Egypt. J. Agron. **Vol. 47**, No. 3, pp: 575 - 595 (2025)

Egyptian Journal of Agronomy

http://agro.journals.ekb.eg/

Response of Egyptian Cotton to Application of Polyacrylamide Polymer and Growth Stimulants under Water Stress Conditions

El-Ashmouny, Amany, A.[1] and **Osama A.M. Ali**[2]

[1]*Cotton Physiology Department, Cotton Research Institute, Agricultural Research Center, Giza, Egypt.*
[2]*Crop Science Department, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt.*

STUDY aimed to evaluate the physiological and yield responses of Egyptian cotton (*Gossypium barbadense*, cv. Super Giza 97) to varying irrigation regimes and growth stimulants under water stress conditions. Field experiments were conducted at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, during the 2021 and 2022 growing seasons. Treatments included three irrigation regimes i.e. irrigation every 14 days (I_1), 28 days (I_2), and 28 days + Polyacrylamide PAM (I_3) and four growth stimulants i.e. control, salicylic acid (SA), boron (B), and potassium (K). Results showed that delaying irrigation from 14 to 28 days significantly reduced physiological traits (chlorophyll, relative water content), squares and bolls production, yield components, and productivity, while increasing stress indicators such as proline content and catalase activity as well as total abscission. Adding PAM to plants that irrigated every 28 days had a significant positive role in alleviating water stress by minimizing these reductions and enhancing yield and water productivity. Growth stimulants have beneficial significant effects on physiological performance and yield, where SA and K were exchange ranks in achieving the best results. The interaction treatment, which involved irrigation every 14 days combined with spraying either SA (I_1×SA) or K (I_1×K), yielded the most favorable outcomes. Interaction treatments of (I_3×SA) or (I_3×K) achieved seed cotton yield/fed that is statistically equal to the combined treatment (I1×control), utilizing total water applied less by 28.10 and 32.28%. This means that (I_3×SA) or (I_3×K) were the most suitable combination treatments in case of limited irrigation water in salt-affected soil.

Keywords: Gossypium barbadense, Salicylic acid, Potassium, Yield, Water productivity.

Introduction

Climate change has caused more extreme weather and an unreliable water supply, which has made droughts more common. Egypt is situated in an arid to semiarid zones, facing critical water shortage problems. Abiotic stresses pose a significant threat to food security. Drought stress is a major abiotic stress resulting from conditions including decrease humidity, and raise thermal stress (Younis *et al*., 2025), it being the primary factor impacting global crop productivity and agricultural sustainability in general. Cotton “king of fibers” is sensitive to drought during flowering and boll formation resulting in increasing squares and boll abscission rates (Kawakami *et al*., 2010 and EL-Shazly *et al*., 2024). In addition, excess of salts negatively impacts soil structure and fertility, it inhibits plant growth, reduces crop yields, and disrupts the activity of microorganisms (Tarolli *et al.*, 2024). The Nile Delta is experiencing a complicated interaction of rising sea levels, diminished sediment transport, and anthropogenic activities that intensify saline intrusion, impacting approximately 35% of arable land (Mabrouk *et al*., 2013). Under stress conditions can lead to the accumulation of a large amount of proline (Addad *et al*., 2025), and reactive oxygen species (ROS) including free radicals, i.e. hydrogen peroxide H_2O_2, peroxide anion (O^{-2}), and hydroxyl radical (OH^-) can be generated within cotton cells (Mosfeq-Ul Hasan *et al*., 2018). Excessive ROS production may lead to cell death and oxidative damage. The effective management of ROS necessitates the action of both enzymatic and non-enzymatic antioxidants (Mittler, 2002 and Shohani *et al*., 2023). Plants can induce the expression and activity of antioxidant enzymes to eliminate ROS in cells to avoid the oxidative stress damage caused by stress (Hasanuzzaman *et al.*, 2020). Antioxidant enzymes like catalase (CAT) are responsible for breaking down hydrogen peroxide (H_2O_2) into water and oxygen. CAT is particularly sensitive to abiotic stress and serves as a biomarker; however, it is located in the

*Corresponding author email: amanyash@hotmail.com Orcid ID: 0000-0001-7111-0117
Received: 08/11/2024; Accepted: 26/05/2025
DOI: 10.21608/agro.2025.334739.1559

peroxisome, which limits its ability to decompose H_2O_2 present in the chloroplast. It is under drought stress CAT enzyme, with other enzymes, can reduce oxidative damage (Gebicka and Krych-Madej, 2019). Plants primarily manage oxidative stress through an endogenous defense system that includes various enzymatic activity, such as superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GR), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione peroxidase (GPX), guaiacol peroxidase (GOPX), glutathione S-transferase (GST); Additionally, nonenzymatic defenses consist of compounds such as ascorbic acid, glutathione, phenolic acids, flavonoids, carotenoids, and nonprotein amino acids (Hasanuzzaman *et al*., 2012 and Hasanuzzaman *et al*., 2020).

Cotton is one of the most precious crops for offering natural fibers for the worldwide textile sector. Egyptian cotton (*Gossypium barbadense,* L.) requires approximately 165 days from sowing to harvesting. During this growing season, irrigation had a major direct impact on cotton growth, yield and quality properties. Exposing cotton plants to drought during their growth stages negatively affected morphological, physiological, biochemical parameter (Hafeez *et al*., 2015 and Mosfeq-Ul Hasan *et al*., 2018) and yield and its components (Zahoor *et al*., 2017, Hu *et al*., 2018 and Rehman *et al*., 2021). This negative effect rises with excess of salts in soil. The root system is the first plant organ to sense a limitation in water supply. In addition to absorbing water and minerals, roots transmit signals to the leaves via xylem sap, with the phytohormone abscisic acid identified as a key stress signal from roots to shoots (Zhang and Davies, 1987). When this stress signal reaches the leaves, it initiates stomatal closure, prompting the plant to adopt a water-saving strategy. Consequently, by modifying stomatal openings, plants can regulate water loss by decreasing transpiration, although this also limits the intake of carbon dioxide. But this will have direct and indirect effects on the reduction of net photosynthesis and consequently growth and yield (Hu *et al*., 2016). Hence, it is essential to soil application superabsorbent polymers such as polyacrylamide (PAM) to save soil moisture. It is white powder with highly water-absorbent, forming a soft gel when hydrated. It has an exceptionally high-water retention capacity. It has a linear-chain structure, allowing them to swell in water and hold significant quantities (Zohuriaan-Mehr and Kabiri, 2008). Polymers can absorb water during irrigation process. When the soil dries out, the polymers release water gradually. It enhances water retention in soils, helping to minimize run off and ensure that moisture remains in the root zone of plant (Sojka *et al*., 2007 and Ekebafe *et al*., 2011). The polymer water retention is sufficient to prevent loss and allow roots to withdraw moisture effectively, making them an excellent medium for plant growth (Ali and Abdel-Aal, 2021). In this concern, *Aase et al.* (1998) mentioned that applying PAM at rates of 2-4 kg per ha decreased runoff by 70% and lowered soil moisture loss by 75% compared to the control. In addition, Xindong *et al.* (2011) indicated that application of PAM concentrations caused increases in soil water content through growth period of maize ranged from 5.62 to 10.96 % over control and improve maize yield by 5.54-14.13% and water use efficiency. Using PAM polymer can help reduce water stress in crops, particularly in dry and semi-dry areas. This approach could lead to increased irrigation intervals and enhanced water use efficiency by 25.87% for soybean crop (Ali and Abdel-Aal, 2021).

The negative impacts of drought on cotton plants can be reduced by external application of plant growth stimulants (Farooq *et al.*, 2009 and EL-Shazly *et al.*, 2024). Salicylic acid (SA) is a phytohormone that helps plants to reduce environmental stresses, particularly drought through regulation of the antioxidant defense system (Khalvandi *et al*., 2021). This acid functions as a stress signaling molecule, triggering the synthesis and expression of non-stress-inducing genes in plants experiencing drought conditions. SA had significant roles in maintaining membrane stability, regulating stomatal function, and inhibiting ethylene biosynthesis (Khalvandi *et al.*, 2021). SA invigorates the responsive genes to modify physiological processes to restore ordinary growth and development (Szalai *et al*., 2005). Application of salicylic acid influences the root tip meristem by increasing auxin levels. It has been shown to enhance the biosynthesis of phenolic compounds under drought stress and increased the activity of antioxidant enzymes (Khalvandi *et al.*, 2021). Numerous investigations have examined foliar spraying of SA, which positively influences the growth and physiological characters of Egyptian cotton (Hussein *et al*., 2012 and EL-Shazly *et al.*, 2024).

Boron (B) is a vital micronutrient for the growth and development of plants and alleviating adverse environmental stresses such as drought through strengthening antioxidant defense systems (Lu *et al.*, 2023). It is primarily found in the cell wall, where it affects both the mechanical strength and flexibility of plant cells, making it essential for the structure of the cell wall. Boron helps build the cell wall by creating borate-ester bonds with pectin polysaccharide, which is important for the formation of primary cell walls (O’Neill *et al.*, 2004). Researchers have indicated that boron plays a key role in protecting the plasma membrane from damage caused by reactive oxygen species under stresses (Lu *et al*., 2023). It plays a positive role in keeping membranes structure strong. It helps in the production of lignin, which strengthens cell walls and offers indirect protection to cell membranes in plants (Abbas *et al*., 2022). When boron is added, the levels of pectin and hemicellulose in the cell wall can increase significantly, by 19% and 50% respectively, especially under conditions of oxidative stress (Riaz *et al*., 2021).

Potassium sulfate is the most commonly source used in potash fertilization. The K component of K_2SO_4 is similar to that found in other typical potash fertilizers. Nevertheless, it provides an important source of sulfur, which is essential for protein synthesis and enzyme activity. Similar to potassium, sulfur can also be insufficient for optimal plant growth. Potassium is recognized as one of elements that stimulate metabolic processes in plants, and helps neutralize free radicals, thereby safeguarding the plant against damage. This protection can extend the lifespan of plant cells and enhance various growth characteristics (Ibrahim *et al*., 2015). Potassium is the primary inorganic cation found in plants and is vital for various physiological and metabolic functions. It helps activate many enzymes, maintain charge balance, regulate cytoplasmic pH, manage osmotic potential and water absorption, and control stomatal conductivity (Oosterhuis *et al*., 2014). Photosynthesis, chlorophyll fluorescence and carbohydrates contents in cotton were significantly affected by K (Hu *et al*., 2016 and ELAshmouny and Moursi, 2024).

Considering the importance of cultivation of Egyptian cotton plant particularly water shortage. The present study was carried out to evaluate physiological response of Egyptian cotton under normal and drought stress conditions, and attempts to a better understanding of the effect of soil polymer and stimulants substance on drought stress in salt-affected soil.

Materials and Methods

1. Experimental procedures

Two field experiments were performed at Experimental farm of Sakha Agricultural Research Station, ARC, Kafr El-Sheikh governorate, Egypt during 2021 and 2022 growing seasons. The site is located at latitude 31°07' N, longitude 30°57' E. The present study was aimed to evaluate physiological response of Egyptian cotton (*Gossypium barbadense*, Super Giza 97 cv.) under normal and drought stress. Each experiment included treatments which were as follows.

Irrigation regimes:

- I_1: Irrigation every 14 days (well-watered in salt-affected soil)
- I_2: Irrigation every 28 days (water-stressed)
- I_3: Irrigation every 28 days + polyacrylamide (PAM)

Growth stimulants:

- Control: treated with water only.
- Salicylic acid (SA): ($C_7H_6O_3$) at the rate of 0.500 g/liter
- Boron (B): Boric acid (H_3BO_3) at the rate of 0.250 g/liter
- Potassium (K): Potassium sulfate (K_2SO_4) at the rate of 3.00 g/liter

The experimental treatments were arranged in a split plot design with three replications. The irrigation regimes were arranged at random in the main plots, while the growth stimulants were assigned in the sub-plots. First irrigation was applied at 25 days after sowing (DAS) for the normal and drought treatments, then normal irrigation was scheduled every 14 days until the harvesting, while drought treatments were implemented every 28 days (Table 1).

