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EFFECT OF SOME ANTIOXIDANTS ON GROWTH, CERTAIN PHYSIOLOGICAL ASPECTS, AND PRODUCTIVITY OF COTTON GROWN UNDER THREE DIFFERENT IRRIGATION INTERVALS

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ABSTRACT: Two field experiments were carried out at Sakha Agricultural Research Station Farm, Kafr El-Sheikh Governorate, Agricultural Research Center, Egypt, during the 2021 and 2022 seasons to study the effect of three levels of moringa leaves extract (MLE), and salicylic acid (SA) on growth, certain physiological aspects and productivity of cotton Super Giza 97 grown under three different irrigation intervals. A split plot design with three replicates was used. The obtained results indicated that cotton plants irrigated every 15 days and sprayed with moringa leaf extract at the high rate (15 %) two times significantly increased photosynthetic pigments, total carbohydrates, nitrogen, phosphorus, and potassium concentrations, total water content, and relative water content, growth traits, yield of seed cotton/feddan and yield components in both seasons. Meanwhile, the same treatment significantly decreased earliness%, plasma membrane permeability, the peroxidase and phenol oxidase activities as well as proline content. The longest fibers and highest strength were obtained from the plants irrigated every 15 days in only one season. It could be concluded that interaction treatment (irrigation every 15 days x spray with moringa leaves extract 15%) recorded the best results. In addition, spraying cotton plants irrigated every 30 days with moringa leaf extract at a high rate (15%) two times can be applied safely to minimize the negative impact of drought stress on cotton plants under conditions like the Sakha location.

Keywords: Egyptian cotton; Moringa leaf extract; Salicylic acid; chemical contents; photosynthetic pigments; irrigation interval.

INTRODUCTION

Egyptian cotton (*Gossypium barbadense*, L.) occupies a distinguished position due to its high quality and the firmness of its existence in overseas markets for a long time due to its prominent position in the markets. It is the mainstay of the textile, ready-made clothing, and oil production industries in Egypt (Abdel-Salam and Negm, 2009). The plant does not consume most of the water it absorbs. About 97-99% of the water supplied to the plants is missing via transpiration. Transpiration is defined as the physiological loss of water in the shape of water vapor, principally from the leaf stomata, but also via evaporation from the surfaces of leaves, flowers, and stems (Trimble, 2021). Plants compensate for the lost water by extracting it from the soil to avoid water stress, reduce the degree of cellular damage, and maintain the water balance between water absorption and lost water during the day light. Drought leads to low water levels in the plant tissues, and low water potential, thus reducing leaf expansion, rate of leaf photosynthesis, and concentration of photosynthetic pigments and destroying photosystem II, altering synthesis of protein, metabolism of nitrogen, and properties of cell membrane leading to a decrease in plant output (Saneoka *et al*., 2004).

Ergashovich *et al*. (2020) found that drought led to a decline in the growth and development of cotton, enlargement of leaf surfaces, and pure photosynthesis productivity, boll weight, yield, and quality. As a result, partial shedding of crop organs and leaves was observed. El-Sayed and Abd El All (2022) reported that irrigation every 14-day significantly increased mineral nutrients, photosynthetic pigments, total carbohydrates,

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total sugars, and free amino acids in the leaves. Fiber length in the 2nd season, growth indicators, measurements of earliness (except the percentage of boll shedding which reduced), seed cotton yield feddan^{-1} and its components in both seasons and lint strength in the 1st season were also increased. Moreover, a significant decrease in micronaire reading, phenolic and proline content due to irrigation at 14-day interval was found.

Water shortages limited water sources in addition to the cost of irrigation pumping, and insufficient capacity of irrigation projects represent a real challenge that forces Egypt to reduce irrigation applications. Water stress is one of the major threats facing plants resulting in modifications at all levels of ecological, morphological, physiological, biochemical, and molecular properties of plants (Muscolo *et al*., 2014). However, cotton plants are very sensitive to water stress during the flowering and boll formation stage resulting in slow growth and increased flowers and boll shedding rate (Kawakami *et al*., 2010). Cotton production also decreased due to a decrease in the total bolls number/plant under water stress conditions.

The harmful effects of water stress on cotton plants can be minimized by external application of plant growth stimulants (Farooq *et al*., 2009). Salicylic acid (SA) is a naturally occurring plant hormone that acts as a vital signalling molecule with a wide distribution in plants and contributes to many plants physiological processes (Clarke *et al*., 2009). External application of SA on water-stressed plants reduces cell membrane injury and enhances antioxidant enzymes activities such as superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) in leaves (Khan *et al*., 2014). External use of plant growth stimulants is the most efficient way to promote plant growth and development by mitigating the harmful effects of water stress on plant metabolism and growth in various crops (Sadak and Dawood, 2014), but this application is expensive. Therefore, there is a constant need to search for safe alternative natural sources that contain nutrients, hormones, and antioxidants with higher economic returns (Yasmeen *et al*., 2018).

Moringa leaf extract (MLE) has been widely applied to enhance stress tolerance in plants by inducing alterations in plant biochemistry and physiology necessary for stress tolerance (Ismail *et al.*, 2016). It is a tremendous source of zeatin (a purine adenine derivative of the cytokinin group of plant hormone), riboflavin, vitamins A and C, phenols, mineral nutrients, antioxidant, and some osmo protectants that make it a potential bio-stimulant (Arif *et al*., 2019). Foliar spray of MLE has favourable effects on growth of wheat plant, rate of photosynthesis, hormonal content, and anti-oxidative resistance activities under stress conditions (Yasmeen *et al*., 2013). Yuniati *et al*. (2022) mentioned that moringa leaf extract (MLE) has been applied as a plant biostimulant to improve product quality. The efficiency of MLE is linked to its useful ingredients which consist of nutrients, phytohormones, secondary metabolites, amino acids, and bioactive compounds. These beneficial components change the physiological processes in plants, such as increasing photosynthesis, nutrient absorption, sink capacity, antioxidative enzymes, and secondary metabolism in plants, contributing to improved quality. In addition, MLE is environmentally friendly and cheap. Mineral fertilizers are costly and constitute a source of environmental pollution (Phiri, 2010). Natural products are inexpensive, environmentally friendly, and easy to employ (Ahmad *et al*., 2019). Among these natural products, moringa leaf extract (MLE) is secure to apply, relatively inexpensive (compared to synthetic growth regulators), and has been found to significantly increase vegetative growth, productivity, and quality of various crops in the world. Applying MLE externally enhanced the antioxidant system, activated the plant defence system, and promoted the levels of plant secondary metabolites (Rady and Mohamed, 2015). Nisar *et al.* (2021) showed that application of MLE significantly increased the cotton yield and therefore, it can be used as an organic fertilizer for maximizing cotton productivity. Hussain *et al.* (2021) found that compared with distilled water, MLE application alone showed an enhancement effect on crop growth rate, net assimilation rate, leaf area index, leaf area period, fruiting branches, and bolls number which leads to increased yield of seed cotton. MLE being a rich source of growth-promoting hormones and nutrients showed its potential to a much greater range under traditional row spacing. Panhwar *et al*. (2022) found that the use of the leaf extract of a miracle plant (*Moringa oleifera* L.) as a foliar spray on cotton, had significant effects on its yield and associated parameters. The highest boll weight and seed cotton yield were registered when foliar spray was done. The lowest boll weight and seed cotton yield were obtained from the control (no foliar spray). However, there is only limited studies available showing the potential of salicylic acid and moringa leaf extract for enhancing cotton growth and productivity under water stress conditions. Therefore, this study aimed to assess the proper irrigation interval and the effect of moringa leaf extract and salicylic acid as anti-transpiration materials on morphysiological and yield characters of the Egyptian cotton cultivar Super Giza 97 grown under the environmental conditions of Sakha region.

MATERIAL AND METHODS

Two field experiments were carried out on cotton Super Giza 97 (*Gossypium barbadense*, L.) at Sakha Agricultural Research Station Farm, Kafr El-Sheikh Governorate, Agricultural Research Center, Egypt, during the 2021 and 2022 seasons. The experiment was designed in a split plot having three replicates.

The net plot size was 14 m^2 comprised of 5 furrows, 0.70 m apart, and 4 m long. Hills were 25 cm apart. Seeds of cotton cultivar Super Giza 97 were obtained from CRI, ARC, Egypt and sown on the middle of April. The main plots included three irrigation intervals *i.e.*, irrigation at 15 days (well-watered), 30- and 45-day intervals (water-stressed) and the sub-plots included seven treatments of twice foliar application with hand sprayer of moringa leaf extract (5, 10, and 15%) and salicylic acid (200, 300, and 400 ppm) in addition to distilled water as a control. The first application was made at 50 days (square stage), while the second application was made at 65 days (flowering initiation). The spraying was taking place till dripping using Tween 20 as a surfactant (0.05 ml/ L).

Salicylic acid was obtained from El-Gomhouria Company for Chemicals - Tanta City - Arab Republic of Egypt.

Moringa oleifera powder was obtained from the moringa production unit at the National Research Center, Giza, Egypt, and different concentrations of aqueous extracts were prepared according to the method described by (Hossain *et al*., 2012). Chemical composition analysis of MLE is shown in Table 1.

Table 1. Chemical composition analysis of MLE according to Rehman *et al*. (2017).

Name of nutrient element/enzymes	**Values (mg g^{-1} DW)**	**Name of nutrient element/enzymes**	**Value (mg g^{-1} DW)**
Total soluble sugars	248.70	Phosphorus	8.10
Amino acids	106.20	Potassium	25.10
Proline	21.00	Calcium	28.00
Ash	102.00	Magnesium	6.70
Soluble phenols	6.20	Zinc	0.27
Ascorbic acid (mg/100 g FW)	242.4	Na^+	0.75
Phytohormones (ug/g DW)		Copper	0.14
Gibberellins	0.74	Iron	0.75
Zeatin	0.96	Manganese	0.84
Abscisic acid	0.29	Total carotenoids	3.10
Indole-3-acetic acid	0.83	Total chlorophyll	3.96

Phosphorus fertilizer was added at a rate of 22.5 kg P_2O_5/fed as calcium super phosphate (15.5% P_2O_5) during land preparation. Nitrogen fertilizer was applied at a rate of 60 kg N/fed in the form of ammonium nitrate (33.5%) in two equal doses before the 1st and 2nd irrigation, respectively. Potassium fertilizer (in the form of Potassein P, contains 32% K_2O and 5% P_2O_5) was applied at a rate of 1 liter/fed as foliar spray twice (at the beginning of flowering and 15 days later). Preceding crop was Egyptian clover (*Trifolium alexandrinum* L.) "berseem" in both seasons. The irrigation treatments were start after the second irrigation.

All agricultural practices, except for the experimental treatments under study, were kept similar in each sub-plot and implemented as recommended (CRI, ARC, Egypt).

Representative soil samples were taken from the surface layer (0-30 cm) before sowing. Soil analysis for the two sites was done according to Jackson (1973) as shown in Table 2.

Meteorological data: The meteorological data during the two growing seasons at the experimental site were obtained from Meteorological Station at Sakha and presented in Table 3.

