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THE EFFECT OF FOLIC AND SALICYLIC ACID ON GROWTH OF COTTON (*Gossypium hirsutum* L.) UNDER DROUGHT CONDITIONS

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ABSTRACT:

This study was performed between February and August 2023 at a local farm affiliated with the Biology Department, College of Science, University of Zakho, Kurdistan Region, Iraq. It aimed to assess the influence of drought stress and the foliar application of salicylic and folic acid on certain growth parameters of two cotton cultivars (MAY 505 and MAY 455). A factorial experiment in the form of randomized complete block design (RCBD) was employed to evaluate the response of growth parameters of cotton cultivars to three concentrations of salicylic acid (0, 1, and 2 mM) and folic acid (0, 5, and 10 mM), either individually or combined, under different irrigation regimes. Additionally, the two cultivars were subjected to three different irrigation regimes: continuous irrigation (Ci), 10-day drought, and 15-day drought. The findings revealed significant differences in shoot length, branch number, longest branch length, leaf surface area, and flower number among cultivars, drought treatments, and spray treatments. Cultivar MAY505 consistently outperformed MAY455 in terms of growth parameters. Moderate drought stress (10 days) slightly enhanced shoot length, while prolonged drought significantly reduced general growth. Foliar application of Salicylic acid (SA) and Folic acid (FA), particularly the combination of 2 mM SA + 10 mM FA, significantly increased shoot length, branch number, and flower number in both cultivars. However, the response to folic and salicylic acids varied between cultivars. These findings suggest that cultivar selection and appropriate foliar spray applications can mitigate the adverse effects of drought stress on cotton plant growth and yield. Further research is needed to elucidate the underlying physiological mechanisms responsible for these responses and to optimize the use of foliar sprays for sustainable cotton production under water-limited conditions.

KEYWORDS: Cotton, Drought, Salicylic Acid, Folic Acid, Shoot Length.

1. INTRODUCTION

Plant growth and development are highly affected by abiotic stress. One of the most prominent environmental factors is drought, which can restrict plant growth and productivity (Tas and Tas, 2007). An estimated 50% reduction in crop growth and harvest occurred globally due to water scarcity. Water scarcity limits photosynthesis due to reduced stomatal conductance, leading to decreased carbon assimilation and energy production. It also causes osmotic stress, impairing nutrient uptake and cellular turgor, which stunts root and shoot development (Lamaouri *et al*., 2018). In addition, processes such as seed germination, aerial growth, and flowering stage are adversely influenced by drought conditions (Li *et al,* 2023). therefore, the application of growth regulators can lessen the negative effects of drought on plant growth.

Cotton, a key fiber and oil production crop, is widely cultivated in temperate regions worldwide. Cotton exhibits an unpredictable development pattern and is susceptible to environmental irregularities (Rehman and Farooq, 2019). Cotton, originating from tropical and subtropical climates, exhibits considerable drought tolerance during vegetative growth; nonetheless, its reproductive growth is significantly susceptible to drought stress (Iqbal *et al.,* 2017, Rehman *et al*., 2022; Niu *et al*, 2018; Wang *et al.,* 2016a). The growth and development of cotton range from planting to emergence to branch formation to boll production (Bauer *et al.,* 2012). Well irrigation is vital for plant establishment and better yield (Zonta *et al*., 2017). However, water deficit impairs the overall plant growth and development and fruiting stage, causing abortion of existing bolls and reducing yield.

Plant growth regulators such as folic acid (FA) and salicylic acid (SA) can mitigate plant growth under harsh environmental conditions. FA has an auxin-like function enhancing aerial growth and yield, as well as its quality in many plants. Even under environmental conditions, FA has shown an effective contributor in capturing free radicals during the processes of respiration and photosynthesis (Hassan *et al*., 2016) and improved the growth of coriander (*Coriandrum sativum* L.) under drought stress (Khan *et al.,* 2022). It has been documented that snap bean crops treated with folic acid showed a decrease in growth and leaf-relative water content under drought stress (Ibrahim *et al*., 2020). Even under Cadmium stress, FA showed a significant tolerance in stimulating seed germination and emergence of seedlings and increased shoot length when applied at moderate doses (Sahito *et al*., 2024). Furthermore, under salinity, FA has been shown to minimize the detrimental effects of salt stress on seedling growth and leaf structure (Zhang *et al*., 2022). SA has reportedly been documented for its significant role in improving plant growth. It is well-studied as a plant growth regulator such as enhancing the growth of *Zea mays,* sesame, and sunflower crops under drought stress (El-BialLy *et al.,* 2022; Rehman *et al*, 2022; Ahmed and Ali, 2024). Under water-deficit conditions, foliar spray of SA can withstand such conditions by regulating biochemical pathways and thus mediating the growth and development of a plant (Das *et al,* 2023). On this occasion, physiological aspects are regulated for better morphological features. In water-limiting areas, choosing a variety resistant to drought with better growth performance is better than harnessing

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chemicals and growth regulators to tolerate harsh environmental conditions.

Plants adapt to a changing environment by changing their morpho-physiological aspects. Therefore, recent studies generally focus on how plants physiologically respond to various drought regimes (Kumar *et al*., 2018; Xu *et al*., 2010). Less attention is paid to plant morphology, therefore, this study shed light on morphological changes. This research studies the growth parameters in two cotton cultivars with foliar application of folic and salicylic acids under drought stress. The studied parameters include; shoot length (LS), leaf surface area (LSA), flowers per plant, branches per plant, and the longest branch of cotton plants under various drought regimes.

2. MATERIALS AND METHODS

Location of the Study:

The research was undertaken at the College of Science, University of Zakho, located in Zakho District, Duhok Governorate. This district is situated in the northwestern part of the governorate at a geographical coordinate of 37.1505° North, 42.6727° East, and an elevation of 440 meters above sea level as shown in Figure (1). Zakho has a Mediterranean climate with hot, dry summers and cool, wet winters. The planting season was conducted in the spring of 2023 (February to August); the area of the study is a plain near Bekher mountain in Zakho. The climatic variables during the planting season, such as monthly rainfall, ranged from 40-150 mm, the maximum temperature ranged from 22-34°C, the minimum temperature ranged from 6-14°C, and the monthly humidity ranged from 55- 70% (Zakho meteorological station, 2023).

The soil of the experimental field was analyzed to measure the physical and chemical properties of the soil. According to the analysis, the soil texture of the studied area is sandy loam, with a pH of 8.07, calcium carbonate ($CaCO3$) of 22.34%, electrical conductivity (EC) of 0.268 dSm^{-1}, and organic matter of 0.98%. The available nitrogen is 68 mg Kg^{-1}, available potassium is 4.30 mg/Kg^{-1}, and available phosphorous is 4.22 mg Kg^{-1}. According to taxonomical classification, the soil of the studied area is classified as vertisol.