Table 1. Time and number of irrigations of tested irrigation regimes.

Irrigations No. / Irrigation regimes	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	Total irrigations No.
	Irrigation time (DAS)									
(I_1) 14 days	25	39	53	67	81	95	109	123	137	**9**
(I_2) 28 days	25	53	81	109	137	-	-	-	-	**5**
(I_3) 28 days + PAM	25	53	81	109	137	-	-	-	-	**5**

Growth stimulants and PAM were sourced from El-Gomhouria Co. for Chemilab, Egypt. Polyacrylamide (PAM) is a polymer with chemical formula [(C_3H_5NO) n]. It was placed on each hill before seeding at a rate of 4.2 kg/fed (fed=4200 m^2). The growth stimulants were sprayed three times at 45, 60 and 75 DAS.

2. Experimental condition

In the study, Sakha Agricultural Research Station was selected as experimental soil which is clay soil with moderate salinity irrigated with surface irrigation system. Soil samples (0-30 cm depth) of experimental field were randomly collected and analyzed before sowing. Physical and chemical analyses was done at laboratories of Sakha Agricultural Research Station according to the methods described by Black (1965), Jackson (1973) and Chapman and Pratt (1978). The soil properties are presented in Table (2). In this location, the temperature mean can satisfy the requirement of cotton crop during growth stages. The meteorological data of the experimental site were recorded from Meteorological Station of Sakha and presented in Table (3).

Table 2. Physical and chemical characteristics of soil (0–30 cm depth) during 2021 and 2022 seasons.

Characteristic	Unit	Season	
		2021	**2022**
Particle size distribution			
Sand	(%)	21.68	22.28
Silt		29.20	27.43
Clay		49.12	50.29
Texture class	---	Clayey	Clayey
Bulk density	(g cm^{-3})	1.24	1.31
Organic matter	(%)	1.68	1.62
pH	---	8.13	8.18
EC_e	(dS m^{-1})	4.32	4.41
SAR		9.21	9.70
Soluble cations			
Ca^{2+}	(meq L^{-1})	9.31	9.19
Mg^{2+}		6.83	6.31
Na^{+}		26.17	27.01
K^{+}		0.55	0.62
Soluble anions			
SO_4^{2-}	(meq L^{-1})	17.37	15.88
Cl^{-}		21.22	22.24
HCO_3^{-}		4.27	5.01
CO_3^{2-}		-	-
Available nutrients			
N	(ppm)	20.24	22.11
P		9.13	9.58
K		367.21	373.18
Soil moisture			
Field capacity	(%)	40.87	40.13
Permanent wilting point		18.04	17.76
Available soil water		22.83	22.37

Table 3. Meteorological data of the experimental site during growing period.

Month	Period (day)	Temperature (C°)				Relative humidity (%)		ETo (mm)	
		2021		2022		(Mean/ period)		(Mean/period)	
		Max.	Min.	Max.	Min.	2021	2022	2021	2022
April	21-30	21.5	19.9	28.3	20.5	66.4	44.7	5.36	5.41
May	1-10	30.6	22.3	27.5	20.7	73.0	55.0	6.23	6.20
	11-20	28.9	23.5	29.8	21.7	77.3	58.4	6.19	6.23
	21-31	31.5	24.6	32.3	23.1	78.6	60.5	6.73	6.81
June	1-10	33.4	24.3	33.6	25.2	65.2	69.0	6.98	7.04
	11-20	35.6	23.1	32.6	22.9	63.5	68.6	7.27	7.13
	21-30	31.4	24.8	32.9	26.2	64.9	68.4	7.71	7.64
July	1-10	35.6	28.6	30.1	26.3	70.9	68.2	7.65	7.51
	11-20	33.4	30.5	32.6	26.3	73.6	68.5	7.81	7.77
	21-31	36.2	33.6	34.1	25.1	73.5	67.5	7.83	7.68
August	1-10	33.5	26.7	33.4	25.5	84.2	66.4	6.72	6.63
	11-20	36.0	27.5	33.6	25.6	81.4	75.4	6.84	6.76
	21-31	35.6	29.2	36.1	27.3	82.6	76.3	6.51	6.62
September	1-10	34.8	26.4	33.0	29.7	80.5	71.4	5.71	5.63
	11-20	34.9	25.0	32.2	25.3	75.8	70.4	6.03	5.95
	21-30	33.5	22.6	33.8	25.5	70.5	69.8	5.61	5.54
October	1-10	30.5	20.5	30.6	21.9	64.0	59.4	4.60	4.52
	11-20	28.6	18.3	28.7	26.2	56.4	57.8	4.28	4.33

3. Agronomic management

After harvesting the preceding crop (Egyptian clover) in the two seasons, the experimental field was prepared by ploughed twice with a chisel plough, harrowed and then furrowed with a furrow width of 70 cm. The area of each experimental plot was 16.8 m^2, including six furrows, 4 meters along and 0.70 m apart. Buffer area (1.4 m) was left between all sub-plots in order to eliminate any interfering effect of irrigation regimes and foliar spray with stimulants. Cotton seeds (Super Giza 97 cv.) were sown on 27^{th} and 30^{th} April in the first and second seasons, respectively in hills 25 cm apart on one side of the furrow. At 35 days from sowing, soil was hoeing, and plants were thinned to two plants/hill, i.e. 48000 plants/fed. For all experimental units, nitrogen fertilizer was applied with a rate of 60 kg N /fed in the form of urea in two equal doses. The first dose was applied before the first irrigation (25 DAS), and the second dose was applied at 53 DAS. Applying a base dose of 150 kg calcium superphosphate (15.5% P_2O_5) during soil preparation. Potassium sulfate (48% K_2O) per feddan was added at a rate of 50 kg divided in two doses at the same time of nitrogen application. The first ginning took place 150 DAS, while the second one followed 15 days later. Other agricultural practices followed standard recommendations for cotton production according to Ministry of Agriculture and Land Reclamation, Egypt.

4. Measurements

The measurement concerned the observation of physiological, flowering and yield characteristic of

Egyptian cotton as well as irrigation water efficiency in the two growing seasons.

*I. **Physiological characters***

At 90 DAS, ten fresh leaves from the fourth upper leaf of main stem of cotton plant were randomly collected to assess the following traits:

Chlorophyll (SPAD value): It was determined by SPAD-502-meter, Konica Minolta Company, Japan.

Membrane stability index (%): It was estimated according to Sairam *et al*., (1997). Fresh leaves samples were cut into discs of uniform size and placed in distilled water in two groups. The first group was kept at 40°C for 30 min., and its conductivity was recorded (C1) using a conductivity meter. The second group was kept in a boiling water bath (100°C) for 15 min., and its conductivity also recorded (C2). MSI% was calculated as formula:

MSI = [1-(C1/C2)] x 100

Relative water content (RWC %): It was measured using the fully expanded leaves of plants. The fresh weight (FW) of the leaves was taken at 7:00 am, after then the leaves were soaked in distilled water for 6 hours to record their turgid weight (TW). The leaves were then dried at 70°C until they reached a constant weight to determine the dry weight (DW). RWC % was calculated using a formula based on Barrs (1968).

$$RWC = \frac{Fw - Dw}{Tw - Dw} \times 100$$

Proline content (µg/g FW): It was estimated according to Bates *et al*. (1973).

Catalase activity (CAT): It was determined according to the method described by Jaleel *et al.* (2007). The activity was estimated as U/mg protein (U = 1 mM of H_2O_2 reduction/min/mg protein).

II. Flowering and abscission

Before flowering stage, ten plants were randomly labeled in each sub-plot to determine the total numbers of squares and total bolls in the main stem and branches of cotton plant. At maturity stage, total abscission/plant (%) was estimated from the following formula:

$$Abs. = \frac{\text{No. of squares/plant} - \text{No.of total bolls/plant at maturity}}{\text{No. of squares/plant}} \times 100$$

*III. **Yield and its attributes***

At harvest, ten guarded plants were randomly collected to determine plant height (cm), number of fruiting branches/plant, number of open bolls per plant, Boll weight (g), 100-seed weight (g), seed cotton yield / plant (g), lint (%). Seed cotton yield of inner three furrows were determined and converted in kentar/fed (1 kentar = 157.5 kg). Earliness (%) was estimated from the following formula:

$$Earliness = \frac{\text{Seed cotton yield of the first pick}}{\text{Total seed cotton yield (first + second picks)}} \times 100$$

IV. Water relations

Water pump motor (3") was used to add irrigation water to experimental field. Water meter was installed on the pump to calculate amount of water applied for each experimental plot (m^3) then converted to fed. The following characters was calculated:

- **Soil moisture content** (%): It is measured on a mass basis, which is known as the oven-dry weight method (Soil Science Society of America, 2008). Five soil samples of rhizosphere area (0-30 cm) are collected at 80 DAS (before irrigation) from each experimental plot, and transported in clean container with the lid. The soil samples were dried in oven at a temperature of 105°C until the weight was constant. The following equation was used to calculate the soil moisture content.

$$\text{Soil moisture (\%)} = \frac{\text{mass of moist soil} - \text{mass of dried soil}}{\text{mass of dried soil}} \times 100$$

- **Total water applied (m^3/fed)**: It is the sum of water added during irrigations of each experimental treatment during growing seasons.

- **Water saved (m^3/fed)**: It is water amount saved by treatment compared to control.

- **Water productivity (kg/m^3)**: The water productivity (WP) was calculated according to the formula of Michael (1978) as follows:

$$WP = \frac{\text{Seed cotton yield (kg)}}{\text{Total water applied (m3)}}$$

5. Statistical analysis

The variance analysis was carried out for each measurements data in each season as outlined by Snedecor and Cochran (1989). The differences between the means of different treatment were tested using the Duncan's Multiple Range method (Duncan, 1955). CoStat (2017) software program (Ver. 6.45) was used for statistical analysis. Principal component analysis (PCA) and Pearson's correlation coefficients for the measured variables were generated using R (2020) software (Ver. 4.00).

Results and Discussion

I. Physiological characters

I.1. Effect of irrigation regimes:

Data cleared that the tested irrigation regimes had significant effect on physiological characters in both seasons as reported in Table (4). Cotton plants irrigated every 14 days (I_1) recorded the highest significant values of total chlorophyll, membrane stability index and relative water content, while registered the lowest values of proline content and catalase activity. On the other hand, exposing cotton plants to water stress by irrigation every 28 days (I_2) achieved results opposite to normal irrigation. Drought affects plant growth by causing stomatal closure, which leads to a decreased transpiration rate. This also results in lower chlorophyll content and restraint photosynthesis process (Rehman *et al*., 2021). This decline might be caused by the production of proteolytic enzymes like chlorophyllase, which plays a key role in chlorophyll degradation (Gadallah, 1995). Drought greatly lowers photosynthesis because of restrictions at the stomata, which leads to reduced leaf stomatal conductance and consequently affects CO_2 fixation. It causes lower stability than normal irrigation due to leads to the build-up of reactive oxygen species, which can damage cell membranes (Gupta *et al*., 2012). Soil moisture deficiency reduced the stability of cell membranes (Coker and Oosterhuis, 2003). Under drought stress conditions reduce the amount of water available, which in turn limits the absorption of water and nutrients by plants (EL-Shazly *et al*., 2024). Cotton plants have developed a complex system to obtain protection from the damage caused by reactive oxygen. When exposing plants to water stress (I_2), it showed increase in proline accumulation and catalase activity (Shallan *et al*., 2016). Plants use the buildup of the osmolyte proline as a way to adapt to water stress. Proline helps to neutralize excess reactive oxygen species (ROS), regulate the osmotic balance within cells, safeguard biological membranes, and stabilize proteins and enzymes (Iqbal *et al*., 2014). Cotton plants that irrigated every 28 days in the presence of PAM (I_3) recorded intermediate values. Polymers mitigate the adverse effect of water stress. PAM polymer has the ability to absorb water during the irrigation process. When the soil dries, this polymer releases the stored water slowly. This helps improve water retention in the soil and keep moisture in the plant's root zone. Sojka and Surapaneni (2000) and Ali and Abdel-Aal (2021) showed that the water retention provided by polymer is sufficient to prevent loss, enabling roots to access moisture effectively. This supports the physiological processes in comparison with absence of polymer under water stress.

