Egypt. J. Agron. **Vol. 43**, No. 3, pp. 391-402 (2021)

Egyptian Journal of Agronomy
http://agro.journals.ekb.eg/

Amelioration of the Adverse Effects of Salinity Stress by Using Bio-stimulant Moringa on Cotton Plant

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SALINITY is one of a great environmental stresses limiting productivity of crops. Moringa leaf extract (MLE) is considered as bio-stimulant and eco-friendly fertilizer, which being rich in amino acids, minerals, and growth hormones. A pot experiment was conducted in 2020 and 2021 seasons at greenhouse of Plant Physiology Department, Cotton Research Institute, Agricultural Research Center, Giza, Egypt. This experiment design was split-plot with three replications, which the main plots were devoted to salinity water irrigation (SWI) concentrations (0, 6000 and 10000ppm), while the sub-plots were randomly of MLE foliar application concentrations (10, 20 and 30%) at three times (squaring, beginning and top flowering stages) to investigate the effective concentration of MLE foliar application on chemical constituents, growth, yield and fiber parameters under SWI concentrations on Giza 97 cotton cultivar. MLE foliar application enhanced significantly chemical constituent, enzymes activity, growth, yield and fiber properties as compared with untreated plants under different SWI concentrations. The best results were recorded by spraying MLE at concentration of 30% about (15.30 and 16.61%) for number of opened bolls/plant, (15.27 and 10.56%) for boll weight and (31.36 and 33.56%) for seed cotton yield as compared to untreated plants in both seasons, respectively. On the other hand, salinity conditions caused significantly reduction in pigments contents, growth and yield. However, it caused significantly increasing in osmolyte compounds and enzymes activity on cotton. The interaction between SWI and MLE treatments effected significantly on chemical constituents, enzymes activity, growth, yield characters, while did not affect significantly on fiber properties.

Keywords: Chemical constituents, Cotton, Growth and yield, Moringa leaves extract, Salinity.

Introduction

Many areas cultivated with cotton in Egypt suffer from increased salinity as a result of irrigation by wastewater and groundwater that raises the concentration of salinity of soil and cotton plants, which causes to poor plant growth and decreasing in yield and its components (Mabrouk et al., 2018). Salinity caused harm effects on plant physiology, metabolism process, growth, yield and its quality that due to cellular ionsimbalance, osmotic stress and increase reactive oxygen species (ROS) production. Also, accumulation of Na^+ and Cl^- ions inside plant cells led to inhibit antioxidant enzymes processes (Rady et al., 2013; Zhang et al., 2014). Under salinity stress, tolerant plantsregulate water andions movements more effectiveness. Besides that, they can improve the antioxidant system including non-enzymatic antioxidants likeproline, soluble sugars, carotenoids, and phenolic compounds; antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) andperoxidase (POD); and enzymes of ascorbate-glutathione cycle like glutathione reductase (GR), which they can alleviate the harmful effects of salinity conditions on plant (Rady et al., 2015; Taha, 2016).

Moringa is one of many species of genus *Moringa* and family Moringnance. Moringa leave extract (MLE) is source of vitamins (A, C, E, B1 and B2), essential nutrients mineral (K, Ca, Mg, Mn, P and Zn), antioxidant, osmoprotectants and some plant secondary metabolites (amino acids, soluble sugars, phenolic acid, and β-caroteine) in a naturally balanced composition, that may be useful for plant growth and development (Yasmeen et al., 2018; Arif et al., 2019). Also, MLE contents phytohormones specially cytokinins (zeatin), which

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Received 15/10/2021; Accepted 26/12/2021
DOI : 10.21608/agro.2021.101121.1284

zeatin stimulate cell division, cell tissue growth and promote nutrient uptake in plant. MLE have high concentration of zeatin between 5- 200 μg/g of leaves (Abusuwar & Abohassan, 2017). MLE regulated physiological processes of crops under salinity conditions, which keepwater status in tissue, enhanced membrane stability, improved antioxidant levels, activated plant defense system, improved plant secondary metabolites, reducedaccumulation of Na^+ and/or Cl^- ions and enhanced leaves K^+ in plant (Yasmeen et al., 2013; Rady et al., 2015; Hanafy, 2017).