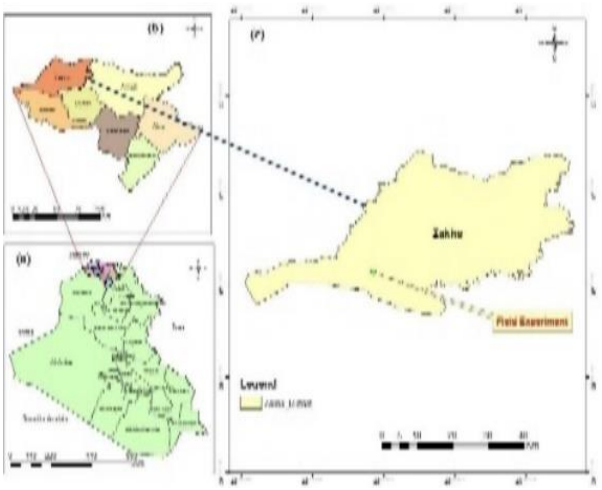

Figure 1: The location of the study.

Field Preparation and Experimental Design:

The experimental field was plowed in mid-February 2023 and left to dry for 15 days. The soil was then harrowed and divided into 3 blocks using the Randomized Complete Block Design (RCBD), and a factorial experiment was used. Each cultivar was planted in 3 blocks (Block1, Block2, and Block3). There were three factors in this study, namely; Folic acid, salicylic acid as a factor in addition to drought, and cultivars. Three concentrations of folic acid (0 mM, 5 mM, 10 mM) and salicylic acid (0 mM, 1 mM, 2 mM) were prepared and applied as nine doses (0 mM, 5 mM, 10 mM, 1 mM, 2 mM, 5Mm + 1mM, 5mM + 2mM, 10mM + 1mM, and 10mM + 2mM) along with three water stress levels (continuous irrigation, 10 days without irrigation, and 15 days without irrigation) see Figure (2). These treatments were applied to two cotton cultivars (May505 and May455) to study their impact on some vegetative growth parameters. The entire experimental unit was 162 experimental units, and each cultivar had 81 experimental units.

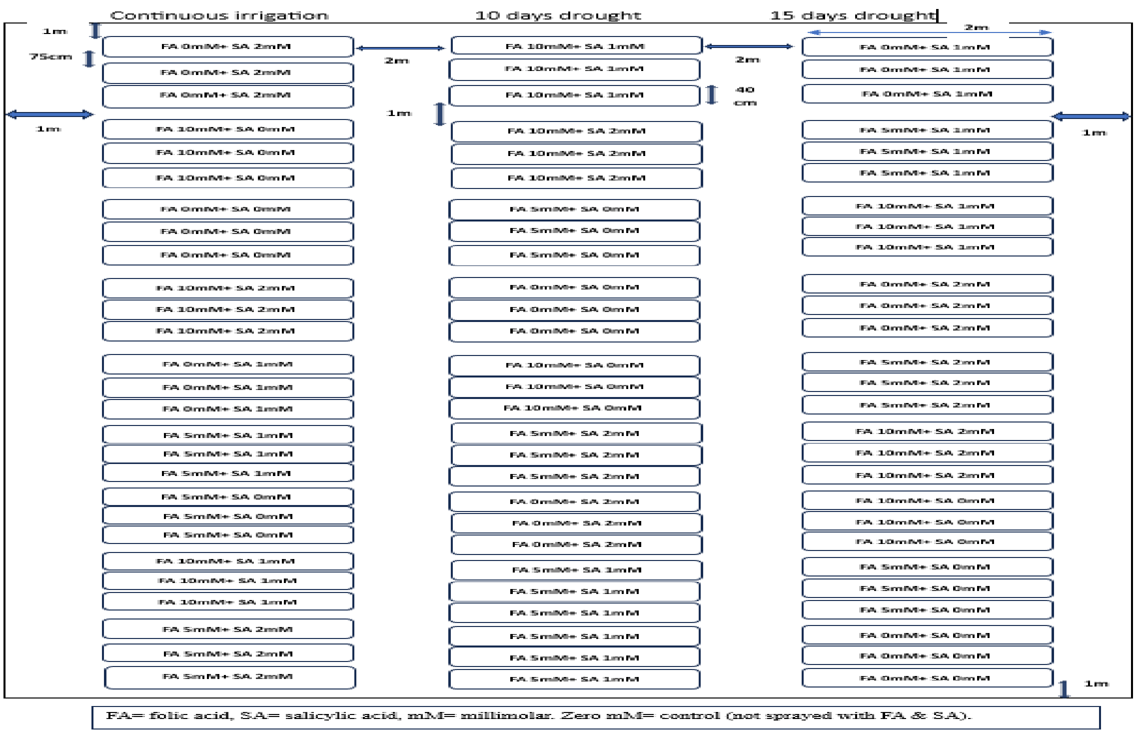

Figure 2: Layout of the field experiment.

Seed Germination and Treatment Application:

The cotton seeds were soaked in water overnight. The seeds were then sown in holes 1.5 inches deep. A distance of 75cm was left between each row, and the plants were 30cm apart. Each row was 2m long, and there was 2m of distance between each block. Then, when the plant reached the growth stage just before flowering, FA and SA were applied directly to the leaf surface via foliar spraying. To reduce water loss, foliar treatments were applied at night during two specific growth stages: when the seedlings had four leaves and at the beginning of flowering.

Growth Parameters:

The growth parameters examined in this study included shoot length (SL), the number of branches per plant, the length of the longest branch, leaf surface area (LSA), and the number of flowers per plant. The length of the main stem, branch lengths, and the longest branches were measured using a measuring tape in centimeters (cm). Leaf surface area was calculated by multiplying the width (cm) by the length (cm) and then multiplying the result by 0.7, which is the conversion factor specific to cotton plants (Raju *et al.,* 1972).

Statistical Analysis:

In this study, the effects of folic acid and salicylic acid on the growth of two cotton cultivars under three drought periods were statistically analyzed using SPSS 2019 software. The experimental design was a factorial arrangement, and the data were subjected to a two-way analysis of variance (ANOVA) to evaluate the main effects and interactions between the factors, including cultivar type, drought stress levels, and hormone treatments. The Duncan multiple range test (Duncan, 1955) was employed as a post hoc analysis to determine significant differences between the means of the measured parameters at a 95% confidence level ($p< 0.05$). The significant differences among treatment means were indicated by lowercase letters. This rigorous statistical approach ensured robust interpretation of the data, providing insights into the differential responses of the cotton cultivars to hormonal treatments under varying drought conditions.

3. RESULTS

Shoot Length (Cm):

The main effect of drought periods on shoot length (SL) showed significant changes in both cultivars ($P<0.001$) (Table 1). The overall SL was the highest in plants undergoing continuous irrigation and 10 days of drought compared to 15 days of drought-irrigated plants, with mean values of 93.24 cm and 92.76 cm long, respectively (Figure 4). The cultivar effect, on the other hand, showed significant differences (P < 0.001) in their values, where cultivar MAY 505 showed the highest length at (95.30 cm) long as compared to MAY 455 at (82.22 cm) long (Table 1 and Figure 3A).

Table 1: Summary of ANOVAs (F – value, and P – Value) of the growth parameters.