I.2. Effect of growth stimulants:

Foliar application of tested growth stimulants had positive effects on the physiological characters (Table 4). The highest chlorophyll content (SPAD reading) was recorded by plants treated with potassium sulfate followed by SA, while untreated plants had 12.87% and 9.38% lower chlorophyll than those of K and SA, respectively as an average of both seasons. This may be due to their role in inhibition the degradation of chloroplasts. Potassium is crucial for photosynthesis, helps regulate water balance, and aids in nutrient absorption (Huang *et al*., 2023). Other researches indicated that the role of potassium (Coker and Oosterhuis, 2003 and Hassan *et al*., 2016) and SA (El-Beltagi *et al*., 2017 and EL-Shazly *et al*., 2024) in enhancing the photosynthetic rate and increase the activity of carboxylation enzymes in cotton plants. Electrolyte leakage noticeably increased in cotton plants that were stressed and untreated with any stimulants. Spraying of growth stimulants in favor of SA significantly enhanced the membranes stability than untreated plants. SA reduces oxidative damage and helps maintain membrane stability by promoting lipid accumulation (Nadarajah *et al*., 2021). Potassium plays a serious role in managing water balance and helps plants to uptake water and nutrients. This could explain the improvement in photosynthesis and leaf water content observed (Huang *et al*., 2023). Untreated plants accumulated more osmolyte proline as a way to adapt to water stress. Proline is a compatible osmolyte that controls osmotic regulation and alleviates stress in cell membranes. There is a notable increase in CAT activity by application of growth stimulants in favor of potassium (El-Beltagi *et al*., 2017). It can be attributed to the role of potassium in neutralizing organic anions and other compounds. This action helps to stabilize the optimal pH range for most enzymatic reactions (Wang *et al*., 2022).

I.3. Effect of the interaction

The interaction between irrigation regimes and tested stimulants was found to be significant for all physiological traits (Table 4). The interaction between irrigation regimes and stimulants (I × S) highlighted that I_1 × K achieved the highest chlorophyll content (52.43 and 50.82 SPAD value), while I_1 × SA recorded the highest membrane stability index (76.91% and 75.54%), emphasizing the synergistic effect of well-watered conditions and stimulants. In this respect, plants which well-watered and sprayed with potassium sulfate followed by SA recorded the highest significant values of chlorophyll and relative water content (Coker and Oosterhuis, 2003 and ELAshmouny and Moursi, 2024). Meanwhile, there were significant decreases in both traits with exposing plants to water stress (I_2) in presence or absence of growth stimulants, where the lowest values were registered with I_2 × control. Addition of PAM polymer under water stress (I_3) and spraying of potassium sulfate caused improvement in plants efficiency in chlorophyll formation and increased relative water content. (I_1 × SA) treatment achieved the highest membrane stability index (%) in both seasons, while the lowest membrane stability was recorded by I_3 × control. It can be noticed that proline content was significantly increased by increasing irrigation interval (I_2) either treated with growth stimulants or untreated plants (El-Gabiery, 2016 and EL-Shazly *et al.*, 2024). The highest proline content obtained from I_2 × control, while the lowest one was obtained by I_1 × K. Growth stimulants plays a positive role in enhancing proline metabolism when plants faced abiotic stresses as reported by Khan *et al.* (2013) and El-Gabiery (2016). Foliar application of tested growth stimulants caused an increase in catalase activity compared to untreated plants (control) under all irrigation regimes. The highest value was recorded when the plants were irrigated every 28 days and sprayed K or B. Using PAM polymer under water stress improves catalase activity especially in presence of K application. The lowest activity obtained from plants irrigated every 14 days in absence of growth stimulants.

Table 4. Effect of irrigation regimes, stimulant substances, and their interaction on physiological characters of cotton during 2021 and 2022 seasons.

Treatments		Chlorophyll (SPAD value)		Membrane stability index (%)		Relative water content (%)		Proline content (µg/g FW)		Catalase activity (mM of H_2O_2 reduction /	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Irrigation regimes (I)											
(I_1) 14 days		48.37 a	46.93 a	73.84 a	73.37 a	76.93 a	77.26 a	388.75 c	431.05 c	207.29 c	224.73 c
(I_2) 28 days		41.20 c	40.91 c	44.78 c	43.01 c	63.15 c	62.27 c	737.30 a	803.50 a	324.12 a	336.08 a
(I_3) 28 days + PAM		44.88 b	43.68 b	62.15 b	64.26 b	71.71 b	72.04 b	563.08 b	585.61 b	270.63 b	279.65 b
Stimulants (S)											
Control		41.07 d	41.33 d	56.31 c	57.09 c	68.20 c	67.46 d	603.41 a	644.76 a	243.54 b	260.47 c
SA		46.32 b	44.65 b	63.28 a	62.93 a	71.01 b	71.67 b	539.15 c	583.74 b	259.60ab	273.34bc
B		43.72 c	42.92 c	59.53 b	59.82 b	70.49 b	70.11 c	566.90 b	607.27 b	280.08 a	285.69ab
K		48.15 a	46.46 a	61.89ab	61.03 b	72.69 a	72.85 a	542.71 c	591.10 b	286.17 a	301.11 a
Interaction (I × S)											
14 days	Control	43.33cd	43.04 e	69.76bc	71.18 b	75.13bc	74.80 b	441.49 f	478.25 d	191.77 f	208.14 g
	SA	50.91 a	47.97 b	76.91 a	75.54 a	77.18ab	78.01 a	377.58 g	411.05 e	197.03 f	223.47 g
	B	46.82 b	45.90 c	73.75 ab	73.22 ab	76.97ab	77.10 a	384.82 g	420.23 e	217.45 ef	228.96fg
	K	52.43 a	50.82 a	74.94 a	73.53 ab	78.42 a	79.13 a	351.12 g	414.67 e	222.92def	238.34efg
28 days	Control	38.67 f	39.57 g	40.40 h	39.60 g	60.83 h	59.77 g	782.44 a	843.48 a	291.67bc	306.85 cd
	SA	41.35 de	41.49 efg	47.22 fg	45.36 f	63.59 g	63.20 ef	693.78 c	773.42 b	313.62ab	316.82bc
	B	40.98 e	40.36 fg	43.12 gh	43.04 f	62.94gh	61.59 fg	746.20 b	813.40 ab	343.39 a	352.14ab
	K	43.80 c	42.21 ef	48.36 f	44.05 f	65.25 g	64.51 e	726.77bc	783.71 b	347.82 a	368.52 a
28 days + PAM	Control	41.21 e	41.37 efg	58.77 e	60.48 e	68.63 f	67.80 d	586.32 d	612.57 c	247.18cde	266.42def
	SA	46.72 b	44.48 cd	65.72 cd	67.88 c	72.27de	73.80 b	546.10 e	566.75 c	268.15bcd	279.75cd
	B	43.37 cd	42.51 de	61.73 de	63.19 d	71.55 e	71.63 c	569.67de	588.18 c	279.39bc	275.96cde
	K	48.23 b	46.35 bc	62.36 de	65.50 cd	74.38cd	74.91 b	550.24de	574.93 c	287.79bc	296.48cd

PAM: Polyacrylamide, SA: Salicylic acid, B: Boric acid, K: potassium sulfate

II. Flowering and abscission

II.1. Effect of irrigation regimes

Variation in squares and bolls production as well as total abscission as affected by irrigation regimes are shown in Table (5). Irrigation cotton plants every 14 days produced the highest significant values of numbers of squares and bolls/plant. Meanwhile, the lowest ones recorded by delaying irrigation to 28 days, but recorded the highest total abscission %. Similar trend was reported by El-Gabiery (2016). Adding PAM polymer under water stress (I_3) enhancing square and boll production (6.07 and 26.81%), while decreasing the total abscission rate (14.66%) compared to without PAM (I_2). Xindong *et al*. (2011) concluded that adding PAM decreasing surface runoff, restricting soil water evaporation and increasing fertilizer utilization rate. When the amount of irrigation water is insufficient, it negatively impacts the plant's physiological and biochemical functions, leading to reduced nutrient uptake (Ahanger *et al*., 2016). Under experiment conditions, the bud formation began in mid-June, while bolls appeared in the beginning of July. These stages may be negatively impacted by insufficient soil moisture and high temperatures, which can disrupt the physiological and biochemical processes involved (EL-Shazly *et al*., 2024). As a result, there is a decline in the production of squares and bolls can occur. This finding indicated that irrigating every 14 days is the ideal schedule for the cotton variety Super Giza 97. Also, in the event of water shortage, PAM polymer must be added to help conserve water (Sojka *et al*., 2007).

Table 5. Effect of irrigation regimes, stimulant substances, and their interaction on squares and bolls production and total abscission of cotton during 2021 and 2022 seasons.

Treatments		No. of squares / plant		No. of total bolls/plant		Total abscission (%)	
		2021	2022	2021	2022	2021	2022
Irrigation regimes (I)							
(I_1) 14 days		43.50 a	41.20 a	24.35 a	22.11 a	44.04 b	46.30 c
(I_2) 28 days		36.86 b	35.82 c	15.67 c	15.53 c	57.48 a	56.57 a
(I_3) 28 days + PAM		39.38 b	37.72 b	20.29 b	19.28 b	48.37 b	48.95 b
Stimulants (S)							
Control		37.87 c	36.21 c	17.68 c	17.24 c	53.39 a	52.63 a
SA		42.33 a	39.88 a	21.90 a	20.28 a	48.70 b	49.27 b
B		39.00 bc	38.14 b	20.24 b	18.94 b	48.44 b	50.48 ab
K		40.44 b	38.75 ab	20.59 b	19.42 b	49.34 b	50.04 ab
Interaction (I × S)							
14 days	Control	41.67 bc	38.83 cd	20.33 d	20.67 bc	51.10 b	46.78 c
	SA	46.67 a	41.97 ab	27.47 a	23.27 a	41.04 d	44.51 c
	B	42.33 bc	40.33 bc	24.83 b	21.90 ab	41.28 d	45.67 c
	K	43.33 b	43.67 a	24.77 b	22.60 a	42.74 cd	48.24 c
28 days	Control	35.10 f	34.03 f	14.37 g	14.33 e	59.06 a	57.87 a
	SA	37.83 def	38.50 cd	16.57 f	16.83 d	56.16 a	56.28 a
	B	36.00 ef	35.50 ef	15.73 f	15.53 de	56.27 a	56.06 a
	K	38.50 de	35.25 ef	16.00 f	15.43 de	58.44 a	56.09 a
28 days + PAM	Control	36.83 def	35.77 ef	18.33 e	16.73 d	49.99 b	53.25 ab
	SA	42.50 b	39.17 cd	21.67 c	20.73 bc	48.89 b	47.03 c
	B	38.67 de	38.60 cd	20.17 d	19.40 c	47.76 b	49.72 bc
	K	39.50 cd	37.33 de	21.00 cd	20.23 c	46.83 bc	45.80 c

PAM: Polyacrylamide, SA: Salicylic acid, B: Boric acid, K: potassium sulfate

II.2. Effect of growth stimulants:

Respecting the effect of growth stimulants, the data in the same table indicated that foliar application of tested growth stimulants exhibit significant values of numbers of squares and bolls/plant and decreased abscission % in both seasons compared with untreated plants. The results indicate a negative correlation between the percentage of abscission and spray stimulants which enhance squares and bolls numbers while lowering the abscission % (El-Gabiery, 2016, El-Beltagi *et al*., 2017 and Huang *et al*., 2023). Abscission of squares and bolls in cotton is seen as a disorder in phytohormones and nutrients balance. Reduction of abscission can be achieved by ensuring that developing squares and bolls receive adequate photo-assimilates and nutrients (Ali *et al*., 2021). SA provides the highest squares and bolls numbers but lowest abscission% followed by K application (El-Beltagi *et al*., 2017 and Huang *et al*., 2023). SA plays an essential role in regulating plant growth by affecting cell division and cell expansion. It does this by stimulating the production of auxin biosynthetic enzymes and promoting the activity of auxin efflux proteins (Fujikura *et al*., 2020). Additionally, potassium plays crucial roles in enzyme activation, protein synthesis and rate of metabolic processes (Ibrahim *et al*., 2015). This may lead to stimulating flowering and consequently increase boll production. The superiority of SA and K amounted to 10.96 and 6.90% in squares production, and 20.75 and 14.55% in bolls production, respectively.