Studied characters

Samples of twenty leaves (4th upper leaf) were randomly taken from plants of each sub-plot after 15 days from the last spraying time (at 80 days old) to determine the following traits:

I. Chemical constituents

Photosynthetic pigments: chlorophyll a, b, and carotenoids (mg/g d.wt.) were determined as described by Vernon and Selly (1966). Total carbohydrates (mg/g d.wt.) were determined using the phenol sulfuric acid method as described by AOAC (2005). Antioxidant enzymes activities such as peroxidase (O.D./g f.wt. after 2 min.) and phenol oxidase (O.D./g f.wt. after 45 min.) were determined according to Fehrman and Dimond (1967) and Broesh (1954). Proline concentration (µg lucine/g f.wt.) was measured according to the ninhydrin method of Bates *et al*. (1973). Percentages of N, P, and K were determined as described by AOAC (2005).

Table 2. The properties of the experimental soil in the two seasons.

Particulars	Season	
	2021	**2022**
Mechanical analysis		
Clay%	47.67	46.64
Silt%	24.11	24.60
Sand%	28.22	28.76
Texture	Clayey	Clayey
Chemical analysis		
pH	8.22	8.18
EC ds/m	3.33	3.41
Organic matter %	1.56	1.65
Soluble cations (meq/l)		
Ca^{+2}	7.32	8.11
Mg^{+2}	5.12	5.38
K^{+}	0.38	0.34
Na^{+}	24.22	23.67
Soluble anions (meq/l)		
CO_3^{-2}	---	---
HCO^-_3	4.01	3.98
Cl^-	20.00	21.13
SO_4^{-2}	13.03	12.39

Table 3. Mean values of some climatological data in the experimental site during the growth period of the two growing seasons 2021 and 2022.

Months		AT (c^o) (Air temperature)				RH% (Relative humidity)			
		2021 season		2022 season		2021 season at		2022 season at	
		Max	Min	Max	Min	7:30	13:30	7:30	13:30
April (days)	1-10	24.0	18.3	29.2	19.6	65.2	55.3	78.3	44.4
	11-20	25.6	19.5	22.6	19.0	70.5	50.8	74.2	54.2
	21-30	21.5	19.9	28.3	20.5	66.4	44.7	76.0	42.1
May (days)	1-10	30.6	22.3	27.5	20.7	73.0	55.0	75.8	44.1
	11-20	28.9	23.5	29.8	21.7	77.3	58.4	80.2	44.9
	21-31	31.5	24.6	32.3	23.1	78.6	60.5	81.3	44.1
June (days)	1-10	33.4	24.3	33.6	25.2	65.2	69.0	83.1	49.1
	11-20	35.6	23.1	32.6	22.9	63.5	68.6	75.4	50.0
	21-30	31.4	24.8	32.9	26.2	64.9	68.4	81.2	52.2
July (days)	1-10	35.6	28.6	30.1	26.3	70.9	68.2	86.5	55.0
	11-20	33.4	30.5	32.6	26.3	73.6	68.5	57.3	85.7
	21-31	36.2	33.6	34.1	25.1	73.5	67.5	52.1	90.0
August (days)	1-10	33.5	26.7	33.4	25.5	84.2	66.4	89.2	57.8
	11-20	36.0	27.5	33.6	25.6	81.4	75.4	90.4	55.2
	21-31	35.6	29.2	36.1	27.3	82.6	76.3	53.7	89.8
September (days)	1-10	34.8	26.4	33.0	29.7	80.5	71.4	85.1	54.2
	11-20	34.9	25.0	32.2	25.3	75.8	70.4	81.5	56.3
	21-30	33.5	22.6	33.8	25.5	70.5	69.8	84.1	55.1
October (days)	1-10	30.5	20.5	30.6	21.9	64.0	59.4	82.5	58.1
	11-20	28.6	18.3	28.7	26.2	56.4	57.8	90.0	72.0
	21-31	26.2	19.2	29.9	25.9	54.3	55.6	101.6	70.3

II. Water relations: Total water content (TWC, %) **(**Gosev, 1960) and (Kreeb, 1990), relative water content (RWC, %) (Barrs and Weatherley, 1962), and plasma membrane permeability (PMP, %) (Yan *et al*., 1996) were determined.

III. Growth: Plant height at harvest from the cotyledonary node to the apex of the main stem (cm) and fruiting branches number plant^{-1} were recorded.

IV. Seed cotton yield, yield components and earliness%: Open bolls number plant^{-1}, boll weight (g) and seed index **(**g**)** were recorded. The yield of seed cotton fed^{-1} was also estimated as the weight of seed cotton in kilograms picked twice from each-sub plot and converted to kentars fed^{-1} (one kentar = 157.5 kg and one feddan = 4200.83 m^2). Earliness was estimated as percentage of the first pick to the total yield.

V. Fiber quality: The following fiber properties were determined at the laboratories of Cotton Research Institute, ARC, Giza, Egypt under the standard conditions of test as reported by **ASTM (2012):** Upper half mean length (UHML) in mm and length uniformity index (%) were determined by fibrograph instrument, fiber fineness was tested by micronaire apparatus (micronaire reading), and fiber strength was measured by Pressley tester (Pressley index).

Statistical analysis

The data obtained were subjected to the proper statistical analysis of split plot design according to the procedure outlined by Gomez and Gomez (1984). For comparison between means, LSD values at 5% level of probability was used**.**

RESULTS AND DISCUSSION

I-Chemical constituents

I.1. Effect of irrigation intervals

Results in Tables (4 and 5) cleared that, cotton plants irrigated every 15 days significantly increased the content of chlorophyll a, b, carotenoids, total carbohydrates, nitrogen, phosphorus, and potassium in the leaves. On the other hand, irrigation every 15 days significantly decreased the activities of peroxidase and phenol oxidase enzymes and the concentration of proline. These results are true at the same period compared to increasing the irrigation period to 30 and 45 days in both seasons. In conditions of water stress, it was found that cotton plants increase phenolic compound production (Sánchez-Rodríguez and Rubio-Wilhelmi, 2010). Phenolic compounds prohibit the oxidative burst of plant cells and consequently save the plants from injury to proteins, lipids, RNA, and DNA structures (Apel and Hirt, 2004).

I.2. Effect of antioxidants

Tables 4 and 5 showed that, spraying moringa leaves extract twice at the high rate (15%) significantly increased chlorophyll a, b, carotenoids, total carbohydrates, N, P, and K concentrations in the treated cotton leaves. Meanwhile, there was a significant decrease in the enzyme's activities of peroxidase and phenol oxidase and concentration of proline. The positive effect resulting from the application of moringa leaves extract (MLE) can be mainly attributed to its components of several nutrients, vitamins, phytohormones, and secondary metabolites (Rehman *et al.*, 2017; Khan et *al.*, 2020). MLE obtained from a fresh leaf also contains a high concentration of antioxidants and osmoprotectants, including proline, amino acid, soluble sugar, α-tocopherol, and glutathione (Zaki and Rady, 2015; Desoky *et al.*, 2019). Aqueous MLE is consists of phytohormones, mineral nutrients, proteins, vitamins, phenolics, etc (Sardar *et al*., 2021; El Sheikha *et al*., 2022). The presence of gibberellin, auxin, and cytokinin has been reported in MLE (El Sheikha *et al.*, 2022). In addition, many necessary and unnecessary nutrients are found in MLE, including nitrogen, phosphorus, potassium, calcium, magnesium, copper, iron, zinc, manganese, selenium, and sulfur (Arif *et al.*, 2022). Arif *et al.* (2019) indicated that MLE is rich in amino acids and ascorbate. Regarding bioactive compounds, the moringa leaf extract has been reported to contain phenolic, flavonoid, and saponin compounds (García-Beltrán *et al.* 2020).

As for the effect of foliar spraying of salicylic acid (SA), it was found that treated cotton plants with SA at 200 ppm significantly increased leaf concentration of chlorophyll a, b, carotenoids, total carbohydrates, N, P, and K. Whereas decreased peroxidase and phenol oxidase activities and the concentration of proline. These results are true during the two growing seasons. The increments of MLE concentrations were followed by an increase in chlorophyll content. This may be related to the role of magnesium in the extract as a component of chlorophyll. Moreover, MLE improved the content of carotenoid and chlorophyll which may be due to the roles of hormones, minerals, and vitamins in MLE, delaying leaf senescence (Aslam *et al.*, 2016). As MLE contains large amounts of minerals, it increases the absorption of nutrients and ameliorates the nutritional status and production quality of the plant (Hoque et al., 2020). Toscano et al. (2021) assured that the amelioration in chlorophyll and carotenoid contents was closely related to the higher amount of carotenoids (xanthin, alpha-carotene, beta-carotene, and lutein) and chlorophyll in MLE. Data in the present investigation indicated that foliar spray with MLE or salicylic acid in water-stressed cotton plants significantly increased the production of antioxidant enzymes. In this regard, it was found that foliar spraying with salicylic acid on water-stressed plants significantly resulted in a significant reduction in the relative cell injury percentage and ameliorated the activities of antioxidants enzyme (SOD, POD, CAT, and phenolic contents) thus increasing the ability to withstand stressed conditions (Hayat and Ahmad, 2007).

Table 4. Effect of irrigation intervals and some antioxidants as well as their interactions on photosynthetic pigments in leaves of Egyptian cotton Super Giza 97 grown during the two growing seasons of 2021 and 2022.

Treatments \ Traits		Season 2021 Chlorophyll a	Season 2021 Chlorophyll b	Season 2021 Carotenoids	Season 2022 Chlorophyll a	Season 2022 Chlorophyll b	Season 2022 Carotenoids
		(mg /g d. wt.)			(mg /g d. wt.)		
A-Irrigation intervals:							
a_1-15 day		4.34	1.38	2.76	4.64	1.67	2.39
a_2- 30 day		3.89	1.33	2.48	3.64	1.30	1.81
a_3- 45 day		3.32	1.23	2.13	2.84	1.07	1.45
LSD at 5%		**0.26**	**0.03**	**0.55**	**1.16**	**0.24**	**0.02**
B- Antioxidants treatments:							
b_1-Control		3.63	1.29	2.32	3.38	1.25	1.71
b_2- Moringa extract 5%		3.73	1.29	2.37	3.48	1.29	1.80
b_3- Moringa extract 10%		3.98	1.32	2.53	3.91	1.40	1.99
b_4-Moringa extract 15%		4.00	1.35	2.58	4.03	1.50	2.05
b_5- Salicylic acid 200 ppm		3.93	1.33	2.50	3.85	1.36	1.97
b_6-Salicylic acid 300 ppm		3.83	1.31	2.44	3.64	1.30	1.82
b_7-Salicylic acid 400 ppm		3.85	1.31	2.47	3.66	1.32	1.85
LSD at 5%		**0.09**	**0.04**	**0.04**	**0.10**	**0.05**	**0.02**
A B Interaction:							
a_1	b_1	4.21	1.35	2.69	4.14	1.55	2.15
	b_2	4.35	1.38	2.76	4.71	1.59	2.45
	b_3	4.42	1.39	2.80	4.84	1.77	2.49
	b_4	4.49	1.40	2.86	4.92	1.99	2.62
	b_5	4.37	1.38	2.78	4.79	1.65	2.46
	b_6	4.32	1.38	2.75	4.66	1.57	2.36
	b_7	4.22	1.36	2.71	4.45	1.55	2.22
a_2	b_1	3.51	1.31	2.24	3.23	1.20	1.63
	b_2	3.77	1.31	2.38	3.26	1.28	1.67
	b_3	4.21	1.35	2.67	4.08	1.38	2.05
	b_4	4.03	1.35	2.63	3.97	1.37	1.91
	b_5	3.95	1.35	2.49	3.85	1.29	1.90
	b_6	3.87	1.33	2.47	3.46	1.29	1.73
	b_7	3.89	1.33	2.48	3.64	1.29	1.80
a_3	b_1	3.16	1.21	2.02	2.77	1.00	1.34
	b_2	3.07	1.17	1.97	2.48	1.00	1.29
	b_3	3.30	1.22	2.11	2.80	1.06	1.43
	b_4	3.49	1.30	2.24	3.20	1.14	1.62
	b_5	3.47	1.27	2.23	2.92	1.14	1.56
	b_6	3.30	1.22	2.10	2.79	1.04	1.37
	b_7	3.45	1.23	2.22	2.89	1.13	1.53
LSD at 5%		**0.16**	**0.07**	**0.06**	**0.17**	**0.08**	**0.03**

Table 5. Effect of irrigation intervals and some antioxidants as well as their interactions on N, P, K, total carbohydrates, proline, peroxidase, and phenol oxidase content in leaves of Egyptian cotton Super Giza 97 (as the average of 2021 and 2022 seasons).