	Parameters	Shoot length (cm)	Leaf surface area (cm^2)	Flowers/plant	Branches/plant	Longest branch/plants (cm)
Cultivars (C)	$F_{1,106}$	59.28	41.4	32.14	246.78	197.4
	P	<0.001	<0.001	<0.001	<0.001	<0.001
Drought Periods (DP)	$F_{2,106}$	24.95	164.4	10.54	11.88	11.45
	P	<0.001	<0.001	<0.001	<0.001	<0.001
Treatments T	$F_{8,106}$	4.12	22.57	2.08	1.52	2.87
	P	<0.001	<0.001	<0.045	0.16	0.006
C × DP	$F_{2,106}$	1.56	0.001	3.51	10.39	0.06
	P	0.216	0.987	0.033	<0.001	0.939
C × T	$F_{8,106}$	2.57	0.62	1.52	1.92	2.87
	P	<0.009	0.757	0.16	0.064	0.006
DP × T	$F_{16,106}$	2.05	38.06	0.9	1.58	1.83
	P	0.016	<0.001	0.576	0.086	<0.036
C × DP × T	$F_{16,106}$	2.52	0.95	0.87	4.03	2.8
	P	0.003	0.518	0.599	<0.001	<0.001

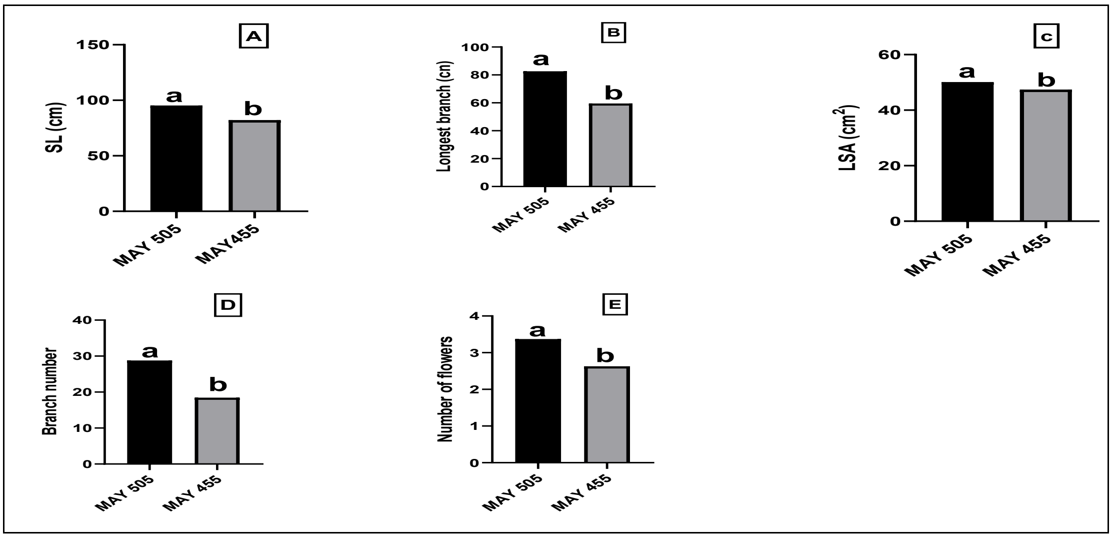

Figure 3: shows the effect of the cultivar on growth parameters. Bars denoted by different letters are significantly different at p < 0.05.

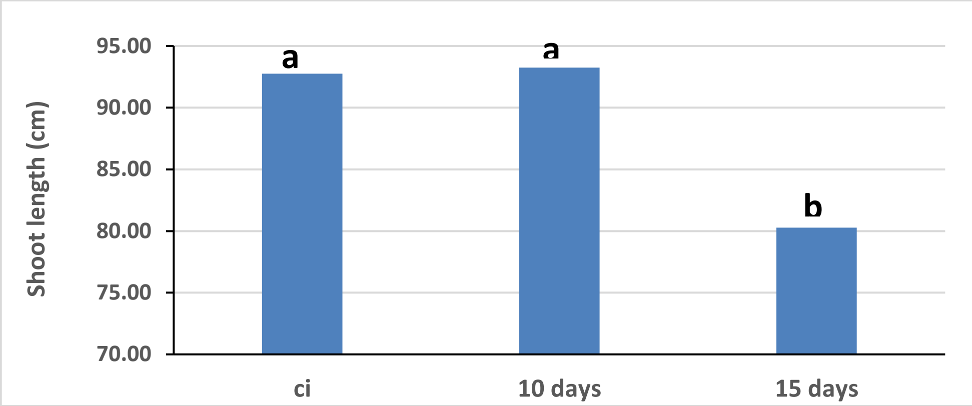

Figure 4: The effect of drought periods on shoot length. Bars denoted by different letters are significantly different at p < 0.05.

Significant variations (*P<0.001*) were observed in spraying treatments applied to both cultivars from the data obtained (Table 1). In this regard, the application of 10 mM FA recorded the highest SL at (95 cm) long compared to 1 mM SA, 5 mM FA, and control. The second most effective treatment was the application of 2 mM SA recording 93 cm long plants. In the meantime, plants treated with 1 mM SA showed the shortest length at 80.62 cm (Figure 5).

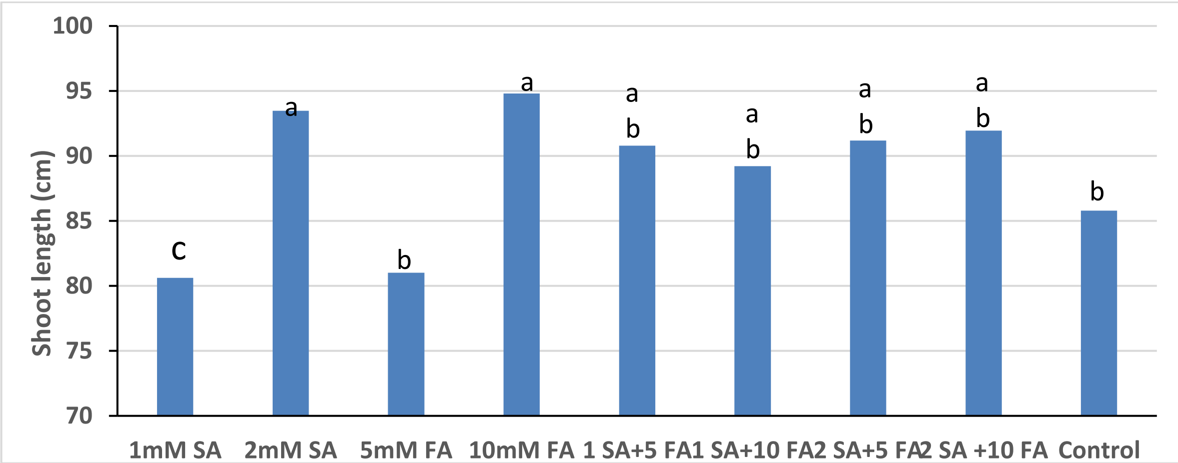

Figure 5: The effect of treatments on shoot length. Bars denoted by different letter are significantly different at p < 0.05.