The main objectives of this study to investigate the effective concentration of MLE foliar applications (10, 20 and 30%) on chemical constituents, enzymes activity, growth, yield characters and fiber properties on cotton under different SWI concentrations (0, 6000 and 10000ppm).

Materials and Methods

Cotton plant material

Cotton (*Gossypium barbadense* L. cv Giza 97) seeds were obtained from the Plant Physiology Department, Cotton Research Institute, Agricultural Research Center, Giza, Egypt.

Moringa leaves extract preparation

Preparation of moringa leaves extraction as described by Khalil et al. (2014) as following: dry powdered *Moringa oleifera* leaves (200g) were extracted with 1l of 70% ethanol and shacked each 8 h by 24 h. After that the hydro-alcoholic extract was filtered using a cotton funnel and repeat four times. The extract was concentrated using a rotator evaporator under reduced pressure. The concentrated extracts were lyophilized and kept at -20°C. The extract was analyzed and its chemical constituents are presented in Table 1.

Methods

Experimental design and treatments

A pot experiment was conducted during 2020 and 2021 seasons at wire green house of Plant Physiology Department, Cotton Research Institute, Agricultural Research Center, Giza, Egypt. This experiment design was split–plot with three replications. The main plots were devoted to SWI concentrations (0, 6000 and 10000ppm), while the subplots were randomly of MLE foliar application concentrations (10, 20 and 30%) at three times (squaring, beginning and top flowering stages) to investigate the effective concentration of MLE on chemical constituents, enzymes activity, growth, yield characters and fiber properties on cotton plants under different SWI concentrations. Seeds of cultivar Giza 97 were sown in clay loam soils on 24th of April in 2020 season and on the 18th April in 2021 season and plants were thinned to two plants per pot (40cm in diameter containing 16kg of soil). The fertilizers and other agricultural practices were done according to the recommendation of the Ministry of Agriculture for cotton plants in Egypt. All pots were irrigated by tap water until 45 days (squaring stage). Then SWI started by with different concentrations followed by tap water alternately during the whole season, which control treatments (0ppm) irrigated by tap water only. The soil analysis was conducted according to Rebecca (2004). The soil chemical properties of the experimental soil are presented in Table 2 during two seasons.

TABLE 1. Chemical constituents of *Moringa oleifera* leaf extract

Chemical determinants	Determined concentration	Chemical determinants	Determined concentration
	Aqueous extract		Aqueous extract
Total Proteins	26.7%	**Nutritional elements**	
Total Carbohydrates	48.6%	Calcium (Ca)	874mg/kg
Total soluble salts	2.21%	Potassium (K)	723mg/kg
Essential amino acids determinants		Magnesium (Mg)	574mg/kg
Isoleucine	1.43	Phosphor (P)	267mg/kg
Leucine	2.67	Manganese (Mn)	23mg/kg
Lysine	2.59	Zinc (Zn)	12mg/kg
Methionine	0.72	**Vitamins determinants**	
Phenylalanine	2.55	Vitamin C	130mg/100mL
Threonine	1.22	Vitamin A (β-carotene)	1.10mg/100mL
Tryptophan	0.61	Vitamin E (α- tocopherol)	61mg/100mL
Valine	1.10	Vitamin B1 (Thiamin)	2.2mg/100mL

TABLE 2. Chemical properties of experimental soil

	2020	2021		2020	2021
pH	7.84	7.95	**Soluble anions (meq/L)**		
E.C. (dsm^{-1})	1.50	1.58	**CO_3^{2-}**	--	--
Available minerals (mg/kg soil)			**HCO_3^-**	3.54	3.67
N	43.93	44.24	**Cl^-**	5.29	5.62
P	9.20	9.53	**SO_4^{2-}**	6.32	6.84
K	477.5	485.2	**Soluble cations (meq/L)**		
Cu	8.12	8.46	**Ca^{2+}**	5.93	6.22
Fe	34.42	35.31	**Mg^{2+}**	2.98	3.18
Mn	8.91	9.04	**Na^+**	5.95	6.17
Zn	11.34	11.52	**K^+**	0.36	0.39