Traits / Treatments		N	P	K	Total carboh-ydrates	Proline	Per-oxidase	Phenol-oxidase
		(%)			(mg/g d. wt.)	(µg lucine /g f. wt.)	(O.D./g f. wt. after 2 min.)	(O.D./g f. wt. after 45 min.)
A-Irrigation intervals:								
a_1-15 day		2.07	0.534	3.40	0.912	265.99	110.87	51.09
a_2- 30 day		1.99	0.512	3.24	0.829	289.07	122.73	56.62
a_3- 45 day		1.85	0.438	2.70	0.742	335.79	141.27	64.00
LSD at 5%		**0.65**	**0.090**	**0.23**	**0.820**	**3.92**	**0.31**	**0.29**
B- Antioxidants treatments:								
b_1-Control		1.95	0.463	2.91	0.778	314.22	131.17	60.08
b_2- Moringa extract 5%		1.96	0.471	3.18	0.793	303.53	128.74	59.61
b_3- Moringa extract 10%		1.97	0.510	3.23	0.853	290.02	124.27	57.13
b_4-Moringa extract 15%		2.00	0.523	3.28	0.868	285.13	116.50	53.72
b_5- Salicylic acid 200 ppm		1.98	0.515	3.24	0.851	287.64	120.28	55.29
b_6-Salicylic acid 300 ppm		1.97	0.510	2.98	0.825	297.13	128.19	57.98
b_7-Salicylic acid 400 ppm		1.96	0.470	2.96	0.827	300.98	125.58	56.85
LSD at 5%		**0.02**	**0.063**	**0.20**	**0.020**	**2.81**	**0.46**	**0.58**
A B Interaction:								
a_1	b_1	2.07	0.524	3.30	0.875	270.76	118.15	54.50
	b_2	2.02	0.523	3.4	0.914	266.33	110.81	51.39
	b_3	2.08	0.539	3.45	0.94	260.95	105.61	50.09
	b_4	2.11	0.555	3.51	0.948	261.28	103.44	46.82
	b_5	2.06	0.537	3.44	0.93	266.39	109.81	50.16
	b_6	2.04	0.532	3.37	0.893	267.53	114.14	52.30
	b_7	2.08	0.528	3.33	0.887	268.71	114.16	52.36
a_2	b_1	1.95	0.500	3.15	0.796	318.77	126.46	58.97
	b_2	1.96	0.508	3.19	0.806	301.50	124.45	57.88
	b_3	1.98	0.514	3.27	0.864	272.08	118.53	55.76
	b_4	2.02	0.521	3.29	0.865	271.31	118.47	55.09
	b_5	2	0.516	3.27	0.838	272.73	122.96	55.80
	b_6	2	0.513	3.25	0.814	290.44	124.22	56.73
	b_7	2.01	0.509	3.23	0.820	296.63	124.05	56.11
a_3	b_1	1.82	0.365	2.29	0.663	353.13	148.91	66.76
	b_2	1.9	0.381	2.94	0.658	342.76	150.95	69.55
	b_3	1.84	0.477	2.96	0.754	337.02	148.66	65.55
	b_4	1.86	0.493	3.04	0.790	322.81	127.58	59.25
	b_5	1.88	0.492	3.02	0.786	323.79	128.07	59.90
	b_6	1.87	0.485	2.33	0.767	333.43	146.20	64.90
	b_7	1.8	0.374	2.31	0.773	337.61	138.53	62.08
LSD at 5%		**0.04**	**0.109**	**0.35**	**0.034**	**4.87**	**0.80**	**1.01**

In addition, MLE being a rich source of growth-promoting hormones improved the production of antioxidant activities. Activation of the self-defence system by external application of MLE is also linked to the high mineral contents found in moringa leaves making it an excellent plant growth promoter (Yasmeen *et al*., 2013). MLE is an important source of natural antioxidants that positively improves antioxidant compounds in the product (Aslam *et al.*, 2016) and influences the plant defence system versus oxidative stress (Hassan *et al*., 2021).

High contents of these pigments could be interpreted by the fact that SA was inhibiting chloroplast degradation. It has been reported that SA induced an increase in the rate of photosynthesis and carboxylation enzymes (Khodary, 2004). The exogenous application of salicylic acid (SA) has reduced the passive impact of water stress (Khan *et al*., 2015) and spraying SA encourages the plant growth (Hayat *et al.*, 2010). SA is an important regulator of photosynthesis because it influences structure of leaf and chloroplast, stomatal closure, contents of chlorophyll and carotenoid (Fariduddin *et al*., 2003), and the efficiency of enzymes like carbonic anhydrase and RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase) (Pancheva and Popova, 1997). The reduction in RuBisCO activity was due to a 50% reduction in levels of protein compared to untreated plants, while total soluble protein was reduced by 68%. Thus, the decrease in photosynthetic activity at high SA concentrations is due to its effects on the thylakoid membranes and light-associated reactions (Pancheva and Popova, 1997). Plants treated with MLE or SA showed higher membrane stability under water stress through inhibition of oxidative stress by generating proline as well as other antioxidants. Exogenous application of MLE or SA can prevent the oxidative injury and consequently save the cell membranes by scavenging ROS (Rady and Mohamed, 2015; Hassan *et al*., 2017). In addition, MLE or SA has been shown to reduce ion leakage, preserve membrane functions, and work as an antioxidant (Yasmeen *et al*., 2013; Hassan *et al*., 2017).

I.3. Effect of the interaction

The results in Tables 4 and 5 showed that, in leaves of cotton plants irrigated every 15 days and received moringa extract two times at the high rate (15%) or at the medium rate (10%) in respective orders significantly increased chlorophyll a, b, carotenoids, total carbohydrates, N, P, and K concentrations. Meanwhile, there was a significant decrease in enzyme activity as peroxidase and phenol oxidase and proline content at these two interaction treatments.

II-Water relations

II.1. Effect of irrigation intervals

Data in Table 6 cleared that, the cotton plants irrigated every 15 days increased leaves total water content, and relative water content and decreased plasma membrane permeability that supports the plasma membrane integrity compared to increasing irrigation period to 30 and 45 days in both seasons. Despite cotton's ability to maintain leaf turgor under conditions of water stress through osmotic adjustment (Nepomuceno *et al*., 1998), leaf water potential of water-stressed plants was significantly lower compared to the control in accordance with da Costa and Cothren (2011). Sibet and Birol (2007) indicated that the plasma membrane is generally saved from desiccation-induced damage by existence of membrane-compatible solutes, such as sugars and amino acid. Thus, a connection may occur between the ability for osmotic modulation and degree of membrane integrity. The water stress-caused decrease in membrane stability indicates the extent of lipid peroxidation induced by active oxygen species.

II.2. Effect of antioxidants

The results in Table 6 showed that spraying twice moringa leaf extract at the high rate (15%) significantly increased TWC and RWC and significantly decreased PMP in both seasons. As for the effect of foliar spraying of salicylic acid (SA), experimental results depicted that the application of 200 ppm SA increased TWC, RWC and decreased PMP than the control plants (without promoters' application) or the application of 300 and 400 ppm of SA. A reason for improvement is explained as an increase in leaf diffusive resistance that reduced the

Table 6. Effect of irrigation intervals and some antioxidants as well as their interactions on water relations (TWC, RWC, and PMP) in leaves of Egyptian cotton Super Giza 97 grown during the two growing seasons of 2021 and 2022.

Treatments \ Traits		Season 2021			Season 2022		
		TWC	RWC	PMP	TWC	RWC	PMP
		%			%		
A-Irrigation intervals:							
a_1-15 day		96.12	85.05	41.69	80.13	76.97	43.47
a_2- 30 day		89.01	81.32	31.73	77.74	72.75	28.32
a_3- 45 day		81.53	73.88	24.27	74.30	54.59	19.84
LSD at 5%		**0.30**	**0.03**	**1.74**	**1.30**	**0.27**	**0.02**
B- Antioxidants treatments:							
b_1-Control		86.81	78.25	36.35	76.20	60.83	34.54
b_2- Moringa extract 5%		86.30	79.29	30.11	76.08	61.69	28.08
b_3- Moringa extract 10%		90.48	80.83	35.02	77.94	72.79	34.58
b_4-Moringa extract 15%		91.78	81.47	29.37	78.86	74.46	25.19
b_5- Salicylic acid 200 ppm		89.95	81.02	33.31	77.96	73.38	33.75
b_6-Salicylic acid 300 ppm		88.07	79.78	31.25	77.11	61.98	28.88
b_7-Salicylic acid 400 ppm		88.82	79.95	32.53	77.59	71.61	28.76
LSD at 5%		**0.10**	**0.27**	**0.60**	**1.12**	**0.05**	**0.03**
A B Interaction:							
a_1	b_1	94.00	82.69	45.55	79.25	74.68	49.15
	b_2	96.00	85.40	41.46	79.86	76.61	43.66
	b_3	98.00	86.13	42.60	80.37	78.21	48.62
	b_4	98.73	86.43	39.19	82.36	80.90	35.78
	b_5	97.00	85.99	42.16	80.12	77.83	47.88
	b_6	95.00	84.88	40.53	79.71	75.68	42.16
	b_7	94.12	83.82	40.33	79.26	74.87	37.02
a_2	b_1	85.39	79.29	36.66	76.44	70.71	31.06
	b_2	86.34	79.90	29.17	77.19	72.17	25.73
	b_3	92.00	82.38	37.53	78.97	74.31	34.01
	b_4	92.00	82.29	27.12	78.30	73.34	23.48
	b_5	90.02	82.26	31.12	77.99	73.33	30.87
	b_6	87.76	81.28	29.57	77.42	72.41	25.78
	b_7	89.54	81.85	30.96	77.87	72.99	27.28
a_3	b_1	81.03	72.76	26.84	72.91	37.09	23.40
	b_2	76.55	72.57	19.71	71.19	36.28	14.84
	b_3	81.45	73.98	24.93	74.47	65.84	21.10
	b_4	84.60	75.69	21.80	75.93	69.14	16.31
	b_5	82.82	74.80	26.65	75.78	68.97	22.51
	b_6	81.45	73.19	23.64	74.21	37.85	18.71
	b_7	82.80	74.18	26.31	75.64	66.96	21.98
LSD at 5%		**0.18**	**0.47**	**1.04**	**1.94**	**0.09**	**0.05**