The interaction effect of cultivar vs drought periods was nonsignificant (P > 0.05). However, the interactive effect between cultivar and treatment showed variations in shoot length (*P=0.009*). This interaction indicated that in most cases the SL was significantly higher with cultivar MAY 505, except with treatments 2mM SA, 2mM + 5 FA, and 2mM SA + 10 FA) (see Figure 6). Further variations were observed in the interaction between drought vs treatment which had a significant effect on shoot length (*P=0.016*). This interaction explains that in most of the cases, under 10 days drought period the application of plant regulators increased SL particularly compared to 15 days drought period, while under 10 days drought period the application of regulator 5mM FA reduced the SL (Table 2). Furthermore, with no regulator application, the SL was significantly reduced with increasing drought periods.

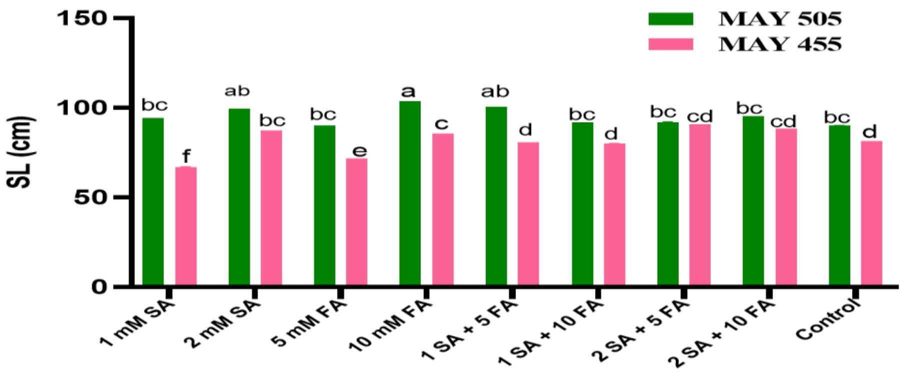

Figure 6: illustrates the interaction between the cultivars and treatments. Bars denoted different letter are significantly different at p < 0.05.

Table 2: The interaction effect of drought vs treatment on shoot length.

Drought periods	Treatments								
	1mM SA	2mM SA	5mM FA	10mM FA	1 SA+5 FA	1 SA+10 FA	2 SA+5 FA	2 SA +10 FA	Control
Continuous	83.11 Dg	97.22 ad	90.77 af	94.76 ad	93.60 ae	92.15 af	91.22 af	97.2 Ad	94.80 ad
10 days	92.95 Ae	100.2 ab	72.72 gh	100.11 ab	99.63 ac	89.72 af	104.48 a	94.75 ad	84.67 cg
15 days	65.8 H	83.03 dg	79.56 eh	89.53 af	79.11 eh	85.81 bg	77.86 fh	83.87 dg	77.9 fh

Mean having different letters are significantly different at P < 0.05.

The effect of the triple interaction of cultivar, drought, and treatment showed a significant influence on shoot length (*P=0.003*). MAY505 generally produced higher plants than MAY455 under the same growing conditions. Plants of cultivar MAY505, which sprayed with 2mM SA, recorded the highest plant length at (107cm) under a continuous irrigation regime. Under 10 and 15 days of drought, the combined treatment of 1mM SA+ 5mM FA scored the highest plants at (110 cm) and (98.46 cm) respectively (Table 3). On the other hand, cultivar MAY455, under continuous irrigation, the plants sprayed with 2mM SA+10mM FA scored the highest shoot length by (93.4 cm). However, under mild drought (10 days of drought), plants that were sprayed with 1mM SA+ 5mM FA recorded the highest shoot length of (99.76 cm). The shoot length decreased with an increased drought period. Therefore, under 15 days of drought, a significant reduction was observed in shoot length. Plant sprayed with 2mM SA+ 5mM FA recorded the highest SL at (84.93 cm) while plant sprayed with 1mM SA+ 5 mM FA had the least impact on shoot length at (59.76 cm)

Table 3: The triple interaction effect of drought, cultivar, and treatment on shoot length.

Cultivar	Drought period	Treatment								
		Salicylic acid		Folic acid		Salicylic acid + Folic Acid				Control
		1mM	2mM	5mM	10mM	1mM+5 mM	1mM+1 0mM	2mM+5 mM	2mM+1 0mM	
May 505	ci	93.46 aj	107 ad	90.33 aj	106.46 ad	93.73 aj	95.26 ai	92.4 aj	101 af	95.33 ai
	10 days	97.6 ah	103.86 ae	93.6 aj	107.8 ac	110 a	87.8 bj	109.2 ab	102.53 ae	91.8 aj
	15 days	92.06 aj	87.8 bj	86.66 cj	97.13 ah	98.46 ah	92.76 aj	73.46 ik	82.8 ej	82.8 ej
May 455	ci	72.76 jk	87.43 bj	91.2 aj	83.06 ej	93.46 aj	89.03 aj	90.03 aj	93.4 aj	94.26 aj
	10 days	88.3 aj	96.5 ah	51.83 lm	92.41 aj	89.26 aj	91.63 aj	99.76 ag	86.96 cj	77.53 hk
	15 days	39.54 m	78.26 gj	72.46 jk	81.93 ej	59.76 kl	78.86 fj	82.26 ej	84.93 dj	73 jk

Mean having different letters are significantly different at P < 0.05.

Branch Per Plant:

The main effect of drought periods showed a significant effect on branch per plant (*P<0.001*) (Table 1). Plants receiving constant irrigation and those with 10 days of drought showed nonsignificant effects on one another, but they were significant had a higher no. of branch when compared to plants that experienced 15 days of drought. Plants under constant irrigation produced 25 branches/plant; under 10 days of drought, the number of branches per plant was 24 Figure (7). The main effect of cultivar showed a significant effect on branch counting (*P<0.001*). MAY 505 produced more branches than MAY455 at (28) and (18) respectively (Figure 3d). The main effect of treatment on branch number showed a nonsignificant effect statistically (P > 0.05) (Table 1).

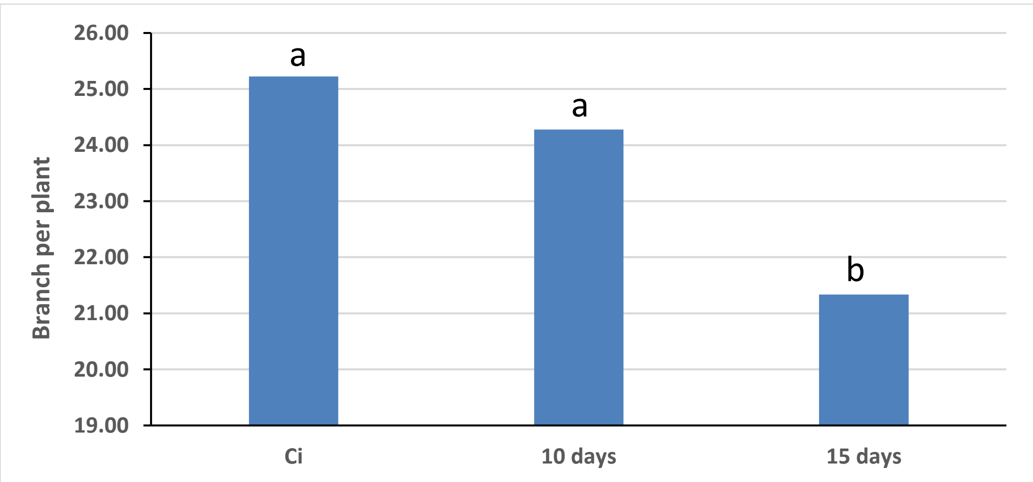

Figure 7: The effect of drought periods on branch number. Bars denoted different letters are significantly different at p < 0.05.