Chemical analysis

Representative samples of cotton leaves were taken randomly from the top of fourth node leaves at 15 days after full flowering stage for 2020 season only to determine the total chlorophyll contents according to Arnon (1949), carotenoids content according to method of Robbelen (1957), as well as determinetotal soluble sugars according to Cerning (1975), total phenols according to Simons & Ross (1971), also determine total free amino acids according to Rosen (1957), Proline content according to method of Bates et al. (1973), total soluble proteins according to Choudhury & Punda (2004) and total antioxidant capacity according to Prieto et al. (1999). In addition to measure enzymes activities such as CAT activity according to Sinha (1972), POX activity according to Herzog & Fahimi (1973), SOD activity according to Beauchamp & Fridovich (1971) and GR activity according to Carlberg & Manneryik (1985).

Growth characteristics

Plant samples were taken after 15 days from last foliar application with MLE concentrations at top flowering stage during the experimental period. In this stage, 4 plants were taken from each treatment. The growth characteristics of plants were recorded for this experiment as follows: plant height (cm), number of fruiting branches/ plant, plant dry weight (g), leaf area (cm^3) by leaf area meter Model L1 – 3100. The root shoot ratio was calculated on the basis of formulae described by Evans (1972). Also, relative water content (%) was determined according to the method of Schonfeld et al. (1988).

Yield and its components

At harvest stage, samples were taken foryield and its components such as number of open bolls/ plant, boll weight (g), lint percentage, seed index (g) and seed cotton yield/plant.

Fiber quality

According to A.S.T.M. (2012) fiber length, micronaire reading and fiber strength were determined fiber length, micronaire reading and fiber strength were recorded during data collection.

Statistical analysis

The measured variables were analyzed by ANOVA using M Stat-C statistical package (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5% level ($P \leq 0.05$) of probability to compare differences between the means (Snedecor & Cochran, 1988).

Results and Discussion

Chemical constituents of cotton leaves

Results in Table 3 inducted that effect of SWI and MLE treatments and their interaction on some chemical constituents, i.e., total chlorophyll, carotenoids, total soluble sugars, total phenols, total free amino acids, free proline and total soluble proteins contents in cotton leaves. As for SWI treatments, the data revealed that increasing the SWI concentrations (0, 6000 and 10000ppm) reduced significantly total chlorophyll and carotenoids contents, while increased significantly total soluble sugars, total phenols, total free amino acids, free proline and total soluble proteins contents in cotton leaves. The results indicated that, cotton plants irrigated by SWI at concentration of 0ppm gave the highest means of total chlorophyll and carotenoids contents (7.25 and 1.377mg/g, FW, respectively), while these gave the lowest means of total soluble sugars (26.61 mg/g, FW), total phenols (13.79mg/g, FW), total free amino acids (11.22mg/g, FW), free proline (14.62mg/g, FW) and total soluble proteins contents (16.62mg/g, FW), respectively. On the other hand, cotton plants irrigated by SWI at concentration of 10000ppm gave the lowest means of total chlorophyll and carotenoids contents (4.55 and 1.127mg/g, FW, respectively), while these gave the highest means of total soluble sugars (41.66mg/g, FW), total phenols (19.76mg/g, FW), total free amino acids (26.24mg/g, FW), free proline (36.67mg/g, FW) and total soluble proteins contents (23.76mg/g, FW), respectively. This might be related to salinity stress reduced photosynthesis rate and decreased chlorophyll content by distortion in chlorophyll ultrastrures, also it suppressed the responsible enzymes for chlorophyll synthesis and reduction in stomatal conductance. Cotton plants under salinity stress activated several metabolic and defense systems to survive like increasing the chemical constituents contents of soluble sugars, soluble proteins, free amino acids especially free proline that act as protective osmolytes enable plants to keep tissue water stations. Also, total phenols accumulation plays an important role as scavenging free radicals. This concern, Rady et al. (2013) and Hanafy (2017) stated that the osmolyte compounds such as (total soluble sugars, total phenol, amino acids and proline) accumulated under stress conditions might be contributed as scavenges of ROS. Similar results are in line with those obtained by Hanafy et al. (2013), Zhang et al. (2014) and Shehzad et al. (2019) on cotton, Rady et al. (2015) on common bean and Taha (2016) on sunflower.

