019). SA had the highest fiber strength values in full irrigation and 25% deficit irrigation plots. All three treatments had a significant positive effect on fiber length, especially in 25% irrigation. Exogenous applications of SA and PRO have been reported to reduce the adverse effects of drought by regulating osmotic pressure in plants (Zahoor et al., 2017; Tanveer et al., 2019; Hu et al., 2020).

Table 4. Mean values for yield components and yield

Çizelge 4. Verim ve verim bileşenlerine ilişkin ortalama değerler

Water Regime	Treatments	PH	BN	BW	GOT	SI	SCY	LY
100%	Control	78.8 c	17.5 cd	5.73	43.6	10.4	7.33	3.19
	PIX	82.0 b	18.5 de	5.37	43.7	10.0	8.36	3.65
	SA	85.5 a	20.0 bc	5.47	43.9	10.6	7.63	3.35
	PRO	85.5 a	23.5 a	6.47	43.9	10.3	8.29	3.64
	Ave.	83.0	19.9	5.76 A	43.7 B	10.3 A	7.90 A	3.46 A
50%	Control	64.3 g	15.8 e-g	4.63	44.2	9.6	6.36	2.81
	PIX	70.7 e	16.5 ef	5.03	44.8	9.8	6.66	2.98
	SA	70.9 e	19.7 b	5.23	44.7	10.1	6.44	2.88
	PRO	74.8 d	20.7 bc	5.43	44.2	10.0	7.22	3.19
	Ave.	71.4	18.2	5.08 B	44.5 A	9.9 B	6.67 B	2.97 B
25%	Control	63.8 f	14.3 g	3.77	44.9	9.3	5.63	2.53
	PIX	63.5 f	15.5 fg	4.27	44.4	9.8	5.83	2.59
	SA	63.7 f	15.7 fg	4.33	43.8	10.0	5.76	2.52
	PRO	64.3 f	20.1 bc	4.67	44.7	9.8	6.26	2.80
	Ave.	65.1	16.3	4.26 C	44.5 A	9.7 B	5.87 C	2.61 C

Table 4 (continued). Mean values for yield components and yield

Çizelge 4 (devamı). Verim ve verim bileşenlerine ilişkin ortalama değerler

Tre. Ave.	Control	70.0 b	16.2 b	4.71 b	44.2	9.8 c	6.44 b	2.84 b
	PIX	75.5 a	16.5 b	4.89 b	44.3	9.9 bc	6.95 a	3.07 a
	SA	73.3 a	18.6 a	5.01 b	44.1	10.3 a	6.61 b	2.92 b
	PRO	74.9 a	21.1 a	5.52 a	44.3	10.1 ab	7.26 a	3.21 a

When the interaction was significant, means not followed by the same letter(s) in the same column are significantly different. Upper- and lower-case letters were used to compare water regimes and seed priming treatments among themselves, respectively. PH; Plant height (cm), BN; The number of open bolls plant^{-1}, SI; 100-seed weight (g), BW; Boll weight (g), GOT; Ginning out-turn (%;), SCY; Seed cotton yield (t ha^{-1}), LY; Lint yield (t ha^{-1})

Significant differences among irrigation levels for plant height, boll number, boll weight, ginning out-turn, seed index, seed cotton yield and lint yield indicated that deficit irrigation is an important abiotic stress factor that negatively affects yield and yield components (Xiao et al. 2009; Loutfy et al. 2012). As the irrigation level decreased from full irrigation to deficit irrigation (25%), plant height decreased by 21.6%, boll number by 18.1%, boll weight by 26.0%, seed index by 5.8%, seed cotton yield by 25.6% and lint yield by 24.6% (Table 4). Much higher rates of decrease were determined for boll number, weight and yield as a result of drought stress (Zhu et al., 2023; Li et al., 2023).

The significant differences among treatments indicated that PIX, SA and PRO could alleviate the adverse effects of moderate (50%) and severe (25%) irrigation deficiency on plant height, boll number, boll weight, seed index, seed cotton and lint yield, fiber length and fiber strength. PRO and PIX significantly positively affected seed cotton yield and, consequently, lint yield under both control and water stress conditions, consistent with Hamani et al. (2021) and Shafiq et al. (2021). Similarly, PRO and SA significantly increased boll number, weight, and seed index. Although not significant, it is noteworthy that the coarsest fibers were detected in the PRO-treated plots (Table 6). The foliar spray of proline was proved effective in alleviating the adverse effects of drought stress in cotton (Noreen et al., 2013; Ullah et al., 2017). PIX mitigate the negative impact of drought by increasing leaf and root thickness and dry matter, especially by inhibiting gibberellin synthesis (Shahrbano et al., 2022).