However, the interaction effect of cultivar vs drought on branch count was nearly two-fold more in MAY505 than in MAY455 and thereby showed a significant effect on branch count (*P<0.001*). This interaction indicates that with cultivar MAY 505, the application of 10-day drought periods significantly increased the no. of branches. In contrast, with cultivar MAY 455, the no. of branches was significantly reduced with drought regimes (Figure 8).

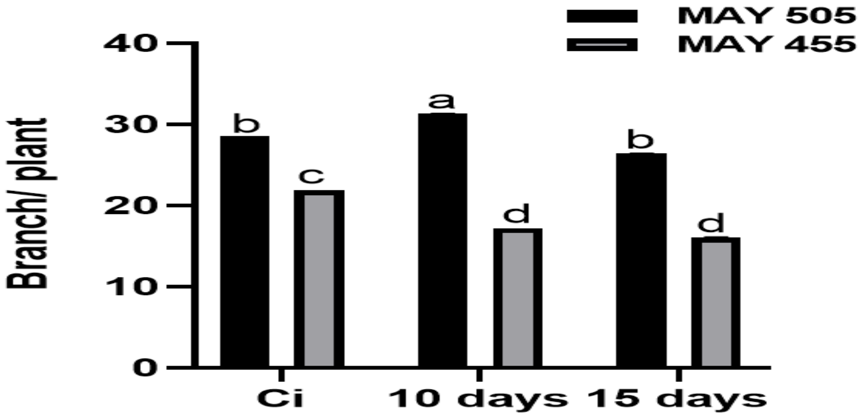

Figure 8: shows the effect of cultivar vs drought periods on branch numbers. Bars denoted different letters are significantly different at p < 0.05.

It is worth mentioning that the interaction of cultivar vs treatment showed a nonsignificant effect on branch count (*P= 0.064*). The interaction effect of drought periods vs treatments was also nonsignificant (*P=0.086*). On the other hand, the triple effect of drought, cultivar, and treatment significantly affected the branch number (*P<0.001*). Under regular irrigation, MAY505 scored the highest number of branches per plant when plants were treated with 2mM SA compared to control with only 30 branches/plant. On the other hand, under 10 days of thirst, the application of 2mM SA+10mM FA scored the highest number of branches per plan at 38 branch/plant (Table 4). Under prolonged drought, plants treated with 1mM SA+5mM FA showed the highest branch number at 33 branch/plant.

In MAY455, when plants were treated with 1mM SA+5mM FA and 1mM SA+10mM FA, the highest number of branches were observed (25 branch/plant). Whereas under 10 days of drought, the application of 2mM SA and 1mM SA+10mM FA showed the maximum number of branches per plants (19 branch/plant). With an increased drought period, plants treated with 10mM FA showed the biggest effect on branch number (21 branch/plant) Table (4).

Table 4: The triple effect of drought, cultivar, and treatment on branch number.

Cultivar	Drought period	Treatment								
		Salicylic acid		Folic acid		Salicylic acid + Folic Acid				Control
		1mM	2mM	5mM	10mM	1mM+ 5mM	1mM+ 10mM	2mM+ 5mM	2mM+ 10mM	
May 505	Ci	24 eo	35 ac	23 ep	35 ac	29 bj	24 eo	26 en	31 af	30 ah
	10 days	29 bj	28 cj	30 ah	37 ab	22 gp	31 af	32 ae	38 a	35 ac
	15 days	31 af	27 cl	29 bj	29 bj	33 ad	23 ep	23 ep	21 ir	22 gp
May 455	ci	23 ep	22 gp	22 gp	16 ot	25 do	25 do	19 lr	20 lr	25 do
	10 days	17 nt	19 lr	14 rt	17 nt	18 nt	19 lr	18 nt	15 ot	18 nt
	15 days	10 t	15 ot	15 ot	21 ir	13 st	17 nt	19 lr	18 nt	18 nt

Mean having different letters are significantly different at P < 0.05.

Longest Branch (Cm):

A significant variation was observed in the longest branch among the treatments with (*P= 0.006*). the impact of treatment was most evident in plants treated with (1 mM SA+5 mM FA) and (2mM SA+ 5mM FA) producing the longest branch long as compared to 1Mm SA and 5Mm FA. (Figure 9)). Figure (10) shows the effect of drought periods on branch length which was significantly affected branch length (*P<0.001*). It appears that plants exposed to 15 days of drought produced the shortest branches (66 cm), compared to those exposed to 10 days of drought (74 cm) and the control plants (73 cm). The impact of the cultivar on branch length varied significantly between the two cultivars studied (*P<0.001*). Cultivar MAY 505 had a greater influence in producing the longest branch at 83 cm, compared to cultivar MAY 455 at 60 cm (Figure 3b).

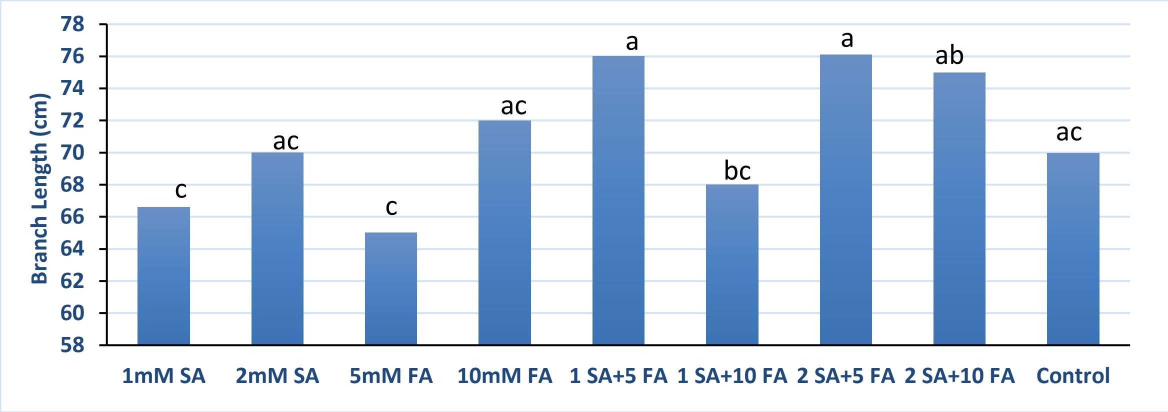

Figure 9: The effect of treatments on branch length. Bars denoted by different letters are significantly different at $p < 0.05$.

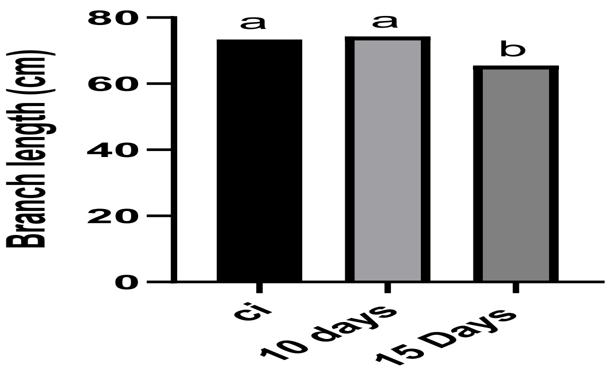

Figure 10: Shows the effect of drought periods on branch length. Bars denoted different letters are significantly different at $p < 0.05$.