TABLE 3. Effect of salinity water irrigation concentrations, moringa leaf extract applications and the interaction between them on total chlorophyll, carotenoids, total soluble sugars, total phenols, total free amino acids, free proline and total soluble proteins contents of cotton leaves

Salinity water conc. (A)	MLE application (B)	Total Chl. (mg/g FW)	Carotenoids (mg/g FW)	Total soluble sugars (mg/g FW)	Total phenols (mg/g FW)	Total free amino acids (mg/g FW)	Free proline (µmol/g FW)	Total soluble proteins (mg/g FW)
0 ppm	Control	6.28	1.282	21.93	12.49	10.54	9.59	14.82
	10%	6.73	1.304	25.31	13.03	10.98	11.57	16.36
	20%	7.81	1.434	28.38	13.67	11.51	17.83	17.32
	30%	8.18	1.490	30.82	16.00	11.86	19.52	17.98
Mean		**7.25**	**1.377**	**26.61**	**13.79**	**11.22**	**14.62**	**16.62**
6000 ppm	Control	4.82	1.147	29.18	15.71	12.85	20.43	19.55
	10%	5.85	1.211	35.52	17.54	14.55	28.12	20.83
	20%	6.40	1.218	37.71	17.69	16.37	29.85	22.09
	30%	7.02	1.262	39.17	22.83	18.53	30.22	22.88
Mean		**6.02**	**1.209**	**35.39**	**18.44**	**15.57**	**27.15**	**21.33**
10000 ppm	Control	3.72	1.010	37.45	17.55	22.66	29.71	22.73
	10%	3.94	1.132	41.62	18.24	25.04	33.87	23.23
	20%	4.97	1.156	42.04	18.98	27.22	38.37	24.16
	30%	5.60	1.213	45.56	24.28	30.07	44.73	24.93
Mean		**4.55**	**1.127**	**41.66**	**19.76**	**26.24**	**36.67**	**23.76**
General mean of MLE application (B)	Control	4.94	1.146	29.52	15.25	15.35	19.91	19.03
	10%	5.50	1.215	34.15	16.27	16.85	24.52	20.14
	20%	6.39	1.269	36.04	16.78	18.36	28.68	21.19
	30%	6.93	1.321	38.51	21.03	20.15	31.49	21.93
LSD at 0.05 of	A	0.066	0.077	0.222	0.126	0.329	0.109	0.363
	B	0.079	0.081	0.250	0.206	0.278	0.373	0.264
	A x B	0.138	0.140	0.434	0.357	0.482	0.647	0.458

Concerning the main effect of MLE foliar application, the results demonstrated that increasing MLE concentration (10, 20 and 30%) was significantly enhanced all chemical constituents of cotton leaves under different SWI concentrations as compared with untreated plants. Spraying MLE at concentration of 30% increased the content of total chlorophyll (40.28%), carotenoids (15.27%), soluble sugars (30.45%), total phenols (37.90%), free amino acids (31.27%), proline (58.16%) and soluble proteins (15.23%) as compared with untreated plants (0 ppm), respectively. The positive effect of MLE foliar application on chemical constituents is mainly due to modulate genes expression of plants metabolic process, which it increased chlorophyll, soluble sugars, phenols, proline and soluble proteins contents that acted as osmoprotectants and caused to synthesis of other substances having protective effects on plant especially under stress conditions. Additionally, MLE content high levels of cytokinin (zeatin), which cytokinin is a promoter to carbohydrate metabolism then phenols in cotton leaves. Hanafy (2017) noted that MLE foliar application increased significantly the contents of total pigment, carbohydrates, phenols and prolinein soybean plants as compared to untreated plants under stress conditions. As well as, Yasmeen et al. (2018) and Arif et al. (2019) inducted that foliar application of MLE have high contents of different macro elements like Mg that increasing chlorophyll and carbohydrate contents and stimulate the production of cytokinin (zeatin) that increased carbohydrate biosynthesis. These results are similar to those reported by Rady et al. (2015) on common bean, Taha (2016) on sunflower and Abusuwar & Abohassan (2017) on cereals forage plants under stress.