II.3. Effect of the interaction:

The highest values of squares and bolls numbers were obtained when the plants were irrigated every 14 days in presence of SA in the first season and SA and K in the second one as compared with the other combination treatments. Meanwhile, the lowest values were recorded by irrigated plants every 28 days in absence of growth stimulants (Table 5). The negative effects of drought on squares and bolls production of cotton plants can be minimized by adding PAM as well as foliar application of plant growth stimulants in favor of SA and K. Significant increases in numbers of squares and bolls were mostly recorded with foliar application of SA and potassium sulfate under different irrigation regimes (El-Gabiery, 2016). Total abscission has taken a direction opposite to these aforementioned results. Irrigated cotton plants every 14 days caused a reduction in total abscission by 17.16, 15.83 and 11.96% when treated with SA, B and K, respectively as compared with irrigated cotton plants every 28 days without stimulants. Exogenous application of PAM polymer and treated plants with K has reduced the negative effect of water stress on total abscission by 10.16%.

III. Yield and its attributes

III.1. Effect of irrigation regimes:

There are significant differences among the tested irrigation regimes with regard to all yield and its attributes characters in both seasons Table (6). Irrigated cotton plants every 14 days (I_1) gave the highest values of plant height and number of fruiting branches followed by irrigated cotton plants every 28 days + PAM (I_3). Meanwhile, the lowest values were produced by irrigated cotton plants every 28 days (I_2). Drought stress can lead to shorter plant height and lower branches because it interferes with the movement of water from the xylem to the cells (El-Gabiery, 2016). This disruption can also result in lower levels of growth-promoting hormones, affecting cell elongation, cell expansion, and mitosis during cell division (Farooq *et al.*, 2009).

Irrigation every 14 days (I_1) was more effective to produce the highest number of open bolls/plant, and heaviest boll weight and 100-seed weight. In the second season, there were no significant differences between I_1 and I_3. The higher weight of bolls might result from increased photosynthesis and the photo-assimilate translocation from leaves to the fruits. Increasing the irrigation interval to 28 days (I_2) caused a reduction in number of open bolls/plant, boll weight and 100-seed weight about 38.89, 15.65 and 14.83%, respectively. Similar trend reported by El-Gabiery (2016). Adding PAM had a significant positive role by minimizing this reduction to 13.27, 4.28 and 5.60%, respectively. The beneficial impact of superabsorbent polymers may be attributed to their ability to adhere to plant roots and enhance the soil's water retention. When soil moisture levels decrease, these polymers gradually release water back to the plants as required (Wu *et al*., 2010 and Ali and Abdel-Aal, 2021).

Seed cotton yield either plant or fed was negatively impacted by longer irrigation interval to 28 days. The findings indicated that exposing cotton plants to water stress (I_2) by extending irrigation intervals to 28 days without adding PAM led to a significant reduction in seed cotton yield per plant and fed amounted to 38.33 and 28.47%, respectively. This decline can be attributed to a negative effect of drought on physiological and biochemical traits (Table 4), squares and bolls production (Table 5) and yield-related traits (Table 6) as previously mentioned. Soil application of PAM to plants irrigated every 28 days had a positive role by minimizing this reduction to 10.42 and 15.36% only, respectively. Similar trends were reported by El-Sayed and Add El All (2022), ELAshmouny and Moursi (2024) and EL-Shazly *et al.* (2024) who reported that increasing irrigation interval caused a reduction in seed cotton yield and its components.

Irrigated plants every 14 days (I_1) boosted the lint%, while delaying irrigation in presence of application of PAM (I_3) recorded the highest earliness% when compared to other irrigation regimes. The differences between I_1 and I_3 in the second season for lint% did not reach the level of significance. The superiority of I_1 in lint percentage and I_3 in earliness percentage may be due to their positive impact on translocation of photosynthetic products to bolls, which likely helps for achieving physiological maturity. In this concern, El-Gabiery (2016) concluded that delaying irrigation cotton plants produced the highest values of lint and earliness%.

Table 6. Effect of irrigation regimes, stimulant substances, and their interaction on yield and its attributes of cotton during 2021 and 2022 seasons.

Treatments		Plant height (cm)		No. of fruiting branches/plant		No. of open bolls /plant		Boll weight (g)	
		2021	2022	2021	2022	2021	2022	2021	2022
Irrigation regimes (I)									
(I_1) 14 days		147.53 a	141.58 a	15.75 a	17.50 a	22.55 a	20.03 a	2.68 a	2.69 a
(I_2) 28 days		114.33 c	117.08 c	12.92 c	13.92 c	13.23 c	12.73 c	2.21 c	2.32 b
(I_3) 28 days + PAM		128.48 b	126.04 b	14.42 b	15.67 b	19.29 b	17.61 b	2.54 b	2.60 a
Stimulants (S)									
Control		126.56 c	124.72 b	12.78 c	14.67 d	15.76 d	14.86 d	2.33 b	2.37 c
SA		134.48 a	130.64 a	15.44 a	16.89 a	20.87 a	18.72 a	2.55 a	2.58 ab
B		128.61 bc	128.33 a	14.44 b	15.33 c	17.63 c	16.03 c	2.42 b	2.50 bc
K		130.81 b	129.23 a	14.78 b	15.89 b	19.17 b	17.54 b	2.60 a	2.70 a
Interaction (I × S)									
14 days	Control	144.67 b	138.40 b	14.33 de	16.33 bc	18.83 d	17.90 d	2.55 cd	2.49 b-e
	SA	150.17 a	144.17 a	17.33 a	18.67 a	26.27 a	22.30 a	2.77 ab	2.72 ab
	B	147.33 ab	142.00 ab	15.33 bc	17.00 b	21.23 c	19.30 bc	2.60 bcd	2.62 bc
	K	147.93 ab	141.73 ab	16.00 b	18.00 a	23.87 b	20.63 b	2.81 a	2.93 a
28 days	Control	111.67 g	114.73 e	11.67 h	13.00 h	11.60 h	11.70 h	2.11 g	2.20 f
	SA	118.00 f	119.27 de	13.67 ef	15.00 de	14.83 f	13.93 fg	2.23 fg	2.34 def
	B	112.67 g	116.60 de	13.00 fg	13.67 gh	12.67gh	12.27 h	2.19 fg	2.30 ef
	K	115.00 fg	117.73 de	13.33 f	14.00 fg	13.80 fg	13.00 gh	2.31 ef	2.43 c-f
28 days + PAM	Control	123.33 e	121.03 d	12.33 gh	14.67 ef	16.83 e	14.97 f	2.35 ef	2.41 c-f
	SA	135.27 c	128.50 c	15.33 bc	17.00 b	21.50 c	19.93 bc	2.64 a-d	2.67 bc
	B	125.83 de	126.40c	15.00 cd	15.33 de	19.00 d	16.53 e	2.47 de	2.58 bcd
	K	129.50 d	128.23 c	15.00 cd	15.67 cd	19.83 cd	19.00 bc	2.68 abc	2.73 ab

PAM: Polyacrylamide, SA: Salicylic acid, B: Boric acid, K: potassium sulfate

Table 6. Continued.

Treatments		100- seed weight (g)		Seed cotton yield / plant (g)		Seed cotton yield / fed (kentar)		Lint (%)		Earliness (%)	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Irrigation regimes (I)											
(I_1) 14 days		13.30 a	11.73 a	48.19 a	46.18 a	12.15 a	11.34 a	38.55 a	38.52 a	58.53 b	60.79 b
(I_2) 28 days		11.43 c	9.99 c	28.11 b	30.02 c	8.22 c	8.55 c	37.46 c	37.72 b	53.98 c	56.28 c
(I_3) 28 days + PAM		12.83 b	10.83 b	42.98 a	41.55 b	10.11 b	9.76 b	38.05 b	38.16 ab	61.24 a	62.72 a
Stimulants (S)											
Control		11.70 c	10.46 b	33.46 c	34.03 d	9.12 d	8.89 d	37.25 c	37.59 c	54.22 c	56.90 c
SA		12.69 b	11.09 a	44.24 a	43.26 a	11.12 a	10.82 a	37.85 b	38.06 b	61.10 a	61.82 a
B		12.37 b	10.57 b	38.57 b	38.48 c	9.70 c	9.52 c	38.13 b	38.29 ab	56.82 b	59.66 b
K		13.32 a	11.28 a	42.76 a	41.23 b	10.71 b	10.31 b	38.84 a	38.61 a	59.51 a	61.33 a
Interaction (I × S)											
14 days	Control	12.41 b-e	11.20 b	40.52 cd	41.54 de	10.75 c	10.31 c	38.05 a	38.19 a	54.20 cd	58.13 cd
	SA	13.40 ab	12.06 a	52.99 a	50.24 a	13.42 a	12.45 a	38.24 a	38.39 a	62.73 ab	63.13 a
	B	13.02bcd	11.33 b	47.27 b	45.13 c	11.37 b	10.95 c	38.38 a	38.45 a	56.60 c	59.63 bc
	K	14.37 a	12.32 a	51.97 a	47.81 b	13.05 a	11.65 b	39.52 a	39.07 a	60.57 b	62.27 ab
28 days	Control	10.67 f	9.77 d	22.84 g	24.34 i	7.72 f	7.65 f	36.30 a	36.96 a	51.77 d	54.47 e
	SA	11.46 ef	10.14 cd	32.21 e	33.68 g	8.88 e	9.32 d	37.52 a	37.68 a	55.43 c	57.50 cd
	B	11.41 ef	9.83 d	27.12 f	29.78 h	8.04 f	8.32 e	37.73 a	38.08 a	53.53 cd	55.57 de
	K	12.16 cde	10.21cd	30.25 ef	32.27 g	8.25 f	8.90 de	38.29 a	38.16 a	55.17 c	57.57 cd
28 days + PAM	Control	12.02 de	10.41 c	37.02 d	36.20 f	8.89 e	8.71 de	37.42 a	37.62 a	56.70 c	58.10 cd
	SA	13.22 bc	11.05 b	47.54 b	45.87 bc	11.05 bc	10.68 c	37.81 a	38.10 a	65.13 a	64.83 a
	B	12.67 bcd	10.54 c	41.31 c	40.54 e	9.69 d	9.28 d	38.29 a	38.34 a	60.33 b	63.77 a
	K	13.42 ab	11.31 b	46.05 b	43.60 cd	10.82 bc	10.36 c	38.70 a	38.59 a	62.80 ab	64.17 a

PAM: Polyacrylamide, SA: Salicylic acid, B: Boric acid, K: potassium sulfate

III.2. Effect of growth stimulants

Data tabulated in Table (6) indicated that application of SA had the greatest plant height and number of fruiting branches with amount 5.50 and 17.97% as an average of both growing seasons. In the second season, the differences among SA, B and K for plant height did not reach the level of significance. The stimulating effect of SA may result from an increased rate of photosynthesis in leaves. This enhancement allows for a greater mobilization of photosynthetic products, which are then delivered to the new growing tissues (Pettigrew, 2008). In this concern, the beneficial roles of SA and K were previously reported by El-Beltagi *et al.* (2017).