rates of transpiration (Szepesi *et al*., 2005). Hussain *et al.* (2009) also found that foliar application of SA augmented the water status in plant bodies by osmotic adjustment, which occurred due to the deposit of compatible solutes that resulted in increased of osmoregulation proficiency in crops. Exogenous application of MLE or SA can prevent the oxidative damage and thus rescue the cell membranes by scavenging ROS (Rady and Mohamed, 2015; Hassan *et al*. 2017). In addition, MLE or SA has been shown to decrease ion leakage, maintain membrane functions, and act as an antioxidant (Yasmeen *et al.,* 2013; Hassan *et al.,* 2017). Because MLE includes many phytohormones, flavonoids, amino acids, antioxidants, and necessary nutrients (Hassan and Fetouh, 2019; Taiz and Zeiger, 2010). It can be used as a biostimulant and plant growth enhancer. Likewise, SA application-maintained plant growth, RWC, and chlorophyll under water stress. This attenuating effect may be a result of the action of SA as a signalling molecule that modulates plant response to environmental stresses, maintains the membrane integrity, accumulates more osmolytes, and preserves photosynthetic pigments (Rady and Mohamed, 2015). Also, foliar spraying of MLE or SA improved the deleterious effects of water stress on plant growth, relative water content, and chlorophyll, which could be related to the additional roles of each treatment.

II.3. Effect of the interaction

The effect of the interaction between irrigation interval and antioxidant treatments (A x b) for relative water content, total water content, and plasma membrane permeability was significant in both seasons. The highest values of RWC and TWC were recorded from plants which irrigated every 15 days and received moringa extract two times at the high rate (15 %) or at the medium rate (10%) in respective order. Also, these two interaction treatments recorded the lowest values of PMP as compared with the control (irrigation at each interval without antioxidants application). In water-stressed plants, antioxidant enzymes activities were increased by foliar spraying with MLE or SA. It is clear that enzymatic and non-enzymatic antioxidants have a major role as ROS scavengers, and therefore they are important in plant defence mechanisms under various stresses (Hassan *et al*., 2020). Thus, enhancement antioxidant defence systems in response to application of MLE or SA, therefore, enhanced ROS scavenging process, thus improved membrane stability which in turn increased water stress tolerance.

III-Growth traits

III.1. Effect of irrigation intervals

Results in Tables 7 and 8 showed that compared to the control (the recommended irrigation period, every 15 days), increasing the irrigation period to 30 and 40 days resulted in significantly shorter plants (125.36 and 115.47 cm; 137.06 and 130.29 cm) with a small number of fruiting branches (14.19 and 12.62; 15.43 and 12.33) in 2021 and 2022 seasons, respectively. While taller plants (144.22 and 155.34 cm) with the higher number of fruiting branches (16.67 and 17.05) were obtained from plants which watered every 15 days. In the present study, a maximum number of fruiting branches plant^{-1} was observed in well-irrigated conditions against the minimum noted under water stress conditions. Significant variation in number of sympodia per cotton plant due to water stress was also obtained by Sahito *et al.* (2015). Under El-Matattana Agricultural Station, Luxor Governorate, Hamoda (2010) reported that irrigation every 15 days led to an increase in the height of plants and the number of sympodia. Emara *et al.* (2015) found that increasing irrigation periods to 4 weeks caused a significant decrease in the height of the plant at harvesting and its number of sympodia.

These results indicated that irrigation every 15 days is proper period for cotton cultivar Super Giza 97, when irrigation water is applied less or more than the optimum requirement of the crop, it negatively affects the physiological and biochemical processes and leads to limited absorption of the inorganic nutrients. Drought is a limiting factor for root growth leads to decreased soil nitrate mobility, root-to-shoot mineral transfer, and altered membrane transfer function and soil physical and chemical properties (Ahanger *et al*., 2016). In addition, it was found that drought led to early closure of stomata, resulting in decreased rate of transpiration and reduced availability and transport of nutrients in the soil matrix and plant tissues (Silva *et al*., 2011). The soil texture is clayey with pH varied from 8.18 to 8.22 (Table 2), which indicated that soil is slightly alkaline but within the optimum range for cotton crop. EC values indicating normal soil and belong to low salinity class. The tallest plants due to irrigation every 15 days compared to the irrigation every 30 or 45 days could be explained increasing length of the internodes and number of nodes.

Table 7. Effect of irrigation intervals and some antioxidants as well as their interactions on the growth, earliness, yield, and yield components of Egyptian cotton Super Giza 97 grown in 2021 season.

Treatments \ Traits		Plant height (cm)	No. of fruiting branches plant^{-1}	No. of open bolls plant^{-1}	Seed index (g)	Boll weight (g)	Seed cotton yield fed^{-1} (kentar)	Earliness %
A-Irrigation intervals:								
a_1-15 day		144.22	16.67	13.61	13.19	2.39	8.40	43.88
a_2- 30 day		125.36	14.19	11.60	11.43	2.32	6.96	49.75
a_3- 45 day		115.47	12.62	10.20	11.48	2.25	5.97	60.95
LSD at 5%		**3.05**	**0.78**	**0.78**	**0.62**	**0.10**	**0.09**	**1.62**
B- Antioxidants treatments:								
b_1-Control		124.83	13.11	10.78	10.89	2.26	6.33	47.59
b_2-Moringa extract 5%		127.34	14.00	11.16	11.44	2.28	6.59	48.82
b_3-Moringa extract 10%		130.18	15.22	12.58	12.44	2.34	7.64	53.98
b_4-Moringa extract 15%		132.28	15.78	13.21	13.22	2.37	8.12	55.46
b_5-Salicylic acid 200 ppm		128.74	14.78	11.92	12.56	2.34	7.24	52.52
b_6-Salicylic acid 300 ppm		127.61	14.22	11.69	11.89	2.33	7.07	52.50
b_7-Salicylic acid 400 ppm		127.46	14.33	11.26	11.78	2.32	6.77	49.81
LSD at 5%		**2.45**	**0.53**	**0.63**	**0.87**	**0.09**	**0.27**	**1.02**
A B Interaction:								
a_1	b_1	136.57	15.33	12.02	12.00	2.36	7.33	41.40
	b_2	143.50	16.00	12.67	12.33	2.31	7.57	42.07
	b_3	147.33	18.00	15.04	14.00	2.41	9.33	45.40
	b_4	153.37	18.00	15.36	15.00	2.46	9.73	47.13
	b_5	144.10	17.33	13.74	13.67	2.42	8.57	45.03
	b_6	143.17	16.33	13.69	12.33	2.40	8.47	43.97
	b_7	141.50	15.67	12.75	13.00	2.37	7.80	42.13
a_2	b_1	122.87	12.67	10.71	10.33	2.22	6.17	45.47
	b_2	124.23	14.00	11.05	11.00	2.31	6.60	47.93
	b_3	127.90	14.33	12.36	12.00	2.34	7.47	52.00
	b_4	127.07	15.67	13.02	12.33	2.36	7.93	52.63
	b_5	126.03	14.00	11.78	12.00	2.34	7.13	49.53
	b_6	124.37	13.67	11.16	11.33	2.33	6.73	52.20
	b_7	125.03	15.00	11.11	11.00	2.33	6.70	48.47
a_3	b_1	114.30	11.33	9.60	10.33	2.20	5.50	55.90
	b_2	115.07	12.00	9.75	11.00	2.21	5.60	56.47
	b_3	115.30	13.33	10.35	11.33	2.28	6.13	64.53
	b_4	116.40	13.67	11.25	12.33	2.30	6.70	66.60
	b_5	116.10	13.00	10.25	12.00	2.27	6.03	63.00
	b_6	115.30	12.67	10.23	12.00	2.26	6.00	61.33
	b_7	115.83	12.33	9.93	11.33	2.25	5.80	58.83
LSD at 5%		**4.24**	**0.93**	**1.09**	**NS**	**0.16**	**0.47**	**1.77**

NS= not significant at 5% level of probability.

Table 8. Effect of irrigation intervals and some antioxidants as well as their interactions on the growth, earliness, yield, and yield components of Egyptian cotton Super Giza 97 grown in 2022 season.

Treatments \ Traits		Plant height (cm)	No. of fruiting branches plant^{-1}	No. of open bolls plant^{-1}	Seed index (g)	Boll weight (g)	Seed cotton yield fed^{-1} (kentar)	Earliness %
A-Irrigation intervals:								
a_1-15 day		155.34	17.05	15.29	11.77	2.65	10.20	46.38
a_2- 30 day		137.06	15.43	13.34	10.90	2.52	8.46	51.84
a_3- 45 day		130.29	12.33	10.63	10.33	2.38	6.42	61.56
LSD at 5%		**0.61**	**0.60**	**0.31**	**0.14**	**0.13**	**0.19**	**1.13**
B- Antioxidants treatments:								
b_1-Control		138.79	14.00	12.37	10.80	2.47	7.86	50.79
b_2-Moringa extract 5%		140.01	14.56	12.63	10.84	2.51	8.03	51.72
b_3-Moringa extract 10%		141.20	15.33	13.34	11.10	2.56	8.73	54.92
b_4-Moringa extract 15%		142.70	16.11	14.20	11.37	2.60	9.21	56.02
b_5-Salicylic acid 200 ppm		141.04	15.22	13.30	11.06	2.51	8.37	53.71
b_6-Salicylic acid 300 ppm		141.57	14.78	13.00	10.94	2.49	8.20	53.04
b_7-Salicylic acid 400 ppm		140.98	14.56	12.77	10.89	2.50	8.12	52.60
LSD at 5%		**2.04**	**0.49**	0.61	**0.19**	**0.12**	**0.21**	**0.75**
A B Interaction:								
a_1	b_1	151.60	16.33	14.00	11.50	2.60	9.27	45.20
	b_2	152.67	16.67	14.60	11.60	2.62	9.60	45.43
	b_3	157.97	17.33	16.03	11.77	2.68	10.77	47.13
	b_4	158.03	18.33	17.00	12.20	2.70	11.30	47.60
	b_5	157.60	17.33	15.60	11.90	2.63	10.33	46.67
	b_6	154.97	17.00	15.00	11.77	2.65	10.10	46.77
	b_7	154.57	16.33	14.80	11.63	2.70	10.00	45.83
a_2	b_1	135.87	14.67	12.70	10.70	2.50	8.13	47.60
	b_2	137.33	15.33	12.90	10.70	2.55	8.33	49.07
	b_3	137.40	15.67	13.30	11.10	2.60	8.80	54.83
	b_4	142.40	16.33	14.20	11.33	2.60	9.17	56.67
	b_5	135.30	15.67	13.80	10.90	2.45	8.40	52.77
	b_6	136.27	15.00	13.50	10.73	2.47	8.23	51.07
	b_7	134.87	15.33	13.00	10.83	2.50	8.17	50.90
a_3	b_1	128.90	11.00	10.40	10.20	2.30	6.17	59.57
	b_2	130.03	11.67	10.40	10.23	2.35	6.17	60.67
	b_3	128.23	13.00	10.70	10.43	2.40	6.63	62.80
	b_4	127.67	13.67	11.40	10.57	2.50	7.17	63.80
	b_5	130.23	12.67	10.50	10.37	2.45	6.37	61.70
	b_6	133.47	12.33	10.50	10.33	2.35	6.27	61.30
	b_7	133.50	12.00	10.52	10.20	2.30	6.20	61.07
LSD at 5%		**3.53**	**NS**	**1.05**	**NS**	**NS**	**0.37**	**1.34**

NS= not significant at 5% level of probability.