The interaction between cultivar and treatment had a significant impact on branch length (*P=0.006*). For instance, with cultivar MAY 505 the length of branch was significantly changed with plant regulator compared to control, while with cultivar MAY 455 the application of 2mM SA+ 5 mM FA increased the branch length compared to control (Figure 11). The interaction of cultivar vs drought periods on branch length was nonsignificant (*P= 0.939*).

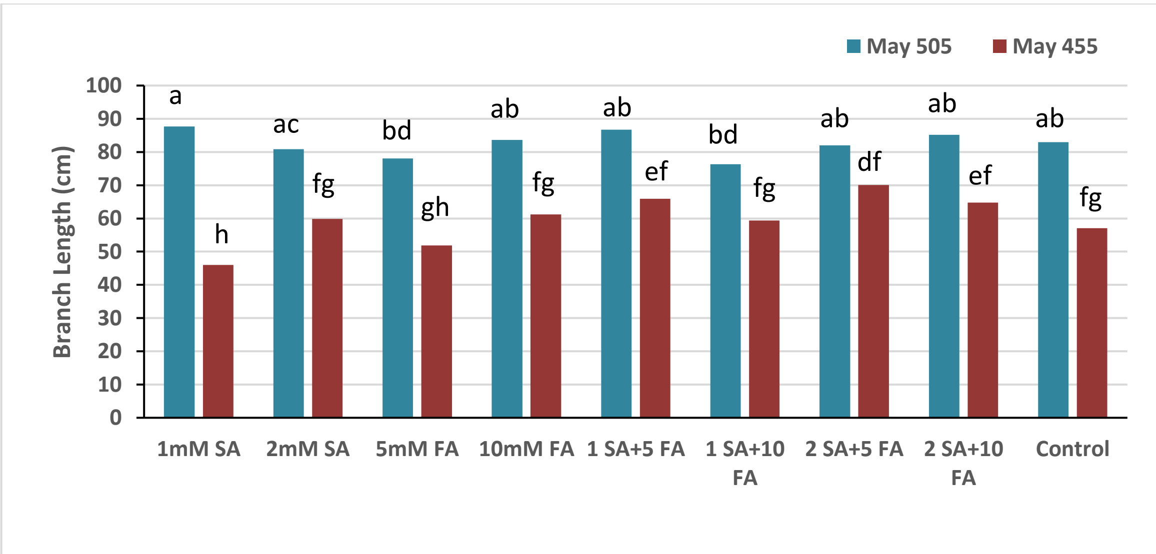

Figure 11: The interaction of cultivar vs treatment on branch length. Bars denoted by different letters are significantly different at $p < 0.05$.

In terms of the interaction between drought and treatment, branch length varied significantly across the three designated drought periods (*P<0.036*). This interaction indicates that under a 15-day drought period, the application of plant regulators significantly reduced branch length, except for the application of 2 mM salicylic acid (SA), which notably increased branch length under the same drought conditions (Table 5).

Table 5: The interaction effect of drought vs treatment on branch length.

	1mM SA	2mM SA	5mM FA	10mM FA	1 SA+ 5 FA	1 SA + 10 FA	2 SA + 5 FA	2 SA + 10 FA	Control
Ci	73.6a-c	61.18 c-e	74.35 a-c	75.35 a-c	77.90 ab	69.50 bc	75.97 a-c	80.93 ab	71.25 a-d
10 days	72.35 a-d	79.55 ab	61.70 c-e	73.65 a-c	84.26 a	67.57 b-e	84.17 a	74.7 a-c	70.65 a-d
15 days	53.83 e	70.38 a-d	58.53 de	68.32 b-c	66.75 b-e	66.48 b-e	68.21 b-c	69.3 b-c	67.96 b-c

Mean having different letters are significantly different at P < 0.05.

The triple effect of cultivar and drought and treatment significantly affected branch length (*P<0.001*). The applied plants with 1mM SA scored the longest branches in MAY505 under regular irrigation. Following that, under 10 days of drought, the application of 2 SA+5 FA significantly increased branch length to 97 cm. Additionally, when MAY505 was subjected to 15 days of drought, the plants treated with 2mM SA showed the longest branch, 80.56 cm. However, different variations were observed in cultivar MAY455. When plants received constant irrigation, the plants applied with 2 SA+5 FA produced the longest branch, 73.13 cm. In contrast, the application of 1 SA+5 FA significantly increased branch length to 82.06 cm. Further reduction in branch length was observed in plants subjected to 15 days of drought. In this regard, plants treated with 1 SA+10 FA significantly increased branch length to 68.76 cm, which is considered a much shorter branch length compared to plants of 10 days of drought and those that received constant irrigation Table (6).

Table 6: The triple interaction effect of cultivar, drought periods, and plant regulator treatments on branch length.

Cultivar	Drought period	Treatment								
		Salicylic acid		Folic acid		Salicylic acid + Folic Acid				Control
		1mM	2mM	5mM	10mM	1mM+ 5mM	1mM+ 10mM	2mM+ 5mM	2mM+ 10mM	
May 505	Continuous	95.13 ab	76.73 al	85.26 af	86.16 ae	87.46 ad	75.26 bl	81.8 ah	88.73 ad	84.8 ag
	10 days	86.06 ae	85.2 af	86.06 ae	93.4 ac	86.46 ae	72.73 co	97 a	87.8 ad	81.2 ai
	15 days	81.93 af	80.56 aj	62.93 hq	71.3 do	86.13 ae	81 ai	67.66 dp	79.06 aj	82.46 ah
May 455	Continuous	52.2 nr	45.63 rq	64.03 gq	64.53 fq	68.33 eo	63.73 gq	70.13 do	73.13 cn	57.7 lq
	10 days	58.63 lq	73.9 cl	37.33 rs	53.9 mr	82.06 ah	62.4 hq	71.33 do	61.6 hp	60.1 iq
	15 days	25.73 s	60.2 iq	54.13 mr	65.33 eq	47.36 pr	51.96 or	68.76 eo	59.53 jq	53.46 mr

Mean having different letters are significantly different at P < 0.05.

Leaf Surface Area (Cm^2):

The average leaf surface area (LSA) changed significantly as the drought periods varied (*P<0.001*). In the control plants (plants that received irrigation continuously), the LSA was 53.65 cm^2. However, in plants exposed to 10 days of drought, it reduced to 47.15 cm^2 and further decreased to 45.98 cm^2 in plants experiencing 15 days of drought Figure (12). Cultivar effect showed significant results on LSA (*P<0.001*). With MAY505, the LSA value was significantly higher at 50.12 cm^2 compared to MAY455 at 47.73 cm^2 (see Figure 3c). The impact of treatment on LSA values significantly changed LSA (*P<0.001*). Plants sprayed with 1 mM SA (53.39 cm^2) and 1 mM SA + 5 mM FA at (52 cm^2) showed the highest LSA value, and lower values of leaf area were found with 5mM FA and 10Mm FA Figure (13).