It is evident that application of SA recorded the first rank in producing number of open bolls, while K produced the heaviest boll weight and 100-seed weight followed by SA. These findings might be due to enhance supply of carbohydrates to bolls through positive contributive effects of SA and K in photosynthetic pigments and reduces the abscission. Open bolls, boll weight and seed weight could be increased by application of K (El-Beltagi *et al*., 2017 and Yasmeen *et al*., 2018) and SA (EL-Shazly *et al*., 2024) compared to untreated cotton plants.

Significant increases in seed cotton yield/plant by 29.67, 24.48 and 14.03% and in seed cotton yield/fed by about 21.82, 16.70 and 6.72% with the foliar application of SA, K and B, respectively compared to untreated plants. These effects could result from how antioxidant systems help plants resist oxidative stress and manage free radical levels in their tissues (El-Beltagi *et al*., 2017). The higher seed cotton yield achieved correlates with the increase in enzymes activity, photosynthetic pigments (Table 4), and other yield-related traits (number of open bolls and boll weight) as indicated in Table 6. This aligns with the findings reported by El-Gabiery (2016), Yasmeen *et al*. (2018) and EL-Shazly *et al*. (2024).

Lint and earliness percentages in both seasons positively responded to stimulants application. Potassium sulfate in both seasons and boron in one season have a positive role in increasing lint % as previously reported by El-Gabiery (2016) and El-Beltagi *et al*. (2017). However, application of SA followed by K were the superior in earliness percentage of cotton without significant between them compared to untreated plants as previously stated by EL-Shazly *et al*. (2024). Higher lint and earliness percentages occurred by K and SA could be attributed to its beneficial effect on the movement of photosynthetic products to the bolls, which leads to earlier opening of bolls and a quicker maturity compared to untreated plants. In this concern, Coker and Oosterhuis (2003) reported that foliar application of potassium increased lint yield by 101 kg/ha.

III.3. Effect of the interaction:

The interaction between irrigation regimes and growth stimulants significantly affects yield and its attributes in both seasons with the exception of lint%. Notably, cotton plants that were irrigated every 14 days in combination with SA or K recorded the highest values, where there were exchange ranks in achieving the highest values of yield and its attributes in both growing seasons. On the other hand, the plants that were watered every 28 days and untreated with any stimulants recorded the lowest values, while cotton plants possessed their higher mean values of earliness% when the plants were irrigated every 28 days + PAM (I_3) or irrigated every 14 days (I_1) in combination of sprayed with SA in both seasons. These findings were consistent with El-Gabiery (2016) and EL-Shazly *et al*. (2024). Soil application of PAM polymer and foliar application of SA or K has become a positive and sustainable strategy in plants under drought stress and is an emerging trend to increase yield and reduce abiotic stresses. The combination of treatments (I_3×SA) or (I_3×K) achieved seed cotton yield/fed that is statistically equal to the treatment combination (I_1×control) in both growing seasons. This indicates that (I_3×SA) or (I_3×K) are optimal combination treatments under limited irrigation conditions.

Recently, released varieties of cotton have high yielding ability, which mainly relies on providing the plants with ideal environmental requirements. Drought stress has a considerable impact on partitioning carbohydrates and dry matter accumulation. Therefore, it is essential to treated cotton plants with growth stimulants that had defense mechanism to alleviating the harmful effects of drought especially on growth, and flowering and bolls production ultimately leading to increase the seed cotton yield.

IV. Water relations

IV.1. Effect of irrigation regimes

Data graphically illustrated in Figure (1) indicated significant changes in moisture content in soil layer (0-30 cm) occurred by irrigation regimes in both seasons. Irrigated soil every 14 days (I_1) had the highest moisture content (28.33 and 27.94%), while increasing the irrigation interval to 28 days (I_2) recorded the lowest ones (19.98 and 20.64%), in the first and second seasons, respectively. Application of PAM (I_3) had positive effect on saving the soil moisture, where recorded 25.20 and 24.96%, in the first and second seasons, respectively with increases 26.13 and 20.93% above I_2 regime. Conserving moisture by PAM might be due to improving the linkage between soil particles at the surface, leading to the formation and stability of water aggregates and reducing soil water evaporation and leaching (Barvenik, 1994 and Sojka *et al*., 2007). Experimental findings by Xindong *et al*. (2011) indicated that throughout the growth period of maize, the water content in the 0-

100 cm soil layer treated with PAM was consistently higher than that of the untreated soil. Moreover, as the concentration of PAM increased, the soil water content also showed a rising trend. Overall, the soil treated with PAM had a water content increase of 5.62% to 10.96% compared to the untreated soil.

Data graphically illustrated in Figure (2) shows the amount of water applied (m^3/fed) per each irrigation for normal irrigation (1^{st} - 9^{th}) and drought stress (1^{st} - 5^{th}) during the two growing seasons. The amount of irrigation water applied was gradually increased to reach its maximum at the irrigation No. 5^{th} for normal irrigation (I_1) and at the irrigation number 4^{th} for drought stress (I_2 and I_3) and then they gradually decreased up to the end of irrigation numbers. The amount of water applied per each irrigation was increased as the intervals between irrigation increased. Meanwhile, the total water applied (m^3/fed) was increased as the intervals between irrigation decreased as shown in the Table (7). In both growing seasons, the highest total water applied (3704.83 and 3683.81 m^3/fed) were noticed with cotton plants irrigated every 14 days (I_1), while the lowest ones (2669.66 and 2797.68 m^3/fed) were registered from those irrigated every 28 days in presence of PAM (I_3). However, irrigated cotton plants every 28 days without PAM recorded intermediate values (2953.23 and 3066.78 m^3/fed). This mean that irrigating cotton plants every 28 days + PAM (I3) can save the water by about 1035.17 and 886.13 m^3/fed (equivalent to 27.94 and 24.05%), respectively in both growing seasons and increase water productivity (WP) by 16.50 and 13.37% compared to normal irrigation every 14 days. From these results, it can be suggested that the reduction in total water applied as well as the increment of water saved, and water productivity obtained by I_3 may be due to the decrease in the number of irrigations applied and properties of PAM that allow to hold significant quantities of water and release it gradually. Where it is enhancing water retention in soils, helping to minimize runoff and ensure that moisture remains in the root zone of plant (Sojka *et al*., 2007 and Ekebafe *et al*., 2011). PAM polymer enhances soil aggregation and increases soil water content. It reduces water evaporation from the surface soil, improves air permeability, and boosts overall soil permeability. This leads to better crop root development and enhances drought tolerance of crops (Xindong *et al*., 2011), in addition save water (Ali and Abdel-Aal (2021). Previous investigation showed that increasing irrigation interval caused decline in water applied, while water saved and water productivity increased (ELAshmouny and Moursi, 2024).

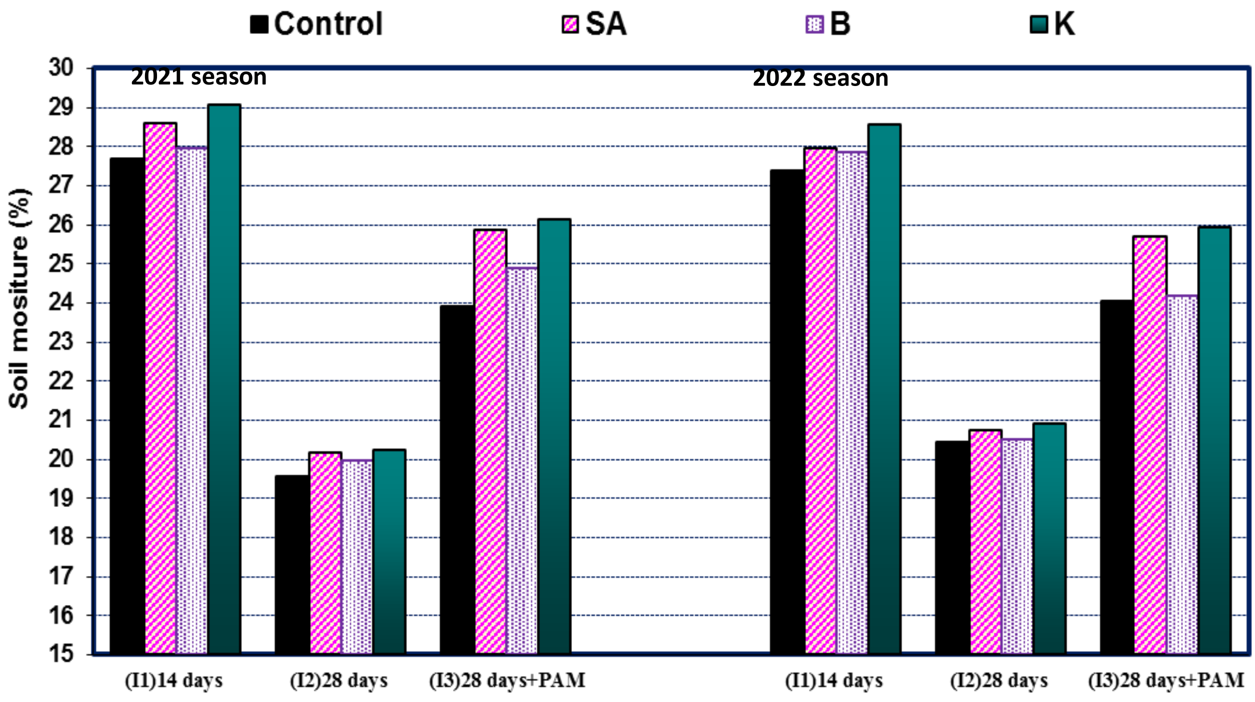

Fig. 1. Effect of irrigation regimes and stimulant substances on soil moisture.