Drought stress decreases plant growth by affecting processes of photosynthesis and cell expansion (Zahoor *et al.*, 2017). Similarly, under drought stress, photosynthesis rate, leaf area, rate of transpiration and total dry matter accumulation are reduced due to stomatal restriction and/or lack of stomata, shedding of leaves and fruiting structures leading to reduced final yield (Pettigrew, 2004). Limited carbon fixation resulting from stomatal closure and reduced photosynthesis under drought stress obstructs the metabolism of carbohydrates and processes of dry matter partitioning (Chaves *et al*., 2002). Drought can affect fruiting and boll abscission in several ways. Water deficiency reduces photosynthesis by reducing leaf size (photosynthetic area) and thus reducing photophosphorylation (Boyer, 1973), causing stomatal closure (Cutler and Rains, 1977), decreasing the synthesis and activity of photosynthetic enzymes (Jones, 1973), Hill reaction activity (Fry, 1970), increasing photorespiration (Lawlor, 1976), leaves may become senescent and abscise (McMichael *et al*., 1973). Other effects of prolonged stress can limit photosynthesis as a result of decreased uptake of nitrate (Shaner and Boyer, 1976) and phosphate (Greenway *et al*., 1969); decreased nitrate reductase activity (Ackerson *et al.*, 1977); increased IAA oxidase activity (Darbyshire, 1971); decreased cytokinin content (Vaadia, 1976); increased ethylene production (McMichael *et al.*, 1972); increased ribonuclease activity (Arad *et al.*, 1973); decreased polyribosome content and decreased protein synthesis (Boyer, 1973). Drought may also decrease the translocation of assimilates, but photosynthesis is affected more than translocation in cotton (Ackerson and Herbert, 1981). Water deficit can alter the hormonal balance in bolls. Loss of water causes bolls to produce increasing amounts of ethylene, both when plants are stressed and when detached bolls are subjected to partial desiccation (Guinn, 1998). Further, the ABA content of young bolls on field-grown plants increases as stress develops between irrigations, and the increase in ABA content parallels an increase in the rate of boll shedding (Guinn, 1998). Thus, both abscission-promoting hormones (ethylene and ABA) increase with increasing stress. Water deficit may also affect boll abscission through an effect on IAA transport to the abscission zone. Cell growth is one of the most drought-sensitive physiological processes due to the reduction in turgor pressure (Taiz and Zeiger, 2010). Under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells (Nonami, 1998)

II.2. Effect of antioxidants

Results in the same Tables show that, antioxidant treatments exhibited significant differences in plant height at harvest and number of fruiting branches/plant in both seasons. Compared to the control (untreated plants), the plants that received moringa leaf extract at the high rate (15%) two times significantly increased plant height and the number of fruiting branches/plant at harvest followed by the plants that received moringa extract at the medium rate (10%) two times. The positive effect in plant height and number of fruiting branches/plant at harvest due to moringa leaf extract application may be attributed mainly to the positive role of higher N, P, and K concentration in leaves (Tables 4 and 5) on average inter-node length and/or number of main stem internodes. MLE application provides higher photosynthetic pigment and a photosynthesis rate that contributes to the leaf area increment and plant growth enhancement (Khan *et al.* 2022). In addition, the amino acids present in biostimulants also play vital roles in increasing the direction and rate of metabolic processes (Kocira *et al.*, 2021). The presence of phytohormones in MLE influences the physiological process in a plant (Rodrigues *et al.*, 2020). MLE possesses phytohormones, such as auxin and GA_3, with special attention to cytokinin (Latif and Mohamed, 2016). Cytokinin also improves sink capacity and photosynthate assimilation because of more extended green areas in the leaf (Zwack and Rashotte, 2013). The presence of zeatin, the most common cytokinin in MLE (Nasir *et al.,* 2020). Zeatin accelerates cell division and cell enlargement during fruit development (Teribia *et al.,* 2016).

Application of 200 ppm SA produced taller plants with higher fruiting branches than the control. Application of 200 ppm SA produced more leaves photosynthesis pigments (chlorophyll a, b, and carotenoids), total carbohydrates, N, P, and K concentration than the control. Foliar spraying with salicylic acid resulted in the production of a significantly higher number of sympodia per plant indicating the role of salicylic acid in improving the reproductive growth of cotton under water stress conditions (Noreen *et al*., 2015).

III.3. Effect of the interaction

The interaction between irrigation interval and antioxidant treatments (A x b) for plant height at harvest was significant in both seasons and for number of fruiting branches/plant was significant in the first season only (Tables 7 and 8). The highest significant values of plant height and number of fruiting branches were obtained by normal interval of irrigation (15 days) with spraying moringa leaf extract at the high rate (15%) two times. Plants irrigated every 45 days without antioxidant application produced the shortest plants with the lower number of fruiting branches.

IV. Yield, yield components and earliness%

IV.1. Effect of irrigation intervals

Regarding the effect of irrigation intervals on seed cotton yield**,** yield components, and earliness%, results in Tables (7 and 8) showed that, a significant difference among the three irrigation intervals for open bolls number plant^{-1}, boll weight, seed index and yield of seed cotton fed^{-1} was found in the two growing seasons, in favour of irrigation every 15 days followed in ranking by irrigation every 30 and 45 days. Significant increase in earliness% was obtained from irrigation every 45 days.

The raise in yield of seed cotton fed^{-1} obtained by irrigation every 15 days was about 20.69% and 40.70%: 20.57% and 58.88% over irrigation every 30 and 45 days in 2021 and 2022 seasons, respectively. Similar results were obtained by Basal *et al*. (2009); El-Ashmouny (2014); Ibrahim *et al*. (2014); Hassan *et al.* (2016). Hamoda (2010) found that extending the irrigation period to 21 days caused a significant decrease in number of open bolls plant^{-1}, boll weight, seed index, seed cotton yield fed^{-1}, while earliness% was significantly increased under El-Matattana Agricultural Station, Luxor Governorate, Egypt. Emara *et al.* (2015) found that increasing irrigation periods to 4 weeks caused a significant decrease in number of open bolls plant^{-1}, boll weight, and seed cotton yield fed^{-1}. Meanwhile, seed index, and earliness percentage were not significantly affected.

The positive effect on seed cotton yield fed^{-1} due to irrigation every 15 days may be due primarily to maximum number of fruiting branches plant^{-1} under good irrigation conditions compared to the minimum number noted under water stress conditions. A significant difference in fruiting branches in reply to water stress was also found by Sahito *et al*. (2015). Application of irrigation water at 15-day intervals produced maximum number of open bolls per plant against the minimum which observed with the application of irrigation water at 30-day and 45-day intervals since bolls are greatly dependent on pre-flowering reserved photo-assimilate and water stress at flower and boll formation stage adversely affected the number and size of bolls. It is also possible that the significant reduction in bolls per plant under water stress conditions can be related to reduced assimilation production during photosynthesis and its disturbance in the allocation of effluent and conserved photo-assimilates to bolls (Veesar *et al*., 2018). Reduction in average boll weight under water stress conditions may be related to the minimal amount of carbohydrates in leaves as shown in Table 5. Water stress significantly decreased cotton productivity. This decrease in productivity was due to the decrease in sympodial branches, bolls harvested, and average boll weight that was related with impaired morphological, physiological, and biochemical characteristics of cotton plants. The decrease in the number of fruiting branches, bolls per plant and average weight of boll under water-stressed conditions eventually led to a decrease in cotton productivity, which may be due to the fact that the traits contributing to yield dependent on the availability of soil moisture and antioxidant enzymes activities (Farooq *et al*., 2009; Korres *et al*., 2016). The data in Table 3 showed that the prevailing climate elements in the experimental location are compatible with the thermal and relative humidity requirements for cotton growth stages during the both growing seasons.

IV.2. Effect of antioxidants

Results in Tables (7 and 8) showed that, plants received moringa leaf extract at the high rate (15%) twice showed a significant increase in number of open bolls/plant, boll weight, seed index, earliness% and seed cotton yield/fed in both seasons. These traits in untreated plants (the control) recorded the lowest values. As for SA treatment, data indicated that foliar spraying with salicylic acid resulted in a significant increase in bolls retention under water stress situations. It was observed that foliar spray with MLE enhanced flowering, bolls setting percentage and seed cotton yield (Arif *et al*., 2019). Bolls treated with growth stimulants had larger photosynthetic pools for carbohydrates and other metabolites resulting in improved the percentage of boll settings and average boll weight (Ren *et al*., 2013). The presence of cytokinin in MLE helps in producing more and superior bolls (Arif *et al*., 2019). However, exogenously applied salicylic acid and MLE resulted in significant improvement in the yield and its components which showed the positive effect of these materials on various physiological processes (Wutipraditkul *et al*., 2015). A higher weight and size of cotton boll might be related to foliar application of growth stimulants which improves the photosynthesis rate, contributing to the influx photo-assimilates towards bolls to increase the supply carbohydrate during the reproductive phase and minerals found in MLE, like potassium and zinc. Potassium regulates the cumulation of starch and sugar, however zinc, a precursor of tryptophan, is involved in the synthesis of IAA, which is necessary for the fruit growth and development (Nasir *et al*., 2016). Calcium (Ca^{+2}) is participating in cell wall formation and plays a binding role in the complex polysaccharides as well as proteins. The role of calcium in the stabilizing cell walls was also mentioned (Martins *et al*., 2020).

The stimulatory impact of SA on earliness%, yield of seed cotton and its components may be related to its influence on several biochemical and physiological processes that are reflected in improving vegetative growth and active translocation of the photosynthesis products from source to sink. This amelioration might be cumulative oxygen ratio and reducing the abscisic acid in plants (Hayat and Ahmed, 2007). Salicylic acid caused a significant increase in photosynthetic pigments (Table 4). The promoting effects of SA on photosynthetic capacity could be attributed to its stimulatory effects on Rubisco activity and pigment contents (Khodary, 2004), in addition to increasing carbon dioxide assimilation, rate of photosynthetic and increasing the plant absorption of minerals (Szepesi *et al*., 2005). Furthermore, SA acts as a concentrated antioxidant substances in the chloroplasts and protects the photosynthetic apparatus when a plant is exposed to stress, by eliminating the highly reactive oxygen species known as free radicals. These effects may be due to the protection of the endogenous antioxidant systems that are often associated with increased resistance to oxidative stress and/or control of the level of free radicals within plant tissues (El-Tayeb and Ahmed 2010). Under drought conditions, SA has regulatory effects on various physiological and biochemical processes within plants such as ion uptake, cell division, protein synthesis, differentiation, elongation, sink/source relation, enzyme activities, photosynthetic activity, and increasing the plants antioxidant capacity (El-Tayeb, 2005). External application of SA has a regulatory effect on growth and development via activating biochemical pathways, which enhances the tolerance mechanisms in plants under water deficiency (Najafian *et al*., 2009).