With regard to the interaction between SWI and MLE treatments, the results illustrated that the chemical constituents of cotton leaves were significantly affected by the interaction between the two factors. Increasing MLE concentration decreased the harmful effect of SWI under the different levels. In general, the highest chemical constituentsobtained for cotton plants sprayed by MLE at concentration of 30% under different SWI levels. Whereas, the lowest values for these chemical constituents were recorded for untreated cotton plants by MLE under different SWI levels. This might be due to MLE application play important role by enhancing the osmotic mechanisms and regulation water potential in cotton plant under salinity stress. Similar trend was founded by Rady et al. (2015) on common bean, Taha (2016) on sunflower and Abusuwar & Abohassan (2017) on cereals forage plants under stress.

Data in Table 4 presented the effect of SWI and MLE treatments and their interactions on enzymes activity and total antioxidant capacity of cotton leaves. Considering the SWI treatments, the results clearly showed that increasing SWI concentration increased significantly total antioxidant capacity and enzymes activity (CAT, POD, SOD and GR) on cotton leaves. The height average of total antioxidant capacity, CAT, POD, SOD and GR activity were (1.705 $O.D_{695}$, 1.883, 1.052, 1.474 and 2.615U/mg protein, respectively) when cotton plants irrigated by SWI at concentration of 10000ppm. On the other hand, The lowest average of total antioxidant capacity, CAT, POD, SOD and GR activity were (1.014 $O.D_{695}$, 0.859, 1.018, 0.549 and 0.410U/mg protein, espectively) when cotton plants irrigated by SWI at concentration of 0 ppm. The negative effect of salinity conditions reduced photosynthesis rate that led to imbalance in production of ROS and antioxidant activities alterations. To avoid this damage caused by oxidative stress, plants have developed many antioxidant systems such as increasing of CAT, POD, SOD and GR enzymes. These enzymes activity increased significantly with increasing SWI at concentrations of 6000 and 10000ppm, and acted in concert to mitigate the cellular damage accumulated as compared to plants irrigated by SWI at concentration of 0ppm. Similar, Taha (2016) showed that salt stress significantly increased the activity of SOD and GR as compared to control sunflower plants.These results are in harmony with Rady et al. (2013) on wheat, Zhang et al. (2014) on cotton, Zaki & Rady (2015) on common bean.

The results clearly showed that MLE foliar application had a positive effect on total antioxidant capacity and enzymes activity of CAT, POD, SOD and GR as compared to untreated plants. Increasing MLE concentration was significantly increased total antioxidant capacity and enzymes activity with increasing SWI levels. Spraying MLE at concentration of 30% increased of total antioxidant capacity (53.89%) and enzymes activity of CAT (114.19%), POD (18.30%), SOD (46.10%) and GR (68.36%), respectively, as compared with untreated plants (0ppm). These results might be attributed to MLE contents of macro- and micronutrients, antioxidants as osmoprotectants and phytohormones as cytokinin, which spraying MLE caused improving in total antioxidant capacity and enzymes activity to protect plants against the generation of ROS, membrane damage and improve plants tolerance under salinity conditions. In this concern, Hanafy (2017) revealed that application of MLE caused high significantly increasing in SOD and GR activities in soybean plants under stress conditions. These results are consistent with Zaki & Rady (2015) on common bean and Taha (2016) on sunflower plants under salt stress.

As for the interaction between SWI and MLE treatments, the data illustrated that antioxidant capacity and enzymes activities were significantly affected by the interaction between their treatments. In general, the best results forantioxidant capacity and all enzymes activity obtained by spraying MLE at concentration of 30% under different SWI levels, while the untreated plants by MLE exhibited lowest ones. These results agree with many workers such as Taha (2016) and Hanafy (2017).