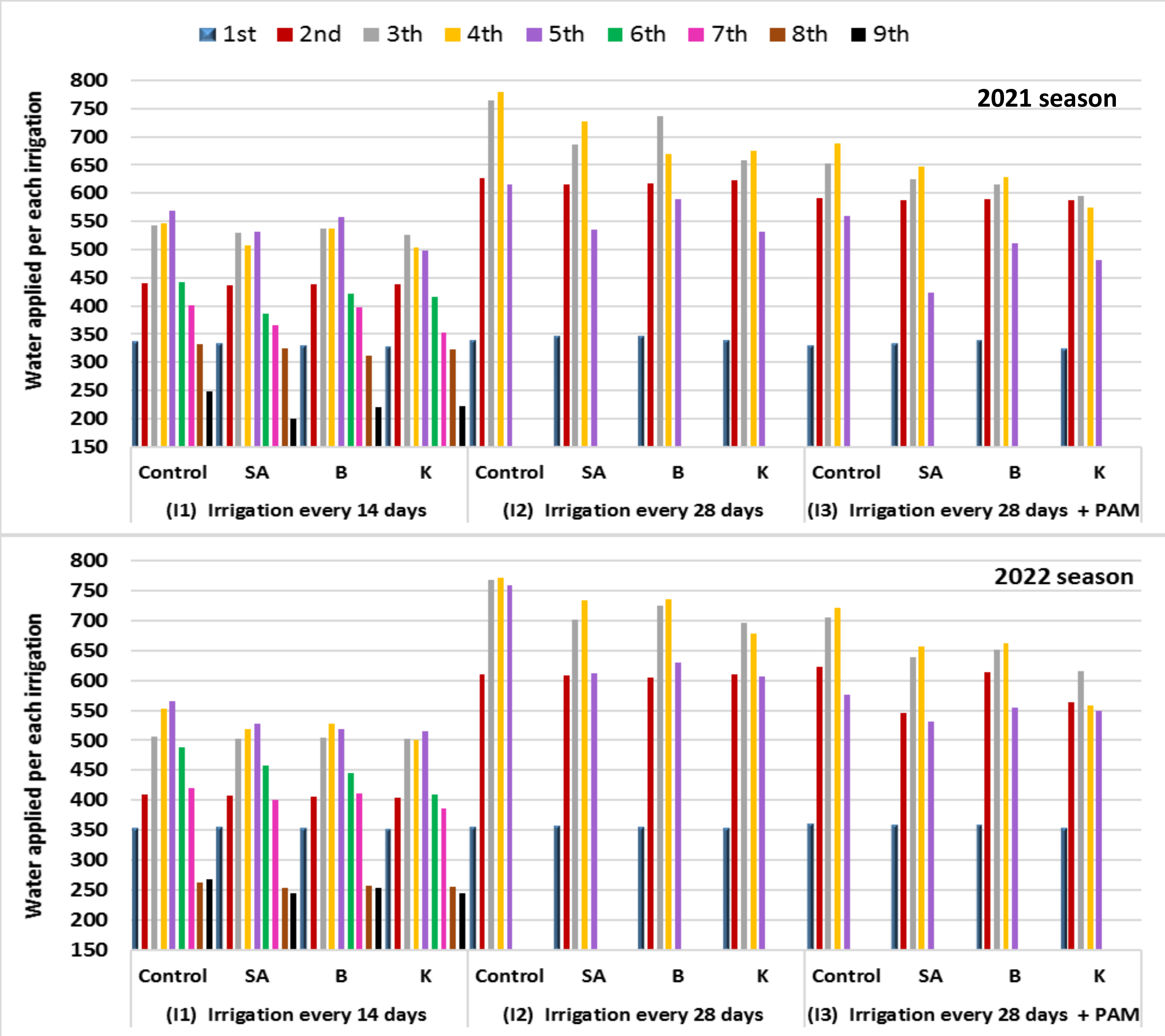

Fig. 2. Amount of water applied (m^3/fed) per irrigation for normal irrigation (1st - 9th) and drought stress (1st - 5th) during the two growing seasons.

IV.2. Effect of growth stimulants:

Concerning the effect of stimulants substances on moisture content (Figure 1), the data showed that application of stimulants in favor of K led to the preservation of soil moisture indirectly, perhaps due to that K is essential for regulating turgor pressure in guard cells, which manage the opening and closing of stomata (Marschner, 2012) and rising leaf resistance to diffusion of water vapor. When stomata close, there is a rapid release of K^+ ions from the guard cells into the surrounding leaf tissue. This led to a reduction in transpiration (Oosterhuis *et al.*, 2014) and consequently less depletion of moisture from the soil layer.

Data in Figure (2) and Table (7) declare that the highest total water applied (3266.65 and 3356.98 m^3/fed) recorded during crop growth stages was obtained by untreated plants in both seasons. Foliar application of growth stimulants plays an opposite role in decreasing total water applied and saved water by 8.72, 6.69 and 4.61%, for K, SA and B, respectively as an average of both seasons. Water productivity was significantly higher when cotton plants treated with SA and K without significant between them. The increment in water productivity amounted to 30.53 and 27.97% by those stimulants respectively. The superiority of stimulants could be explained in the light of their favorable effect on increasing seed cotton yield (Table 6) and decreasing water loss. Transpiration rate is a physiological characteristic that reflects the moisture in the soil, plant water requirement, and various environmental stresses (Weksler *et al.*, 2021). Researchers show that K regulate stomatal conductivity, where the plants given potassium exhibited lowest transpiration rates. Also, Hussain *et al.* (2009) mentioned that spraying salicylic acid improved the water status in plant organs. This improvement happened through osmotic adjustment, which was linked to the accumulation of compatible solutes. As a result, the ability of crops to regulate water balance increased. These results are in line with Hassan *et al.* (2016) and ELAshmouny and Moursi (2024).

IV.3. Effect of the interaction:

Data tabulated in Table (7) revealed significant interaction between irrigation practices and growth stimulants for total water applied and water productivity. The combination treatment ($I_1\times$ control) led to increase the total water applied (3856.74 and 3822.87 m^3/fed), while ($I_3 \times K$) recorded the lowest ones (2562.67 and 2637.59 m^3/fed) across both growing seasons. This decline by such treatment amounted to 32.28% as an average of both seasons. The increment in water saved may be related to the positive effects of PAM and K as previously discussed. It is obvious to notice that the greatest water productivity was recorded in cotton plants irrigated every 28 days + PAM (I_3), along with a foliar spray of SA (0.666 and 0.616 kg/m^3) or K (0.665 and 0.619 kg/m^3), without significant between them. Conversely, the lowest water productivity (0.390 and 0.369 kg/m^3) occurred by plants that were irrigated every 28 days in case of not receiving any stimulants. The superiority of the combination of treatments ($I_3\times$SA) or ($I_3\times$K) in water productivity may be related to that such combinations achieved seed cotton yield/fed (Table 6) that is statistically equal to the treatment combination ($I_1\times$control), utilizing significantly less water (Table 7). These results are agreement with ELAshmouny and Moursi (2024).

V. Correlation

Pearson's correlation coefficient (r) was estimated (Figure 3) to assess the association among all studied traits as affected by irrigation regimes and growth stimulants. The correlation was calculated as an average of both seasons after homogeneity test. In the correlogram, the color of each circle represents the correlation coefficient. A coefficient close to (+1) indicates a strong positive correlation and appears in blue color, while a coefficient near (-1) shows a strong negative correlation and is represented in red color. Additionally, the color size of the circles reflects the significance level.

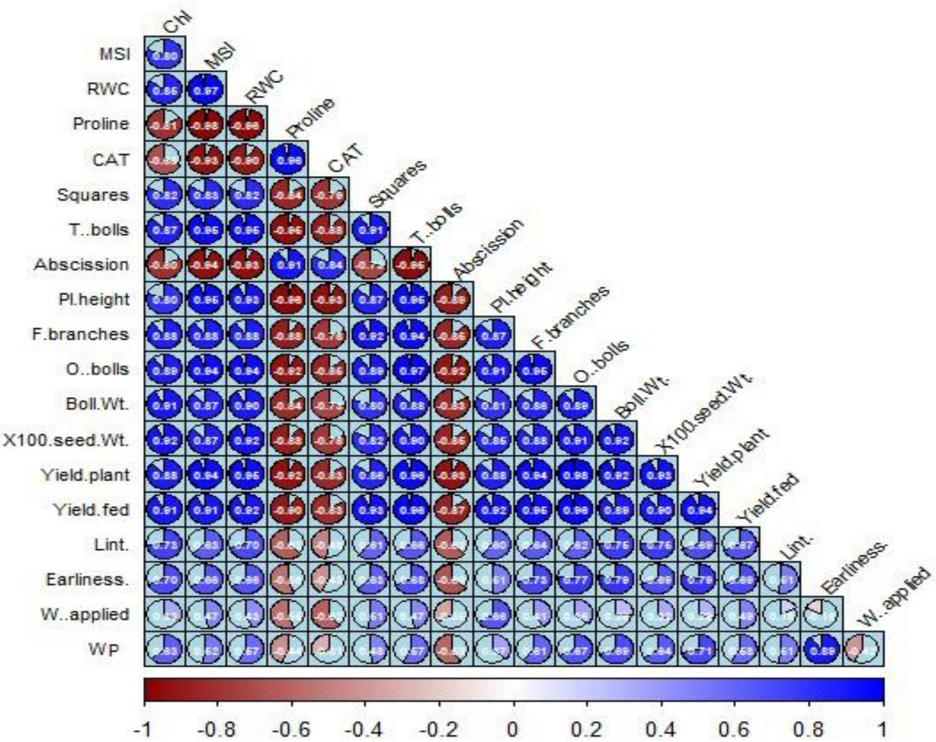

Fig. 3. Correlation coefficients among studied traits as overall irrigation regimes and growth stimulants (as an average of both seasons).

Insignificant correlation between water applied and each of Chl, abscission %, boll weight, 100-seed weight, seed cotton yield/plant, lint % and earliness %. Also, there is an insignificant correlation between WP and CAT. Other correlations were significant. Concerning the correlations among physiological traits, chlorophyll positively correlated with MSI and RWC, while negatively correlated with proline and CAT. MSI positively correlated with RWC, while negatively correlated with proline and CAT. RWC negatively correlated with proline and CAT. However, proline positively correlated with CAT.

Seed cotton yield/fed showed a strong positive correlation with the following traits: total bolls (+0.98), open bolls (+0.98), fruiting branches (0.96), and seed cotton yield/plant (+0.94). Also, other significant correlations included: squares (+0.93), RWC (+0.92), plant height (+0.92), chlorophyll (+0.91), MSI (+0.91), 100-seed weight (+0.90), boll weight (+0.89), earliness% (+0.88), lint% (+0.87), WP (+0.68), and total water applied (+0.49). However, seed cotton yield/fed negatively correlated with each of proline (-0.90), followed by abscission (-0.87) and CAT (-0.83). These results clearly indicated that a stronger association could be observed between seed cotton yield /fed and numbers of total bolls and open bolls than other traits.

VI. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was conducted to explore the relationships between various agronomic traits in cotton plants subjected to different irrigation regimes: I_1 (14 days), I_2 (28 days), and I3 (28 days + PAM). The results are visualized in the provided PCA plot (Figure 4). Among all the dimensions analyzed for the PC, the first dimensions are Dim1 and Dim2, had eigenvalues greater than 1. In contrast, the other dimensions showed eigenvalues less than 1. Together, these two dimensions accounted for 88.7 (with PC1 explaining 78.9% and PC2 9.4%) and 89.9% (with PC1 explaining 82.6% and PC2 6.3%) of the total variance in the first and second seasons, respectively. Therefore, PC1 and PC2 can be used as the basis of the relationships between measurements examined under water regimes.

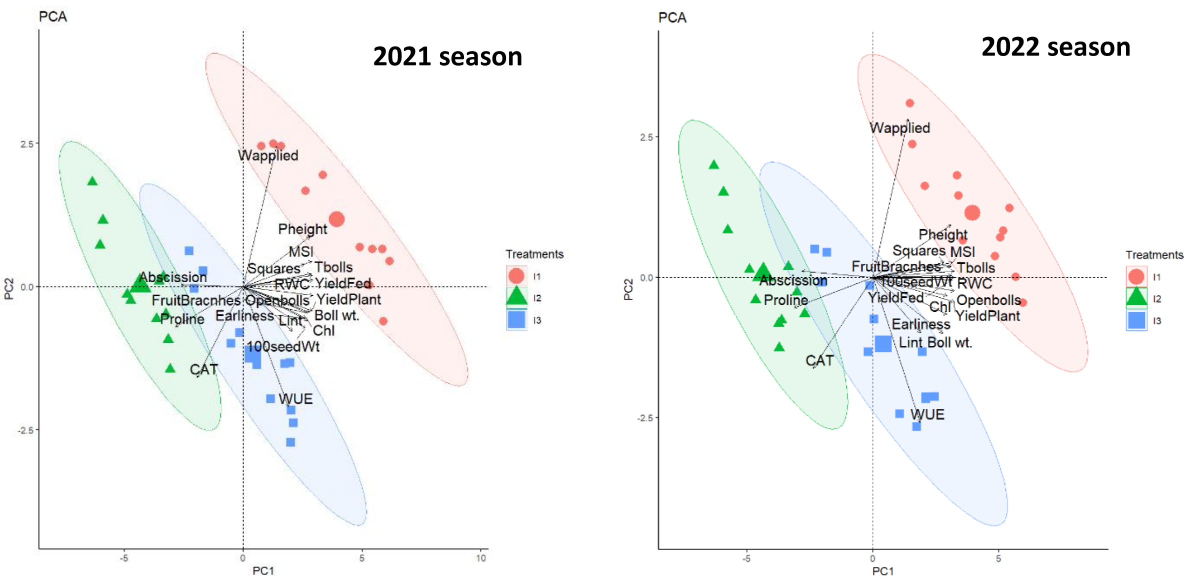

Fig. 4. Principal component analysis for cotton measurements subjected to different irrigation regimes in both seasons.