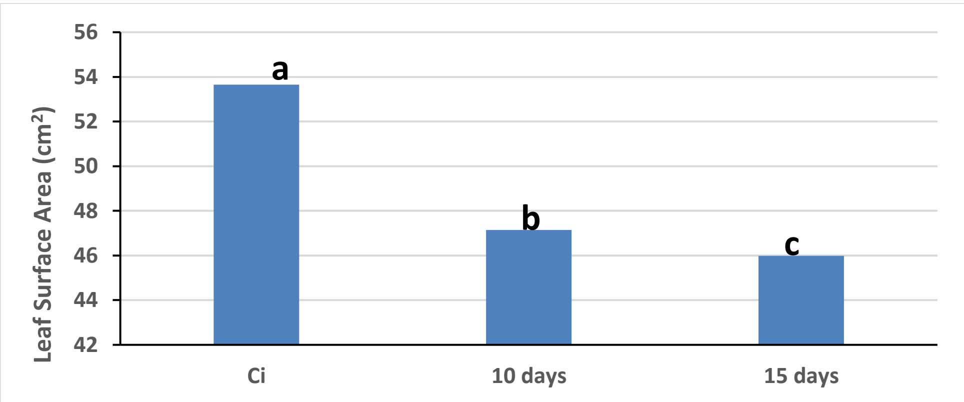

Figure 12: The effect of drought periods on LSA. Bars denoted by different letter are significantly different at p < 0.05.

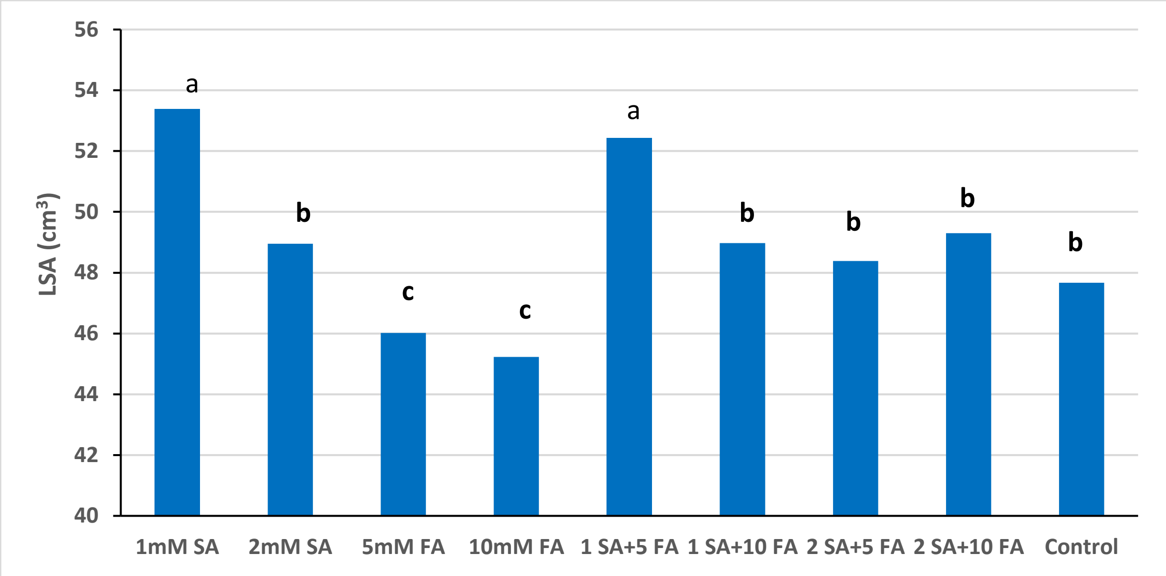

Figure 13: The effect of treatment on LSA. Bars denoted by different letters are significantly different at p < 0.05.

The interaction effect of drought periods vs treatment significantly affected LSA (*P<0.001*). This interaction indicated that in most of the cases under plant regulator applications, the leaf surface area decreased with increasing drought periods up to 15 days drought periods, except 1mM SA + 10mM FA, where the leaf surface area increased with the application of 10 days drought periods (Table 7).

Table 7: Shows the interaction effect of drought vs treatment on LSA.

Treatments	1mM SA	2mM SA	5mM FA	10mM FA	1 SA + 5FA	1 SA + 10 FA	2 SA + 5 FA	2 SA + 10 FA	Control
Ci	65.17 a	54.38 B	48.72 cd	52.77 bc	56.72 b	50.46 c	48.35 bc	59.99 ab	46.33 d
10 days	50.3 c	50.61 C	43.63 de	33.76 f	54.05 ab	54.75 ab	45.6 d	45.85 d	45.77 d
15 days	44.71 de	41.88 E	45.72 d	49.15 c	46.52 d	41.695 e	51.21 c	42.05 e	50.9 c

Flowers Per Plant:

The main effect of cultivar on flower count showed a significant effect (*P<0.001*). MAY505 produced more flowers than MAY455 with mean values of 4 and 2, respectively (Figure 3e). Regarding the effect of drought periods on flower number, there were significant differences in the number of flowers during the three drought periods (*P<0.001*). The no. of flowers per plant was significantly reduced with increasing drought periods (Figure 15a). The effect of treatment showed significant differences in flower number (*P=0.045*). The plants treated with 2 SA+10 FA showed the highest number of flowers (4) followed by the application of 10 mM FA with 3 flowers per plants. On the hand, plants that were treated with 1Mm SA and 5 mM FA, showed the least effect on flower production Figure (14).

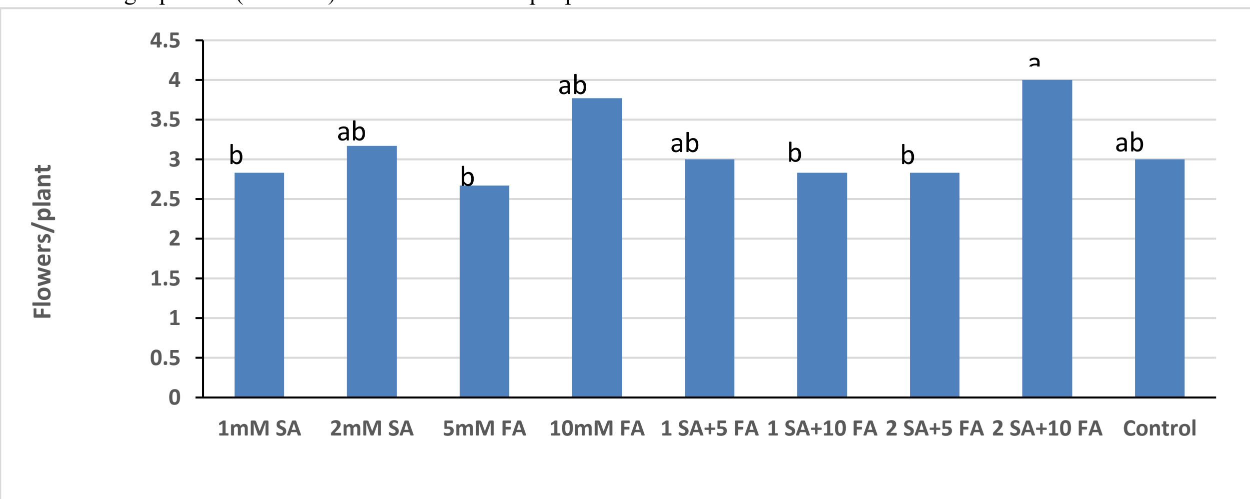

Figure 14: The effect of treatment on flower number. Bars denoted by different letter are significantly different at p < 0.05.