Growth characteristics

Data in Table 5 reported growth characteristics as affected by SWI and MLE treatments and their interaction on cotton plant in 2020 and 2021 seasons. With regard the main effect of SWI treatments, the results clearly stated that increasing SWI concentration significantly reduced growth characteristics (plant height, no. of fruiting branches/ plant, plant dry weight, root shoot ratio, leave area and relative water content) of cotton plant. The cotton plants irrigated by SWI at concentration of 0 ppm, recorded the highest means of plant height (68.53 and 65.04g), no. of fruiting branches/ plant (7.01 and 6.66), plant dry weight (25.99 and 24.67g), root shoot ratio (1.12 and 1.11g/g), leave area (705.39 and 656.95cm^2) and relative water content (60.67 and 55.52%) in the first and second seasons, respectively. On the other hand, Cotton plants irrigated by SWI at concentration of 10000ppm obtained the lowest means of plant height (47.27 and 44.95g), no. of fruiting branches/ plant (4.69 and 4.42), plant dry weight (13.31 and 12.17g), root shoot ratio (1.29 and 1.13 g/g), leave area (397.98 and 375.10cm^2) and relative water content (44.07 and 42.45%) in the first and second seasons, respectively. The reduction in cotton plants growth might be attributed to the osmotic effect by salinity stress that caused decreasing in photosynthesis rate, water available, increasing growth inhibitors, ionic imbalance, toxic ions accumulation and stomatal closure, which that led to reduce plant growth and productivity. These results are in line with Rady et al. (2013) on wheat, Hanafy et al. (2013), Zhang et al. (2014) on cotton, Rady et al. (2015), Zaki & Rady (2015) on common bean and Taha (2017) on sunflower plants.

As for the main effect of MLE application, the results revealed that increasing MLE concentration were associated with increasing significantly in growth characteristics (plant height, no. of fruiting branches/ plant, plant dry weight, root shoot ratio, leave area and relative water content) of cotton plant. The relative increasingin growth characteristics caused by spraying MLE at concentration of 30% over untreated plants reached to plant height (23.84 and 24.32%), no. of fruiting branches/ plant (32.32 and 35.20%), plant dry weight (39.81 and 38.47%), leave area (24.44 and 24.99%) and relative water content (21.27 and 27.34%) in two seasons, respectively.This is explained that MLE application considered as biofertilizer contents of mineral, vitamins, phytohormones and some plant secondary metabolites that enhancing cotton plant growth and development especially under stress conditions. Also, spraying MLE might be due to improved formation of carbohydrates, protein synthesis and increased photosynthesis rate, which it act as a growth promoter and increasing growth characteristics. In this connection, Zaki & Rady (2015) mentioned that the increased MLE content of IAA, GAs and zeatin, ascorbic acid and minerals enhanced plant growth and productivity under salt stress conditions. These results are in line with those stated by Rady et al. (2015) on common bean, Taha (2016) on sunflower, Abusuwar & Abohassan (2017) on canola, and Hanafy (2017) on soybean under stress conditions.

Regarding the interaction effect between SWI and MLE treatments, the results found that the interaction significantly affected on plant dry weight, root shoot ratio, leave area and relative water content, while plant height was not affected in both seasons. In general, the highest values of growth characteristics were obtained in cotton plants sprayed by MLE at concentration of 30% under different SWI levels, while the untreated cotton plants recorded the lowest one. Similar results were observed by Rady et al. (2015), on common bean, Taha (2016) on sunflower, and Hanafy (2017) on soybean under stress conditions.

TABLE 4. Effect of salinity water irrigation concentrations, moringa leaf extract applications and the interaction between them on catalase, peroxidase, superoxide dismutase and glutathione reductase activities and total antioxidant capacity of cotton leaves

Salinity water conc.	MLE application	Total antioxidant capacity ($O.D_{695\ nm}$)	Catalase activity (U/mg protein)	Peroxidase activity (U/mg protein)	Superoxide dismutase (U/mg protein)	Glutathione reductase (U/mg protein)
0ppm	Control	0.602	0.382	0.921	0.362	0.212
	10%	1.071	0.866	1.004	0.584	0.484
	20%	1.160	0.903	1.045	0.605	0.823
	30%	1.224	1.284	1.103	0.643	0.122
Mean		**1.014**	**0.859**	**1.018**	**0.549**	**0.410**
6000ppm	Control	1.275	0.685	0.966	1.020	1.045
	10%	1.597	1.202	1.008	1.254	1.423
	20%	1.730	1.621	1.023	1.403	1.582
	30%	1.876	1.783	1.191	1.442	1.641
Mean		**1.620**	**1.323**	**1.047**	**1.280**	**1.423**
10000ppm	Control	1.434	1.384	0.980	1.201	1.682
	10%	1.578	1.785	1.060	1.405	2.485
	20%	1.810	1.980	1.068	1.603	3.104
	30%	1.998	2.183	1.100	1.688	3.188
Mean		**1.705**	**1.833**	**1.052**	**1.474**	**2.615**
General mean of MLE application (B)	Control	1.104	0.817	0.956	0.861	0.980
	10%	1.415	1.284	1.024	1.081	1.464
	20%	1.567	1.501	1.045	1.204	1.836
	30%	1.699	1.750	1.131	1.258	1.650
LSD at 0.05 of	A	0.037	0.014	0.005	0.008	0.011
	B	0.054	0.011	0.004	0.010	0.023
	A x B	0.095	0.020	0.008	0.017	0.040