The first principal component (PC1) captures the majority of the variation in the data and is primarily associated with seed cotton yield-related traits. The direction of PC1 is likely linked to higher seed cotton yield. The clustering of data points for treatment I_1 in the positive direction of PC1 indicates that this treatment is associated with higher yield compared to I_2 and I_3. The second principal component (PC2) explains a smaller portion of the variation. Irrigation regimes showed a distinct pattern among most traits studied, indicating a positive correlation. However, the strength and consistency of this correlation differ for each trait. The contributions revealed a sharp angle among most studied measurements, demonstrating a positive correlation. Irrigated cotton plants every 28 days (I_2) was more correlated with abscission%, proline and CAT, while other traits were more correlated with I_1 and I_3. For instance, there was a very strong positive correlation between seed cotton yield and numbers of total bolls and open bolls/ plant.

Conclusion

Based on the interaction results, it can be concluded that adding PAM polymer to the soil during cultivation and foliar application of growth stimulants especially salicylic acid under drought stress positively affects plant physiological performance and seed cotton yield through a defensive mechanism against drought stress. This provides a new approach to water management aimed at reducing water stress. The use of agricultural superabsorbent polymers to enhance water and nutrient use efficiencies will become increasingly important in the future. Therefore, PAM and SA can be used as a practical and effective strategy to enhance drought tolerance in cotton plants and improve irrigation water utilization, representing a significant advancement in managing drought in salt-affected soil.

Consent for publication:

All authors declare their consent for publication.

Author contribution:

The manuscript was edited and revised by all authors.

Conflicts of Interest:

The author declares no conflict of interest.

References

Aase, J.K., Bjorneberg, D.L., & Sojka, R.E. (1998) Sprinkler irrigation runoff and erosion control with polyacrylamide-laboratory tests. *Soil Sci. Soc. Am. J.*, 62, 1681-1687.

Abbas, M.A., Sarwar, G., Shah, S. H., Muhammad, S., Zafar, A., Manzoor, M.Z., Murtaza, G., & Latif, M. (2022) Evaluating the effectiveness of boron on the growth of cotton (*Gossypium hirsutum* L.) under saline conditions. *Pak. J. Bot.*, 54(5), 1619-1628.

Addad, Dalila, Hamli, S., Mekersi, N., Kadi, K., Dib, D., Hamdellou, A., Khelifi, A., Lekmine, S., Kellil, H., Gueboudji, Z. & Bouzerzour, H. (2025) Morpho-physiological responses of durum wheat (*Triticum durum* Desf.) seedlings to drought stress and their correlation with yield. *Egypt. J. Agron.* 47 (2), 179-209.

Ahanger, M.A., Talab N.M., Abd-Allah E.F., Ahmad P., & Hajiboland R. (2016) Plant growth under drought stress: Significance of mineral nutrients. *Water Stress and Crop plants: a Sustainable approach*, 2, 649-668.

Ali, O.A.M., Abdel-Aal, M.S.M., & Hussien, M.A.M. (2021) Effect of plant distribution patterns and growth regulators on morphological, yield and technological characters of Egyptian cotton. *J. of Plant Production*, 12(8), 847-860.

Ali, O.A.M. & Abdel-Aal, M.S.M. (2021) Importance of some soil amendments on improving growth, productivity and quality of soybean grown under different irrigation intervals. *Egypt. J. Agron.* 43 (1), 13-27.

Barrs, H.D. (1968) Determination of water deficits in plant tissues. *In*: T.T. Kozolvski (Ed.). *Water Deficits and Plant Growth*, 235–368 pp. Academic Press, New Delhi.

Barvenik, F. W. (1994) Polyacrylamide characteristics related to soil applications. Soil Sci, 158(4), 235-243.

Bates, L.S., Waldren, R.P., & Teare, I.D. (1973) Rapid determination of free proline for water-stress studies. *Plant and Soil*, 39, 205-207. https://doi.org/10.1007/BF00018060

Black, C.A. (1965) *Method of Soil Analysis.* American Society of Agronomy, Inc, Publisher, Madison, Wisconsin USA.

Chapman, H., & Pratt, P. (1978) *Methods of Analysis for Soils and Waters*, USA, University of California, Division of Agriculture Science, CA.

Coker, D.L., & Oosterhuis, D.M. (2003) Effects of soil and foliar potassium status and water deficit on cotton physiology and yield. *World Cotton Research Conference*, Cape Town - South Africa.

CoStat (2017) CoStat Software for Windows, Ver 6.45. Release 02.1.2017. CoHort software. https://www.cohortsoftware.com/costat.html.

Duncan, D.B. (1955) Multiple range and multiple F. tests. *Biometrics*, 11, 1-42.

Ekebafe, L.O., Ogbeifun, D.E., & Okieimen, F.E. (2011) Polymer applications in agriculture. *Biokemistri*, 23(2), 81-89.

ELAshmouny, A.A., & Moursi, E. A. F. (2024) Effect of anti-transpirants foliar application on productivity and quality of Egyptian cotton under water stress conditions in clay soils. *J. of Agricultural, Environmental and Veterinary Sci.*, 8(1), 62-74.

El-Beltagi, H.S., Ahmed, S. H., Namich, A. A. M., & Abdel-Sattar, R. R. (2017) Effect of salicylic acid and potassium citrate on cotton plant under salt stress. *Fresenius Environmental Bulletin*, 26 (1A), 1091-1100.

El-Gabiery, A.E. (2016) Response of cotton plant to spraying some natural materials under water stress conditions. *J. Plant Prod., Mansoura Univ*., 7(12), 1295-1302.

El-Sayed, S.O., & Abd El All, A.M. (2022) Effect of foliar spraying with anti-transpirants natural materials under different irrigation intervals on productivity and quality of cotton plant cv. Super Giza 86. Middle East *J. of Applied Sciences*, 12(4), 468-498.

EL-Shazly, M.W.M., El-Ashmouny, Amany, A., & Abd El All, A.M. (2024) Effect of some antioxidants on growth, certain physiological aspects, and productivity of cotton grown under three different irrigation intervals. *Menoufia J. of Plant Production*, 9(3), 143-167.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. & Basra, S.M.A. (2009) Plant drought stress, effects, mechanisms and management. *Agron. for Sustain. Dev.*, 29(1), 185-212.

Fujikura, U., Kazune, E., Horiguchi, G., Seo, M., Yuri, K., Yuji, K., Lenhard, M. & Tsukaya, H. (2020) Suppression of class I compensated cell enlargement by xs2 mutation is mediated by salicylic acid signaling. *PLoS Genet.*, 16(6), e1008873, 1-17.

Gadallah, M.A.A. (1995) Effect of water stress, abscisic acid and proline on cotton plants. *J. of arid environments*, 30(3), 315-325.

Gebicka, L., & Krych-Madej, J. (2019) The role of catalases in the prevention/promotion of oxidative stress. *J. of inorganic biochemistry*, 197, 110699.

Gupta, S., Gupta, N.K., Arora, A., Agarwal, V.P., & Purohit, A.K. (2012) Effect of water stress on photosynthetic attributes, membrane stability and yield in contrasting wheat genotypes. *Indian J. Plant Physiol*, *17*(1), 22-27.

Hafeez, M.N., Sadique, S., Hassan, S., Sarwar, M.B., Rashid, B., Ali, Q., & Husnain, T. (2015) Physiological, morphological, biochemical and molecular basis of drought tolerance in cotton. *Int. J. Biol. Pharm. Allied Sci*., 4, 1091-1112.

Hasanuzzaman, M., Bhuyan, M. B., Zulfiqar, F., Raza, A., Mohsin, S. M., Al Mahmud, J., Fujita, M., & Fotopoulos, V. (2020) Reactive oxygen species and antioxidant defense in plants under abiotic stress: Revisiting the crucial role of a universal defense regulator. *Antioxidants*, 9(8), 681, 1-52.

Hasanuzzaman, M., Hossain, M.A., Teixeira da Silva, J.A., & Fujita, M. (2012) Plant responses and tolerance to abiotic oxidative stress: Antioxidant defense is a key factor. *In Crop Stress and its Management*: Perspectives and Strategies; Bandi, V., Shanker, A.K., Shanker, C., & Mandapaka, M., Eds.; Springer, Berlin, Germany, pp. 261–316.

Hassan, S.F., Ahmed S.A. & Mohammed, L.I. (2016) Response of cotton to potassium levels under water regime. *Int. J. Appl. Agric. Sci.*, 2(4),56-63.

Hu, W., Jiang, N., Yang, J., Meng, Y., Wang, Y., Chen, B., Zhao, W., Oosterhuis, D.M., & Zhou, Z. (2016) Potassium (K) supply affects K accumulation and photosynthetic physiology in two cotton (*Gossypium hirsutum* L.) cultivars with different K sensitivities. *Field Crops Res*., 196, 51-63. https://doi.org/10.1016/j.fcr.2016.06.005

Hu, W., Snider, J. L., Wang, H., Zhou, Z., Chastain, D. R., Whitaker, J., Perry C.D., & Bourland, F.M. (2018) Water-induced variation in yield and quality can be explained by altered yield component contributions in field-grown cotton. *Field Crops Res*., 224, 139-147. https://doi.org/10.1016/j.fcr.2018.05.013

Huang, L., Li, J., Yang, P., Zeng, X., Chen, Y., & Wang, H. (2023) Potassium application alleviated negative effects of soil waterlogging stress on photosynthesis and dry biomass in cotton. *Agronomy*, 13(4), 1157, 1-14. https://doi.org/10.3390/agronomy13041157

Hussain, M., Malik, M.A., Farooq, M., Khan, M.B., Akram, M. & Saleem, M.F. (2009) Exogenous glycine betaine and salicylic acid application improves water relations, allometry and quality of hybrid sunflower under water deficit conditions. *J. Agron. Crop Sci*., 195, 98-109. https://doi.org/10.1111/j.1439-037X.2008.00354.x

Hussein, M.M., Mehanna, H., &Abou-Baker, N.H. (2012) Growth, photosynthetic pigments and mineral status of cotton plants as affected by salicylic acid and salt stress. *J. of Applied Sci. Res*., 8(11), 5476-5484.

Ibrahim, M.F.M., Abd El–Gawad, H.G. & Bondok, A.M. (2015) Physiological impacts of potassium citrate and folic acid on growth, yield and some viral diseases of potato plants. *Middle East J. of Agriculture Res*., 4(3), 577- 589.

Iqbal, N., Umar, S., Khan, N. A., & Khan, M. I. R. (2014) A new perspective of phytohormones in salinity tolerance: regulation of proline metabolism. Environ. Exp. Bot. 100, 34-42. doi: 10.1016/j.envexpbot.2013.12.006

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India, Ltd., New Delhi.

Jaleel, C.A., Gopi, R., Manivannan, P. & Panneerselvam, R. (2007) Antioxidative potentials as a protective mechanism in *Catharanthus roseus* (L.) G. Don. plants under salinity stress. *Turkish J. of Botany*, 31(3), 245-251.

Kawakami, E. M.; Oosterhuis, D. M. & Snider, J. L. (2010) Physiological effects of 1-methylcyclopropene on well-watered and water stressed cotton plants. J. *Plant Growth Regul*., 29, 280-288.

Khalvandi, M., Siosemardeh, A., Roohi, E., & Keramati, S. (2021) Salicylic acid alleviated the effect of drought stress on photosynthetic characteristics and leaf protein pattern in winter wheat. *Heliyon*, 7(1),1-11.