Table 5. ANOVA for physiological and fiber quality traits

Çizelge 5. Fizyolojik ve lif kalite özellikleri için varyans analizi

Source of Variation	**df**	**SPAD**	**LAI**	**RLWC**	**FL**	**FF**	**FS**
Replications	2	60.74	0.13	11.13	0.18	0.04	0.66
Water Regime (WR)	2	79.68	1.94*	135.34*	1.31	0.02	5.88
Error-1	4	22.78	0.27	10.47	0.33	0.13	1.02
Treatment (T)	3	45.18*	0.10	6.34	0.62*	0.05	4.38*
WR × T	6	20.88	0.19	8.93	1.04**	0.01	4.98*
Error-2	18	9.40	0.16	8.74	0.14	0.05	1.38
General	35						

*: $p \leq 0.05$; **: $p \leq 0.01$. SPAD; Soil plant analysis development chlorophyll meter, LAI; Leaf area index (cm^2), RLWC; Relative leaf water content (%), FL; Fiber length (mm), FF; Fiber fineness (micronaire), FS; Fiber strength (g tex^{-1}).

SPAD, LAI and RLWC, which are the physio-morphological traits most likely to react to water deficit, were evaluated during the boll opening period. The significant differences among irrigation levels for LAI and RLWC indicated that deficit irrigation adversely affected leaf area and water holding capacity (Table 5). LAI values statistically decreased by 15.36% and 22.15% in 50% and 25% irrigation plots, respectively, while these reductions for RLWC were 6.84% and 10.51% (Table 6). It was emphasized that decreased soil water content negatively affected RLWC and LAI, necessary for high photosynthetic capacity in cotton (Gadallah, 2000; Ashraf et al., 2020). According to our results, treatments increased SPAD value in all irrigation levels, and SA had a significant performance. It was emphasized that SA, which has a defensive mechanism under stress conditions, increases the chlorophyll content in cotton (El-Beltagi et al., 2017; Heidari et al., 2022), wheat (Khalvandi et al., 2021), okra (Ayub et al., 2020), onion (Semida et al., 2020). Our results indicate that SA decreases the amount of chlorophyll but increases the amount of carotenoid, Anandhi and Ramanujam, 1997; Moharekar et al., 2003) is contradictory. It was concluded that the effect of SA on chlorophyll content and leaf characteristics differed according to stress conditions. In addition, PIX and seed priming plots showed insignificant increases in RWLC. It has been emphasized in many studies that seed priming with PIX under stress conditions positively affects growth parameters, especially during germination and seedling development (Zheng & Liu, 2001; Duan & Tian, 2011; Wang et al., 2019; Wang et al., 2021). Seed priming with PIX decreases leaf phenolic compounds and gibberellin content in roots but increases abscisic acid content and provides favourable performance under drought conditions (Shahrbanoet al., 2022). In fact, PIX is an important growth regulator that regulates cotton growth and increases productivity (Tian et al., 2008; Zhang et al., 2021).

Table 6. Mean values for physiological and fiber quality traits

Çizelge 6. Fizyolojik ve lif kalite özelliklerine ilişkin ortalama değerler

Water Regime	Treatments	SPAD	LAI	RLWC	FL	FF	FS
100%	Control	46.03	3.47	63.10	29.1 de	5.06	30.3 bc
	PIX	49.97	3.57	64.40	29.4 cd	5.14	29.0 cd
	SA	55.23	3.40	62.17	30.2 a	5.16	32.9 a
	PRO	47.07	3.30	62.33	29.8 a-c	5.23	30.0 b-d
	Ave.	*49.58*	*3.43 A*	*63.00 A*	29.6	5.15	30.6
50%	Control	52.47	2.67	59.83	29.2 c-e	5.14	30.2 bc
	PIX	51.50	3.00	59.90	29.3 c-e	5.10	29.9 b-d
	SA	56.13	3.07	60.47	29.8 a-c	5.14	28.5 cd
	PRO	57.57	2.63	56.57	29.6 b-d	5.38	28.0 d
	Ave.	*54.42*	*2.84 B*	*59.19 B*	29.4	5.19	29.2
25%	Control	47.83	2.70	54.47	28.8 ef	5.25	28.9 cd
	PIX	52.20	2.23	59.07	29.8 ac	5.23	29.9 b-d
	SA	51.37	2.93	55.60	30.1 ab	5.13	31.2 ab
	PRO	50.47	2.80	56.40	29.5 b-d	5.28	29.5 b-d
	Ave.	*50.47*	*2.67 B*	*56.38 B*	29.3	5.23	29.9
Treatments Ave.	Control	48.78 b	2.94	59.13	29.0 b	5.15	29.8 b
	PIX	51.22 ab	2.93	60.96	29.5 a	5.16	29.6 b
	SA	54.24 a	3.13	59.41	29.5 a	5.14	30.8 a
	PRO	51.70 ab	2.91	58.43	29.6 a	5.30	29.2 c

When the interaction was significant, means not followed by the same letter(s) in the same column are significantly different. Upper- and lower-case letters were used to compare water regimes and seed priming treatments among themselves, respectively. SPAD; Soil plant analysis development chlorophyll meter, LAI; Leaf area index (cm^2), RLWC; Relative leaf water content (%), FL; Fiber length (mm), FF; Fiber fineness (micronaire), FS; Fiber strength (g tex^{-1}).

Similar to the results of many studies, the effect of water deficit on yield, yield components and physio-morphological characteristics was confirmed in this study. Seed treatment with mepiquat chloride and foliar application of salicylic acid and proline alleviated the adverse effects of water deficit. In addition, the application of salicylic acid had favourable fibre quality parameters under deficit irrigation conditions.

STATEMENT OF CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTIONS

The authors declare that their contributions are equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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