IV.3. Effect of the interaction

The effect of the interaction between irrigation interval and antioxidant treatments (A x b) for open bolls number/plant and seed cotton yield/fed was significant in both seasons and for boll weight was significant in the first season only (Tables 7 and 8), in favor of normal interval of irrigation (15 days) with spraying moringa leaf extract at the high rate (15%) two times. Plants irrigated every 45 days without antioxidant application produced the lowest values of these traits and the highest value of earliness%. Seed index was insignificantly affected by the interaction in both seasons.

V-Fiber traits

V.1. Effect of irrigation intervals:

Irrigation intervals significantly affected upper half mean length in the first season and fiber strength in the second season (Table 9), in favor of the cotton plants irrigated every 15 days compared to increasing irrigation period to 30 and 45 days. Micronaire reading and length uniformity index were insignificantly affected by irrigation intervals in the two seasons of the study. In this concern, Basal *et al.* (2009) reported that fiber quality was significantly affected by irrigation levels. Hamoda (2010) reported that prolonging the irrigation period to 21 days caused a significant decrease in fiber length and strength. Moisture stress negatively affects the actin cytoskeleton formation which stimulates the secondary cell wall synthesis, a key component in determining the strength of fiber (Wang *et al*., 2010). El-Ashmouny (2014) found that cotton plants irrigated every 14 days gave the highest fineness and strength values as compared to 21 or 28 days.

Irrigation periods had insignificant effect on fiber properties (Emara *et al.*, 2015). El-Gabiery (2016) reported that irrigation intervals did not exert any significant effect on fiber strength and fineness. El-Shazly (2017) found that irrigated cotton plants every 21 days significantly increased fiber length as compared to 14 or 28 days. Pinnamaneni *et al*. (2021) found that full irrigation, half irrigation, and rain-fed had a significant effect on micronaire, strength, and upper half mean length (UHML). They added that irrigation has a significant positive impact on UHML.

VI.2. Effect of antioxidants

The data in Table (9) showed that fiber length, uniformity index, fiber strength, and micronaire reading were insignificantly affected by antioxidant treatments in both seasons.

VI.2. Effect of the interaction

The interaction had an insignificant effect on fiber traits under study in both seasons (Table 9).

CONCLUSION

It could be concluded that interaction treatment (irrigation every 15 days x spray with moringa leaves extract 15%) recorded the best results. In addition, spraying cotton plants irrigated every 30 days with moringa leaf extract at a high rate (15%) two times can be applied safely to minimize the negative impact of drought stress on cotton plants under conditions like the Sakha location.

Table 9. Effect of irrigation intervals and some antioxidants as well as their interactions on fiber properties of Egyptian cotton Super Giza 97 grown during the two growing seasons of 2021 and 2022.

Treatments \ Traits		Fiber fineness (Micronaire reading)		Fiber strength (Pressley index)		Upper half mean length (mm)		Length uniformity index (%)	
		2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
A-Irrigation intervals:									
a_1-15 day		4.13	4.15	10.89	10.52	34.24	34.07	85.81	85.69
a_2-30 day		4.02	4.17	10.73	10.44	33.62	33.79	84.96	86.23
a_3-45 day		4.01	4.17	10.72	10.46	33.95	33.39	85.52	86.55
LSD at 5%		**NS**	**NS**	**0.09**	**NS**	**NS**	**0.23**	**NS**	**NS**
B- Antioxidants treatments:									
b_1-Control		4.11	4.14	10.63	10.49	34.34	33.44	85.20	85.97
b_2-Moringa extract 5%		4.07	4.10	10.62	10.54	33.91	34.12	85.50	86.16
b_3-Moringa extract 10%		4.06	4.20	10.87	10.50	33.89	33.71	85.56	86.34
b_4-Moringa extract 15%		4.04	4.19	10.73	10.52	33.84	34.12	85.63	86.41
b_5-Salicylic acid 200 ppm		3.99	4.17	10.86	10.43	33.76	33.06	85.38	86.04
b_6-Salicylic acid 300 ppm		4.18	4.13	10.66	10.50	34.09	33.89	85.33	85.86
b_7-Salicylic acid 400 ppm		3.94	4.19	11.09	10.34	33.73	33.90	85.40	86.32
LSD at 5%		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
A B Interaction:									
a_1	b_1	4.13	4.20	10.87	10.57	34.20	34.13	85.50	85.73
	b_2	4.13	4.17	10.83	10.50	34.13	33.73	86.17	85.83
	b_3	4.23	4.33	10.83	10.67	34.37	33.77	86.37	85.73
	b_4	4.07	4.10	10.63	10.50	34.07	34.33	85.43	85.90
	b_5	4.13	3.97	11.17	10.40	34.17	33.87	86.20	85.30
	b_6	4.27	4.00	10.73	10.40	34.50	34.20	85.47	85.67
	b_7	3.93	4.27	11.13	10.63	34.23	34.43	85.53	85.63
a_2	b_1	4.00	4.10	10.53	10.60	34.63	34.50	84.73	85.63
	b_2	4.00	4.10	10.53	10.53	34.07	34.07	85.07	86.33
	b_3	4.07	4.07	10.77	10.53	33.57	34.13	84.60	86.07
	b_4	4.00	4.17	10.93	10.50	33.80	34.30	85.47	86.53
	b_5	3.97	4.30	10.63	10.40	32.80	32.33	84.70	86.20
	b_6	4.13	4.30	10.63	10.50	33.47	34.30	85.13	86.20
	b_7	4.00	4.13	11.10	10.03	33.03	32.93	85.00	86.67
a_3	b_1	4.20	4.13	10.50	10.30	34.20	31.70	85.37	86.53
	b_2	4.07	4.03	10.50	10.60	33.53	34.57	85.27	86.30
	b_3	3.867	4.20	11.00	10.30	33.73	33.23	85.70	87.23
	b_4	4.067	4.30	10.63	10.57	33.67	33.73	86.00	86.80
	b_5	3.87	4.23	10.77	10.50	34.30	32.97	85.23	86.63
	b_6	4.13	4.10	10.60	10.60	34.30	33.17	85.40	85.70
	b_7	3.90	4.17	11.03	10.37	33.93	34.33	85.67	86.67
LSD at 5%		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS= not significant at 5% level of probability.

REFERENCES

Abdel-Salam, M. E. and Negm, M. A. M. E. (2009). The Egyptian Cotton; current constraints and future opportunities. Textile Industries Holding Co. 2009. Modern Press-Alexandria-Egypt.

Ackerson, R.C. and Hebert, R.R. (1981). Osmoregulation in cotton in response to water stress. I. Alterations in photosynthesis, leaf conductance, translocation, and ultrastructure. Plant Physiol., 67: 484-488.

Ackerson, R.C.; Krieg, D.R.; Haring, C.L. and Chang, N. (1977). Effects of plant water status on stomatal activity, photosynthesis, and nitrate reductase activity of field grown cotton. Crop Sci., 17: 81- 84.

Ahanger, M.A.; Talab, N.M.; Abd-Allah, E.F.; Ahmad, P. and Hajiboland, R. (2016). Plant growth under drought stress: Significance of mineral nutrients. Water Stress and Crop plants: a Sustainable approach, 2, First Edition. Edited by Parvaiz Ahmad. © 2016 John Wiley & Sons, Ltd. Published 2016 by John Wiley & Sons, Ltd.

Ahmad, G.; Nishat, Y.; Haris, M.; Danish, M. and Hussain, T. (2019). Efficiency of soil, plant and microbes for healthy plant immunity and sustainable agricultural system. Plant Microbe Interface, pp. 325-346.

AOAC (2005). Association of official analytical chemists. "Official Methods of Analysis", 26th ed. AOAC International, Washington, D.C; USA.

Apel, K. and Hirt, H. (2004). Reactive oxygen species: metabolism, oxidative stress and signal transduction. Annu. Rev. Plant Biol., 55: 373-399.

Arad, S. M.; Mizrahi, Y. and Richmond, A. E. (1973). Leaf water content and hormone effects on ribonuclease activity. Plant Physiol., 52: 510-512.

Arif, M.; Kareem, S. H. S.; Ahmad, N. S.; Hussain, N.; Yasmeen, A.; Anwar, A.; Naz, S.; Iqbal, J.; Shah, G. A. and Ansar, M. (2019). Exogenously applied bio-stimulant and synthetic fertilizers to improve the growth, yield and fiber quality of cotton. Sustain., 11: 2171.

Arif, Y.; Bajguz, A. and Hayat, S. (2022). *Moringa oleifera* extract as a natural plant bio stimulant. J. Plant Growth Regul., 42(3): 1-16.

Aslam, M.; Sultana, B.; Anwar, F. and Munir, H. (2016). Foliar spray of selected plant growth regulators affected the biochemical and antioxidant attributes of spinach in a field experiment. Turk. J. Agric. For., 40: 136–145.

ASTM (2012). Standards of Textile Materials. Designation, (D-1447-07), (D1448-97), (D1445-67).

Barrs, H.D. and Weatherley, P.E. (1962). Arc examination of the relative turgidity technique for estimating water deficits in leaves. Aust. J. Bio. Sci., 15: 413 - 428.

Basal, H; Dagdelen, N.; Unay, A. and Yilmaz, E. (2009). Effects of deficit drip irrigation ratios on cotton (*Gossypium hirsutum* L.) yield and fibre quality. J Agron. Crop Sci., 195: 19-29

Bates, L.S.; Waldem, R. P. and Teare, D. (1973). Rapid determination of free proline under water stress studies. Plant and Soil, 39: 205- 207.

Boyer, J.S. (1973). Response of metabolism to low water potentials in plants. Phytopathology, 63: 466- 472.

Broesh, S. (1954). Colorimetric assay of phenoloxidase. Bull. Soc. Chem., Biol., 36: 711-713.

Chaves, M.M.; Pereira, J.S.; Maroco, J.; Rodriguez, M.L.; Ricardo, C.P.P.; Osorio, M.L.; Carvalho, I.; Faria, T. and Pinheiro, C. (2002). How plants cope with water stress in the field. Photosynthesis and growth. Ann. Bot., 89: 907-916.

Clarke, S.M.; Cristescu, S.M.; Miersch, O.; Harren, F.J.; Wasternack, C. and Mur, L.A. (2009). Jasmonates act with salicylic acid to confer basal thermotolerance in Arabidopsis thaliana. New Phytol., 182: 175-87.

Cutler, J.M. and Rains, D.W. (1977). Effects of irrigation history on responses of cotton to subsequent water stress. Crop Sci., 17: 329-335.

da Costa, V.A. and Cothren, J.T. (2011). Drought effects on gas exchange, chlorophyll, and plant growth of 1-methylcyclopropene treated cotton. Agron. J., 103: 1230-1241.

Darbyshire, B. (1971). Changes in indoleacetic acid oxidase activity associated with plant water potential. Physiol. Plant, 25: 80-84.