Khan, M. I. R., Iqbal, N., Masood, A., Per, T. S., & Khan, N. A. (2013) Salicylic acid alleviates adverse effects of heat stress on photosynthesis through changes in proline production and ethylene formation. *Plant Signal. Behav*., 8 (11), e26374, 1-10. https://doi.org/10.4161/psb.26374

Lu, K., Yan, L., Riaz, M., Babar, S., Hou, J., Zhang, Y., & Jiang, C. (2023) Exogenous boron alleviates salt stress in cotton by maintaining cell wall structure and ion homeostasis. *Plant Physiology and Biochemistry*, 201 (1), 107858. https://doi.org/10.1016/j.plaphy.2023.107858

Mabrouk, M.B., Jonoski, A., Solomatine, D., & Uhlenbrook, S. (2013) A review of seawater intrusion in the Nile Delta groundwater system – the basis for assessing impacts due to climate changes and water resources development. Hydrol. *Earth Syst. Sci. Discuss*. 10, 10873–10911.

Marschner, P. (2012) *Marschner's Mineral Nutrition of Higher Plants*. 3rd ed. Academic Press; London, UK, pp. 178–189.

Michael, A.M. (1978) *Irrigation Theory and Practice*. Vikas publishing House PVT. Ltd.

Mittler, R. (2002) Oxidative stress, antioxidants and stress tolerance. *Trend Plant Sci*., 7, 405-410.

Nadarajah, K., Abdul Hamid, N.W., & Abdul Rahman, N.S.N. (2021) SA-mediated regulation and control of abiotic stress tolerance in rice. *International J. of Molecular Sci.*, 22(11), 5591, 1-16.

O'Neill, M.A., Ishii T., Albersheim P., & Darvill A.G. (2004) Rhamnogalacturonan II: structure and function of a borate cross-linked cell wall pectic polysaccharide. Annu. Rev. Plant Biol. 55, 109–139. https://doi.org/10.1146/annurev.arplant.55.031903.141750

Oosterhuis, D.M., Loka, D.A., Kawakami, E.M., & Pettigrew, W.T. (2014) Chapter three - The physiology of potassium in crop production.

Advances in agronomy, 126, 203-233. https://doi.org/10.1016/B978-0-12-800132-5.00003-1

Pettigrew, W.T. (2008) Potassium influences on yield and quality production for maize, wheat, soybean and cotton. *Physiol. Plantarum*, 133, 670-681.

R (2020). The R Project for Statistical Computing, Ver 4.00. Release 24.4.2020. R software. https://www.r-project.org/.

Rehman, M., Bakhsh, A., Zubair, M., Rehmani, M.I.A., Shahzad, A., Nayab, S.F., Khan, M.M., Anum, W., Akhta, R., Kanwal, N., Manzoor, N., & Ali, I. (2021) Effects of water stress on cotton (*Gossypium* spp.) plants and productivity. *Egypt. J. of Agronomy*, 43(3), 307-315.

Riaz, M., Kamran, M., Fang, Y., Yang, G., Rizwan, M., Ali, S., Zhou, Y., Wang, Q., Deng, L., Wang, Y., & Wang, X. (2021) Boron supply alleviates cadmium toxicity in rice (*Oryza sativa* L.) by enhancing cadmium adsorption on cell wall and triggering antioxidant defense system in roots. *Chemosphere*, 266, 128938. 10.1016/j.chemosphere.2020.128938

Sahito, A.; Baloch, Z.A., Mahar, A., Otho, S.A., Kalhoro, S.A., Ali, A.; Kalhoro, F.A., Soomro, R.N., & Ali, F. (2015) Effect of water stress on the growth and yield of cotton crop (*Gossypium hirsutum* L.). *Am. J. Plant Sci*., 6, 1027-1039.

Sairam, R.K., Deshmukh, P.S., & Shukla, D.S. (1997) Tolerance to drought and temperature stress in relation to increased antioxidant enzyme activity in wheat. *J. Agron. Crop Sci*. 178, 171-177.

Shallan, M.A., Hassan, H., Namich, A.A., & Ibrahim, A.A. (2016) Biochemical and physiological effects of TiO_2 and SiO_2 nanoparticles on cotton plant under drought stress. *Research J. of Pharmaceutical, Biological and Chemical Sci.*, 7(4), 1540-1551.

Shohani, F., Fazeli, A. & Sarghein, S.H. (2023) The effect of silicon application and salicylic acid on enzymatic and non-enzymatic reactions of *Scrophularia striata* L. under drought stress. Scientia Horticulturae, 319, 112143, 1-15. https://doi.org/10.1016/j.scienta.2023.112143

Snedecor, G.W., & Cochran, W.G. (1989) Statistical Methods, 8thEd, USA, Iowa State University Press.

Sojka, R.E., Bjorneberg, D. L., Entry, J. A., Lentz, R. D., & Orts, W. J. (2007) Polyacrylamide in agriculture and environmental land management. *Advances in Agronomy*, 92, 75-162.

Sojka, R.E., & Surapaneni, A. (2000) *Polyacrylamides in irrigated agriculture. National Program for Irrigation Research and Development*. Project No. UNE39, 1-32.

Soil Science Society of America (2008) *Glossary of Soil Science Terms*, 2008. ASA-CSSA-SSSA. pp 62.

Szalai, G., Páldi, E., & Janda, T. (2005) Effect of salt stress on the endogenous salicylic acid content in maize (*Zea mays* L.) plants. Acta Biol. Szeged. 2005, 49, 47-48.

Tarolli, P., Luo, J., Park, E., Barcaccia, G., & Masin, R. (2024) Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering. IScience, 27(2),108830, 1-9.

Wang, H., Liu, X., Yang, P., Wu, R., Wang, S., He, S., & Zhou, Q. (2022) Potassium application promote cotton acclimation to soil waterlogging stress by regulating endogenous protective enzymes activities and hormones contents. *Plant Physiology and Biochemistry*, 185, 336-343. https://doi.org/10.1016/j.plaphy.2022.06.019

Weksler, S., Rozenstein, O., Haish, N., Moshelion, M., Wallach, R., & Ben-Dor, E. (2021) Detection of potassium deficiency and momentary transpiration rate estimation at early growth stages using proximal hyperspectral imaging and extreme gradient boosting. *Sensors*, 21(3), 958, 1-18.

Wu J., Liang, S., Dai, H., Zhang, X., Yu, X., Cai, Y., Zhang, L., Wen, N., Jiang, B., & Xu, J. (2010) Structure and properties of cellulose/chitin blended hydrogel membranes fabricated via a solution pregelation technique. *Carbohydr. Polym.* 79**,** 677-684.

Xindong, W., Xuefeng, Y., Yumei, L., Youke, W., Xuefeng, Y., Xindong, W., & Yumei, L. (2011) Research on the water-saving and yield-increasing effect of polyacrylamide. *Procedia Environmental Sciences*, 11, 573-580. https://doi.org/10.1016/j.proenv.2011.12.090

Yasmeen, A., Arif, M., Hussain, N., Naz, S., & Anwar, A. (2018) Economic analyses of sole and combined foliar application of moringa leaf extract (MLE) and K in growth and yield improvement of cotton. *Int. J. Agric. & Biol*., 20(4), 857-863.

Younis, A. M., Mansour, H. A. & Bakry, B. A. (2025) Enhancing maize productivity through aquacrop modeling under modern irrigation systems and drought stress conditions. *Egypt. J. Agron.* 47 (1), 55-71.

Zahoor, R., Zhao, W., Abid, M., Dong, H., & Zhou, Z. (2017) Potassium application regulates nitrogen metabolism and osmotic adjustment in cotton (*Gossypium hirsutum* L.) functional leaf under drought stress. J. of Plant Physiology, 215, 30-38. https://doi.org/10.1016/j.jplph.2017.05.001

Zhang J. & Davies W.J. (1987) Increased synthesis of ABA in partially dehydrated root tips and ABA transport from roots to leaves. *J Exp Bot.*, 38(12), 2015-2023. https://doi.org/10.1093/jxb/38.12.2015

Zohuriaan-Mehr, M.J., & Kabiri K. (2008) Superabsorbent Polymer Materials: A Review, *Iranian Polym. J.*, 17(6), 451-477.

استجابة القطن المصري لإضافة بوليمر البولي أكريلاميد ومحفزات النمو تحت ظروف الإجهاد المائي

أماني أحمد الأشموني [١] ، وأسامة علي محمد علي [٢]

[١] قسم بحوث فسيولوجى القطن معهد بحوث القطن، مركز البحوث الزراعية، الجيزة، مصر
[٢] قسم المحاصيل، كلية الزراعة، جامعة المنوفية، شبين الكوم، مصر

هدفت الدراسة إلى تقييم الاستجابات الفسيولوجية والمحصولية للقطن المصري (صنف سوبرجيزة ٩٧) لأنظمة الري المختلفة ومحفزات النمو تحت ظروف الإجهاد المائي. لذا نُفذت تجارب حقلية في المزرعة البحثية لمحطة بحوث سخا الزراعية، مركز البحوث الزراعية، محافظة كفر الشيخ، مصر خلال موسمي الزراعة ٢٠٢١ و ٢٠٢٢م. تضمنت التجربة دراسة أنظمة الري المختلفة وهى الري كل ١٤ يومًا (I_1) ، والري كل ٢٨ يومًا (I_2) ، والري كل ٢٨ يومًا + بوليمر البولى أكريلاميد PAM (I_3)، بالإضافة إلى الرش الورقي لبعض محفزات النمو (الكنترول للمقارنة، حمض الساليسيليك SA ، حمض البوريك B وكبريتات البوتاسيوم K). وقد أوضحت النتائج أن تأخير فترة الري من ١٤ إلى ٢٨ يومًا قد سجلت إنخفاضًا معنويًا في الصفات الفسيولوجية (الكلوروفيل الكلي، دليل ثبات غشاء الخلايا والمحتوى المائي النسبي)، وإنتاج الوسواس واللوز، والصفات المحصولية، بينما سجلت أعلى محتوى للبرولين بالأوراق ونشاط الكتالاز ونسبة التساقط الكلي. هذا وقد كان لإضافة بوليمر البولى أكريلاميد PAM إلى النباتات التي يتم ريها كل ٢٨ يومًا دورًا إيجابيًا معنويًا في تخفيف تأثير الإجهاد المائي وتعزيز إنتاجية المحصول والمياه. كما أظهر الرش الورقي لمحفزات النمو تأثيرات إيجابية على الخصائص الفسيولوجية للنباتات والصفات المحصولية، حيث حقق كل من حمض الساليسيليك و كبريتات البوتاسيوم أفضل النتائج في كلا موسمي الزراعة. وقد أسفرت معاملة التفاعل التي تضمنت الري كل ١٤ يومًا مع الرش الورقى إما بحمض الساليسيليك (I_1×SA) أو كبريتات البوتاسيوم (I_1×K) عن أفضل النتائج المحصولية. علاوة على ذلك، حققت كلتا معاملتى التفاعل التي تضمنت الري كل ٢٨ يومًا + اضافة البوليمر PAM مع الرش الورقى إما بحمض الساليسيليك (I_3×SA) أو كبريتات البوتاسيوم (I_3×K) إنتاجية لمحصول القطن الزهر للفدان مساوية إحصائيًا لمعاملة التفاعل التي تتضمن الري كل ١٤ يومًا بدون الرش الورقى لمحفزات النمو (I_1×control) في كلا موسمي الزراعة، وباستخدام إجمالى مياه رى مضافة أقل بنسبة ٢٨.١٠ و٣٢.٢٨٪ على الترتيب . مما يشير إلى أن (I_3×SA) أو (I_3×K) تعد أفضل المعاملات لإنتاج القطن تحت ظروف نقص مياه الري بالأراضى المتأثرة بالملوحة.

الكلمات الدالة: القطن المصرى، حمض الساليسيليك، البوتاسيوم، المحصول، إنتاجية المياه.