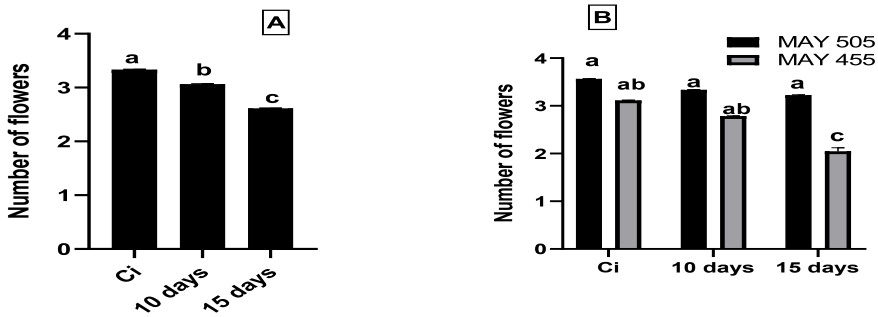

Figure 14: shows: a) the effect of drought on flowers, b) the interaction between cultivar vs drought. Bars denoted by different letters are significantly different at $p < 0.05$.

The interaction of cultivar vs drought showed significant differences (*P=0.033*). This interaction indicates that the cultivars respond differently to irrigation regimes. It was observed that the application of drought periods significantly changed flower no. with cultivar MAY 505. In contrast, with cultivar MAY 455, the number of flowers was reduced considerably during the 15-day drought period (Figure 15b). It can also be seen from the interaction that there were no significant differences in the no. of flowers between cultivars under continuous and 10-day drought periods, while under 15-day drought periods, the no. of flowers was significantly higher with MAY 505 than MAY 455. Concerning the other interaction effect, no significant interaction was observed to be significant ($P > 0.05$) (Table 1).

4. DISCUSSION

This study investigated the impact of drought periods and foliar application of FA and SA on some growth parameters in two cotton cultivars (MAY 505 and MAY 455). The results revealed interesting interactions between these factors, with significant variations in plant growth parameters.

The results indicate that drought stress significantly affected SL (Rehman *et al.*, 2022). While a moderate level of drought (10 days) slightly enhanced SL, prolonged drought (15 days) led to a substantial reduction. This suggests that a brief period of water stress might stimulate compensatory growth, but prolonged stress inhibits plant growth (Niu *et al*., 2018). Cultivar MAY 505 exhibited superior SL compared to MAY 455, suggesting inherent genetic differences in drought tolerance. The interaction between cultivar and treatment revealed that MAY 505, when treated with 10 mM FA, displayed the highest SL, indicating a synergistic effect between the cultivar and the specific treatment (Hassan *et al*., 2016; Khan *et al*., 2022).

The interaction between drought and spray treatment yielded intriguing results. While 2 mM SA + 5 mM FA maximized shoot length under 10 days of drought, the same treatment resulted in a significant decrease in SL for plants experiencing 15 days of drought stress. This suggests complex interactions between drought severity and spray type on plant responses. These results indicate that the application of growth could work under moderate drought conditions (10 days of drought stress). These findings support previous research on the potential of FA and SA to enhance plant growth under stress conditions (Khan *et al*., 2022; El–Bially *et al*., 2022).

The number of branches per plant was significantly influenced by both cultivar and drought stress. MAY 505 consistently produced more branches than MAY 455, highlighting its superior branching potential. Additionally, the number of branches decreased with increasing drought duration. These findings came in agreement with those obtained by (Zonita *et al*., 2017). The interaction between cultivar and treatment showed that MAY 505 produced the highest number of branches when treated with 2 mM SA and 2 mM SA + 10 mM FA. This suggests that these specific treatments may enhance branching in MAY 505 (El–Bially *et al.*, 2022; Ahmed *et al.,* 2024).

The longest branch length was influenced by both drought and treatment. Prolonged drought (15 days) resulted in shorter branches compared to 10 days of continuous irrigation. These results were consistent with those obtained by (Bauer *et al.,* 2012). Cultivar MAY 505 consistently produced longer branches than MAY 455, indicating its potential for greater plant architecture. The interaction between cultivar and treatment revealed that MAY 505, when treated with 2 mM SA, produced the longest branches, suggesting a positive impact of this treatment on branch elongation in this cultivar (El–Bially *et al.,* 2022).

Leaf surface area (LSA) decreased with increasing drought duration, indicating a strategy to reduce water loss through transpiration (Kumar *et al.,* 2018; Xu *et al.,* 2010). Cultivar MAY 505 generally exhibited a larger LSA compared to MAY 455. This suggests that MAY 505 may have a higher photosynthetic capacity and potentially greater growth potential (Rehman and Farooq, 2019). This indicates that the impact of drought periods on LSA reveals the plant's adaptation to environmental changes

The number of flowers was influenced by both drought and treatment. Prolonged drought reduced flower number, indicating that severe water stress can negatively impact reproductive growth (Lamaoui *et al.,* 2018). Cultivar MAY 505 consistently produced more flowers than MAY 455, suggesting its superior reproductive potential. The interaction between cultivar and treatment revealed that MAY 505, when treated with 2 mM SA + 10 mM FA, produced the highest number of flowers, indicating a positive impact of this treatment on flowering in this cultivar (Hassan *et al*., 2016).

Since folic acid regulates cell division and protects the plant from undesirable effects of the environment, this study showed a slight increase in flower production. This effect of FA was also observable in enhancing the growth performance of *Solanum nigrum* L. (Sahito *et al.,* 2024). According to the data obtained in this study, SA is more effective in the induction of flowers than FA. A similar research revealed the same effect of SA on plant growth, such as seed germination, root growth, and flowering induction (Bagautdinova *et al*., 2022; Liu *et al.*, 2022; Ahmed *et al*., 2024).

CONCLUSION

In conclusion, this study highlights the valuable insights between drought stress, cultivar genotype, and foliar spray treatments in influencing plant growth and development. MAY 505 exhibited superior performance in terms of shoot length, branch number, longest branch length, leaf surface area, and flower number compared to MAY 455. Foliar application of specific combinations of SA and FA can enhance plant growth and reproductive potential under drought stress conditions (El–Bially *et al*., 2022; Hassan *et al.,* 2016; Khan *et al.,* 2022). Beside enhancing growth performance, the foliar application of SA and FA protected the plant structure from the destructive effects of environmental stress.

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Ethical Statement

This research did not involve human participants or animal subjects. Therefore, ethical approval was not required.

Author Contributions

M.B.I., Conceptualization, writing, and data analysis **D.A.I.,** investigation, and review. Both authors approved the final manuscript.

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