Desoky, E. S. M.; Elrys, A. S. and Rady, M. M. (2019) Integrative moringa and licorice extracts application improves *Capsicum annuum* fruit yield and declines its contaminant contents on a heavy metals-contaminated saline soil. Ecotoxicol. Environ. Saf., 169: 50–60.

El Sheikha, A.F.; Allam, A.Y.; Taha, M. and Varzakas, T. (2022). How does the addition of biostimulants affect the growth, yield, and quality parameters of the snap bean (*Phaseolus vulgaris* L.)? How is this reflected in its nutritional value? Appl. Sci.,12: 776.

El-Ashmouny, A. A. M. (2014). Effect of some bioregulators on cotton yield grown under different planting dates and irrigation intervals. Ph. D. Thesis, Fac. of Agric., Minufiya Univ.

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, Shaimaa O. and 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. Appl. Sci., 12(4): 468-498.

El-Shazly, B.W.M. (2017). Using nano and natural materials for increasing cotton productivity and quality under water stress conditions. M. Sc. Thesis, Fac. of Agric. Mansoura Univ.

El-Tayeb, M.A. (2005). Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regul., 45: 215–224.

El-Tayeb , M. A. and Ahmed N. L. (2010). Response of Wheat Cultivars to Drought and Salicylic Acid. American-Eurasian J. of Agron., 3 (1): 01-07.

Emara, M.A.A.; Abdel-Aal, Amal, S. A. and Hamoda, S.A.F. (2015). Effect of water stress and foliar feeding with boron and zinc under NPK fertilizer levels on growth and yield of the new promising cotton genotype (Giza 86 X 10229). Fayoum J. Agric. Res. & Dev., 29 (1): 27-48.

Ergashovich, K.A.; Azamatovna, B.Z.; Toshtemirovna, N.U. and Rakhimovna, A.K. (2020). Eco physiological effects of water deficiency on cotton varieties. J. of Critical Rev., 7 (9): 244-246.

Fariduddin, Q.; Hayat, S. and Ahmad, A. (2003). Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity and seed yield in Brassica juncea. Photosynthetica, 41: 281–284.

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

Fehrman, H. and Dimond, A.E. (1967). Peroxidase activity and phytophthora resistance in different organs of the potato. Plant pathology, 57: 69-72.

Fry, K.E. (1970). Some factors affecting the hill reaction activity in cotton chloroplasts. Plant Physiol., 45: 465-469.

García-Beltrán, J.M.; Mansour, A.T.; Alsaqufi, A. S.; Ali, H.M. and Esteban, M. A. (2020). Effects of aqueous and ethanolic leaf extracts from drumstick tree (*Moringa oleifera*) on gilthead seabream (*Sparus aurata* L.) leucocytes, and their cytotoxic, antitumor, bactericidal and antioxidant activities. Fish Shellfish Immunol., 106: 44–55.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Edition, John Wiley and Sons, New York, 680 p.

Gosev, N. A. (1960). Some methods in studying plant water relation. Leningrad Acad. of Sci. U.S.S.R.

Greenway, H.; Hughes, P.G. and Klepper, B. (1969). Effects of water deficit on phosphorus nutrition of tomato plants. Physiologia Plantarum, 22: 199-207.

Guinn, G. (1998). Causes of square and boll shedding. In: Proc. Beltwide Cotton Prod.

Res. Conf. National Cotton Council, Memphis, Tenn., pp. 1355-1364.

Hamoda, S.A.F. (2010). Impact of water stress and nitrogen fertilizer levels on cotton under high temperature in Upper Egypt. Tenth Int. Conf. on Dev. of Dray lands, 12-15 December 2010, Cairo, Egypt.

Hassan, F.; Al-Yasi, H.; Ali, E.; Alamer, K.; Hessini, K.; Attia, H. and El-Shazly, S. (2021). Mitigation of salt-stress effects by moringa leaf extract or salicylic acid through motivating antioxidant machinery in damask rose. Can. J. Plant Sci.,101: 157–165.

Hassan, F.A.S. and Fetouh, M.I. (2019). Does moringa leaf extract have preservative effect improving the longevity and postharvest quality of gladiolus cut spikes? Sci. Hortic., 250: 287–293.

Hassan, F.A.S.; Mazrou, R.; Gaber, A. and Hassan, M.M. (2020). Moringa extract preserved the vase life of cut roses through maintaining water relations and enhancing antioxidant machinery. Postharvest Biol. Technol. 164: 111156.

Hassan, F.A.S.; Morsi, M.M. and Aljoudi, N.G.S. (2017). Alleviating the adverse effects of salt stress in rosemary by salicylic acid treatment. Res. J. Pharm. Biol. Chem. Sci., 8: 1980–1995.

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

Hayat, Q.; Hayat, S.; Ifran, M. and Ahmad, A. (2010). Effect of exogenous salicylic acid under changing environment: a review. Environ. and Exp. Botany, 68: 14-25.

Hayat, S. and Ahmad, A. (2007). Salicylic acid a plant hormone. The Netherlands: Springer

Hoque, T.S.; Jahan I.; Ferdous, G. and Abedin, M.A. (2020). Foliar application of moringa leaf extract as a biostimulant on growth, yield and nutritional quality of brinjal. J. Agric. Food Environ., 1: 94–99.

Hossain, Md. Moktar; Miah, G.; Ahamed, T. and Sarmin, N. S. (2012). Study on allelopathic effect of Moringa oleifera on the growth and productivity of mungbean. Int. J. Agri Crop Sci., 4 (15): 1122-1128.

Hussain, M.; Malik, M.A.; Farooq, M.; Khan, M.B.; Akram, M. and 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.

Hussain, N.; Anwarb, A.; Yasmeena, A.; Arifa, M.; Naza, S.; Bibib, M.; Iqbalc, J.; Qadira, I.; Salimb, M. N. and Latifb, S. (2021). Resource use efficiency of cotton in improved vs conventional planting geometry with exogenous application of bio-stimulant and synthetic growth retardant. Braz. J. Biol., 81(1): 18-26.

Ibrahim, M.E.; Bekheta, M.A.; Alia A. Namich and El-Ashmouny, Amany A. (2014). Effect of irrigation intervals and growth retardant (paclobutrazol) on leaf endogenous hormones content and yield of cotton (cultivar Giza 92). Minufiya J. Agric. Res., 39 No. 4(1): 1359-1370.

Ismail, H.; Maksimovic, J.D.; Maksimovic, V.; Shabala, L.; Živanovic, B.D.; Tian, Y.; Jacobsen, S.E. and Shabala, S. (2016). Rutin, a flavonoid with antioxidant activity, improves plant salinity tolerance by regulating K^+ retention and Na^+ exclusion from leaf mesophyll in quinoa and broad beans. Funct. Plant Biol., 43: 75-86.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall of Indian Private Limited, New Delhi.

Jones, H.G. (1973). Moderate-term water stresses and associated changes in some photosynthetic parameters in cotton. New Phytol., 72: 1095-1105.

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

Khan, M.I.R.; Asgher, M. and Khan, N.A. (2014). Alleviation of salt-induced photosynthesis and growth inhibition by salicylic acid involves glycinebetaine and ethylene in mungbean (*Vigna radiata* L.). Plant Physiol. Biochem., 80: 67-74.

Khan, M. I. R.; Fatma, M.; Per, T. S.; Anjum, N. A. and Khan, N. A. (2015). Salicylic acid on photosynthetic pigments and antioxidative enzymes of soybean plant. Frontier of Plant Sci., 6:1-17.

Khan, S.; Basra, S.M.A.; Nawaz, M.; Hussain, I. and Foidl, N. (2020). Combined application of moringa leaf extract and chemical growth-promoters enhances the plant growth and productivity of wheat crop (*Triticum aestivum* L.) S. Afr. J. Bot., 129: 74–81.

Khan, S.; Ibrar, D.; Bashir, S.; Rashid, N.; Hasnain, Z.; Nawaz, M.; Al-Ghamdi, A.A.; Elshikh, M.S.; Dvořáčková, H. and Dvořáček, J. (2022). Application of moringa leaf extract as a seed priming agent enhances growth and physiological attributes of rice seedlings cultivated under water deficit regime. Plants., 11: 261.

Khodary, S (2004). Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plants. Intel J. of Agric. and Biol., 6 (1): 5-8.

Kocira, S.; Szparaga, A.; Krawczuk, A.; Bartoš, P.; Zaguła, G.; Plawgo, M., and Černý, P. (2021). Plant Material as a Novel Tool in Designing and Formulating Modern Biostimulants—Analysis of Botanical Extract from *Linum usitatissimum* L. Materials., 14: 6661.

Korres, N.E.; Norsworthy, J.K.; Tehranchian, P.; Gitsopoulos, T.K.; Loka, D.A. and Oosterhuis, DM (2016). Cultivars to face climate change effects on crops and weeds: A review. Agr. Sust. Devel., 36: 12.

Kreeb, K.H. (1990). Methoden Zur Pflanzenokologie und Bioindikation Gustav Fisher, Jena, 327 pp.

Latif, H.H. and Mohamed, H.I. (2016). Exogenous applications of moringa leaf extract effect on retrotransposon, ultrastructural and biochemical contents of common bean plants under environmental stresses. S. Afr. J. Bot.,106: 221–231.

Lawlor, D.W. (1976). Water stress induced changes in photosynthesis, photorespiration, respiration and CO_2 compensation concentration of wheat. Photosynthetica, 10: 378-387.

Martins, V.; Garcia, A.; Alhinho, A.T.; Costa, P.; Lanceros-Méndez, S.; Costa, M.M.R. and Gerós, H. (2020). Vineyard calcium sprays induce changes in grape berry skin, firmness, cell wall composition and expression of cell wall-related genes. Plant Physiol. Biochem.,150: 49–55.

McMichael, B.L.; Jordan, W.R. and Powell, R.D. (1972). An effect of water stress on ethylene production by intact cotton petioles. Plant Physiol., 49: 658-660.

McMichael, B.L.; Jordan, W.R. and Powell, R.D. (1973). Abscission processes in cotton: induction by plant water deficit. Agron. J., 65: 202-204.

Muscolo, A.; Sidari, M.; Anastasi, U.; Santonoceto, C. and Maggio, A. (2014). Effect of PEG-induced drought stress on seed germination of four lentil genotypes. J. Plant Interact., 9: 354-363.

Najafian, S.; Khoshkhui, M.; Tavallali, V. and Saharkhiz, M.J. (2009). Effect of salicylic acid and salinity in thyme (*Thymus Vulgaris* L.): Investigation on changes in gas exchange, water relations, and membrane stabilization and biomass accumulation. Aust. J. Basic Appl. Sci., 3: 2620-2626.

Nasir, M.; Khan, A.S.; Basra, S.M.A. and Malik, A.U. (2016). Foliar application of moringa leaf extract, potassium and zinc influence yield and fruit quality of 'Kinnow' mandarin. Sci. Hortic., 210: 227–235.

Nasir, M.; Khan, A.S.; Basra, S.M.A. and Malik, A.U. (2020). Improvement in growth, productivity and quality of 'Kinnow' mandarin fruit after exogenous application of *Moringa olifera* leaf extract. S. Afr. J. Bot., 129: 263–271.

Nepomuceno, A.L.; Oosterhuis, D.M. and Stewart, J.M. (1998). Physiological responses of cotton leaves and roots to water deficit induced by polythelene glycol. Environ. and Exp. Bot., 40: 29-41.

Nisar, M.; Nasir, M.; Saleem, S.; Iqbal, M. U. and Athar, T. (2021). "Effect of Foliar Application of Moringa Leaf Extract (MLE) on Growth and Yield of *Gossypium hirsutum*". Acta Scientific Agric., 5.2: 33-36.

Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials, J. Plant Res., 111: 373–382.

Noreen, S.; Zafar, Z. U.; Hussain, K.; Athar, H.U.R. and Ashraf, M. (2015). Assessment of economic benefits of foliarly applied some protectants in alleviating the adverse effects of water stress on growth and yield of cotton (*Gossypium hirsutum* L.). Pak. J. Bot., 47(6): 2223-2230.

Pancheva, T.V. and Popova, L.P. (1997). Effect of salicylic acid on the synthesis of ribulose-1,5-bisphosphate carboxylase/oxygenase in barley leaves J. Plant Physiol., 152: 381-386.

Panhwar, B.U.; Keerio, A.; Panhwar, A.K.; Panhwar, R.A.; Panhwar, F.H. and Channa, AR. (2022). Potential of Leaf Extract of Miracle Plant (Moringa oleifera L.) As Seed Priming Agent and Foliar Fertilization of Cotton *(Gossypium hirsutum L.).* RADS J. Biol. Res. Appl. Sci.,13(2): 148-156.

Pettigrew, W.T. (2004). Physiological consequences of moisture deficit stress in cotton. Crop Sci., 44: 1265-1272.

Phiri, C. (2010). Influence of *Moringa oleifera* leaf extracts on germination and early seedling development of major cereals. Agric. Biol. J. N. Am., 1: 774–777.

Pinnamaneni Srinivasa, R.; Anapalli Saseendran, S.; Sui Ruixiu, Bellaloui Nacer and Reddy Krishna, N. (2021). Effects of irrigation and planting geometry on cotton (*Gossypium hirsutum* L.) fiber quality and seed composition. J. of Cotton Res., 4(2): 1-11.

Rady, M.M. and Mohamed, G.F. (2015). Modulation of salt stress effects on the growth, physio-chemical attributes and yields of *Phaseolus vulgaris* L. plants by the combined application of salicylic acid and *Moringa oleifera* leaf extract. Scientia Hort.,193: 105-113.

Rehman, H.U.; Basra, S.M.A.; Rady, M.M.; Ghoneim, A.M. and Wang, Q. (2017). Moringa leaf extract improves wheat growth and productivity by delaying senescence and source-sink relationship. Int. J. Agric. Biol., 19: 479–484.

Ren, X.; Zhang, L.; Du, M.; Evers, J.B.; Werf, W.V.D.; Tian, X. and Li, Z. (2013). Managing mepiquat chloride and plant density for optimal yield and quality of cotton. Field Crops Res.,149: 1-10.

Rodrigues, M.; Baptistella, J.L.C.; Horz, D.C.; Bortolato, L.M. and Mazzafera, P. (2020). Organic Plant Biostimulants and Fruit Quality-A Review. Agron., 10: 988.

Sadak, M.S. and Dawood, M.G. (2014). Role of ascorbic acid and α tocopherol in alleviating salinity stress on flax plant (*Linum usitatissimum* L.). J. Stress Physiol. And Biochem., 10: 93-111.

Sahito, A.; Baloch, Z.A.; Mahar, A.; Otho, S.A.; Kalhoro, S.A.; Ali, A.; Kalhoro, F.A.; Soomro, R.N. and Ali, F. (2015) Effect of Water Stress on the Growth and Yield of Cotton Crop (*Gossypium hirsutum* L.). American J. of Plant Sci., 6: 1027-1039.

Sánchez-Rodríguez, E. and Rubio-Wilhelmi, M. (2010). Genotypic differences in some physiological parameters symptomatic for oxidative stress under moderate drought in tomato plants. J. Plant Sci., 178: 30-40.

Saneoka, H.; Moghaieb, R.E.A.; Premachandra, G.S. and Fujita, K. (2004). "Nitrogen nutrition and water stress effects on cell membrane stability and leaf water relations in *Agrostis palustris* Huds". Environ. Exp. Bot., 52 (2): 131-138.

Sardar, H.; Nisar, A.; Anjum, M.A.; Naz, S.; Ejaz, S.; Ali S.; Javed, M.S. and Ahmad, R. (2021). Foliar spray of moringa leaf extract improves growth and concentration of pigment, minerals and stevioside in stevia (*Stevia rebaudiana* Bertoni). Ind. Crops Prod., 166: 113485.

Shaner, D.L. and Boyer, J.S. (1976). Nitrate reductase activity in maize (*Zea mays* L.) leaves. II. Regulation by nitrate flux at low leaf water potential. Plant Physiol., 58: 505-509.

Sibet, T. and Birol, T. (2007). Some physiological responses of drought stress in wheat genotypes with different ploidy in turkey. World, J. Agric. Sci., 3 (2): 178-183.

Silva, E.C.; Nogueira, R.J.M.C.; Silva, M.A. and Albuquerque, M. (2011). Drought stress and plant nutrition. Plant Stress, 5(1): 32- 41.

Szepesi, A.; Csiszár, J.; Bajkán, S.; Gémes, K.; Horváth, F.; Erdei, L.; Deér, A. K.; Simon, M. L. and Tari, I. (2005). Role of salicylic acid pre-treatment on the acclimation of tomato plants to salt- and osmotic stress. Acta Biol. Szeged., 49: 123–125.

Taiz, L. and Zeiger, E. (2010). Plant physiology. 5th ed. Sinauer Associates, Sunderland, MA, USA.

Teribia, N.; Tijero, V. and Munné-Bosch, S. (2016). Linking hormonal profiles with variations in sugar and anthocyanin contents during the natural development and ripening of sweet cherries. New Biotechnol., 33: 824–833.

Toscano, S.; Ferrante, A.; Branca, F. and Romano, D. (2021). Enhancing the quality of two species of baby leaves sprayed with moringa leaf extract as biostimulant. Agron., 11: 1399.

Trimble, S. (2021). Transpiration in Plants: Its Importance and Applications. CID Bio-Sci.

Vaadia, Y. (1976). Plant hormones and water stress. Philosophical Transactions of the Royal Society of London. B. Biol. Sci., 273: 513-522.

Veesar, N.F.; Baloch, M.J.; Kumbher, M.B. and Chachar, Q.D. (2018). Field screening of cotton genotypes for drought tolerance on the basis of yield and fibre traits. Sindh Univ. Res. J., 50 (001): 45-52.

Vernon, L.P. and Selly, G.R. (1966). The chlorophylls. Academic Press. New York and London. In: Kado CJ, Agrawal HO (eds) Virology. Van Nostrand Reinhold Company, New York.

Wang H.; Robinson R. C. and Burtnick L. D. (2010). The structure of native G-actin. Cytoskeleton, 67 (7): 456–465.

Wutipraditkul, N.; Wongwean, P. and Buaboocha, T. (2015). Alleviation of salt-induced oxidative stress in rice seedlings by proline and/or glycinebetaine. Biol. Plant., 59: 547-553.

Yan, B.; Dai Q; Liu, X.; Huang, S. and Wang, Z. (1996). "Flood-induced membrane damage, lipid oxidation and activated oxygen generation in corn leaves". Plant and Soil, 179: 261- 268.

Yasmeen, A.; Arif, M.; Hussain, N.; Naz, S. and 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: 857-863.

Yasmeen, A.; Basra, S.M.A.; Farooq, M.; Rehman, H.U. and Hussain, N. (2013). Exogenous application of moringa leaf extract modulates the antioxidant enzyme system to improve wheat performance under saline conditions. Plant Growth Regul., 69: 225-233.

Yuniati, N.; Kusumiyati, K.; Mubarok, S. and Nurhadi, B. (2022). The Role of Moringa Leaf Extract as a Plant Bio stimulant in Improving the Quality of Agricultural Products. Plants (Basel), 11(17): 2186.

Zahoor, R.; Dong, H.; Abid, M.; Zhao, W.; Wang, Y. and Zhou, Z. (2017). Potassium fertilizer improves drought stress alleviation potential in cotton by enhancing photosynthesis and carbohydrate metabolism. Environ. Exp. Bot., 137: 73-83

Zaki, S. N.S. and Rady, M.M. (2015). Moringa oleifera leaf extract improves growth, physiochemical attributes, antioxidant defence system and yields of salt stressed *Phaseolus vulgaris* L. plants. Int. J. Chem Tech. Res., 8(11): 120–134.

Zwack, P. and Rashotte, A.M. (2013). Cytokinin inhibition of leaf enescence. Plant Signal. and Behav., 8(7): 1-7.

تأثير بعض مضادات الأكسدة على النمو، بعض الصفات الفسيولوجية وإنتاجية القطن النامى تحت ثلاث فترات رى مختلفة

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الملخص العربى

أجريت تجربتان حقليتان في مزرعة محطة بحوث سخا الزراعية بمركز البحوث الزراعية- مصرخلال موسمى الزراعة ٢٠٢١ ، ٢٠٢٢ لدراسة تأثير ثلاث فترات رى (١٥ ، ٣٠ ، ٤٥ يوم) والرش ببعض مضادات الأكسدة (مستخلص أوراق المورينجا بتركيز (٥ ، ١٠ ،١٥%) ، حامض الساليسيليك بتركيز (٢٠٠، ٣٠٠، ٤٠٠جزء فى المليون) مقارنة بالنباتات غير المعاملة أو هما معا على النمو، بعض الصفات الفسيولوجية وإنتاجية وجودة محصول القطن (المصرى) صنف سوبرجيزة ٩٧ باستخدام تصميم القطع المنشقة في ثلاث مكررات.

أوضحت النتائج أن نباتات القطن المروية كل ١٥ يوماً والتى عوملت رشا بمستخلص المورينجا بمعدل (١٥%) أدت إلى زيادة معنوية في صبغات التمثيل الضوئي للأوراق، تركيزات الكربوهيدرات الكلية والنيتروجين والفسفور والبوتاسيوم، ومحتوى الأوراق من الماء الكلي والمياه النسبية مع تحسين صفات النمو ومحصول القطن الزهر للفدان ومكوناته في كلا الموسمين. وقد لوحظ انخفاض معنوي في النسبة المئوية للتبكير ونفاذية الغشاء البلازمى(مما يدعم سلامة الغشاء البلازمى) ونشاط أنزيمات البيروكسيديز والفينول أوكسيديز ومحتوى البرولين. وقد تم الحصول على أطول ألياف وأعلى متانة للقطن من النباتات المروية كل ١٥ يومًا في موسم واحد فقط .

وكانت أفضل النتائج المتحصل عليها فى هذا الشأن من معاملة التفاعل (الرى كل ١٥ يوم مع الرش بمستخلص المورينجا ١٥% مرتين) ويمكن التوصية بأستخدام مستخلص المورينجا رشا بمعدل (١٥%) مرتين وبشكل آمن للحد من التأثير السلبي للجفاف وهو ما يمكن التوصية بأستخدامها عند أطالة فترات الرى تحت ظروف منطقة سخا لزيادة العقد وتقليل التأثير السلبي للاجهاد المائى مع زيادة الإنتاجية.