TABLE 5. Effect of salinity water irrigation concentrations, moringa leaves extract applications and the interaction between them on growth characters on cotton plant during 2020 and 2021 seasons

Treatments		Plant height (cm)		No. of fruiting branches/ plant		Plant dry weight (g)		Root shoot ratio (g/g)		Leave area (cm^2)		Relative water content %	
Salinity water conc. (A)	MLE application (B)	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
0 ppm	Control	60.22	58.45	6.14	6.00	22.63	20.47	1.07	1.09	648.57	611.27	52.24	47.90
	10%	67.56	63.83	6.82	6.45	24.35	23.83	1.11	1.19	664.93	633.95	58.57	52.00
	20%	71.84	67.56	7.26	6.93	26.72	26.05	1.15	1.08	736.75	685.36	64.53	58.64
	30%	74.51	70.32	7.85	7.26	30.26	28.36	1.17	1.08	771.31	697.23	67.36	63.57
Mean		**68.53**	**65.04**	**7.01**	**6.66**	**25.99**	**24.67**	**1.12**	**1.11**	**705.39**	**656.95**	**60.67**	**55.52**
6000 ppm	Control	49.43	46.51	4.86	4.47	16.91	16.28	1.04	1.20	516.16	453.35	46.82	41.34
	10%	53.55	50.36	5.32	5.15	19.42	17.45	1.19	1.22	536.53	516.73	49.00	46.82
	20%	56.71	53.67	5.91	5.73	21.16	19.00	1.18	1.18	572.61	560.62	50.58	49.00
	30%	59.00	56.29	6.45	6.28	22.75	20.79	1.18	1.23	594.57	592.38	52.63	50.48
Mean		**54.67**	**51.70**	**5.63**	**5.40**	**20.06**	**18.38**	**1.14**	**1.20**	**554.96**	**530.77**	**49.75**	**46.91**
10000 ppm	Control	40.48	37.24	3.85	3.43	9.82	9.57	1.39	1.20	320.00	306.19	40.00	37.36
	10%	46.53	44.57	4.63	4.25	13.27	11.28	1.35	1.16	384.46	379.92	42.91	40.92
	20%	49.67	47.82	4.92	4.74	14.16	12.84	1.27	1.14	405.62	390.45	44.74	44.35
	30%	52.42	50.18	5.36	5.26	16.00	15.00	1.17	1.04	481.86	423.86	48.65	47.17
Mean		**47.27**	**44.95**	**4.69**	**4.42**	**13.31**	**12.17**	**1.29**	**1.13**	**397.98**	**375.10**	**44.07**	**42.45**
General mean of MLE application (B)	Control	50.04	47.40	4.95	4.63	16.45	15.44	1.16	1.16	494.91	456.93	46.35	42.20
	10%	55.88	52.92	5.59	5.28	19.01	17.52	1.21	1.19	528.64	510.20	50.16	46.58
	20%	59.40	56.35	6.03	5.80	20.68	19.29	1.20	1.13	571.66	545.47	53.28	50.66
	30%	61.97	58.93	6.55	6.26	23.00	21.38	1.17	1.11	615.91	571.15	56.21	53.74
LSD at 0.05 of	A	2.796	1.228	0.080	0.113	0.385	0.996	0.023	0.033	10.962	10.440	1.724	1.912
	B	1.283	1.241	0.244	0.152	0.347	0.722	0.025	0.031	14.701	6.734	1.775	1.869
	A x B	N.S	N.S	N.S	0.263	0.601	1.251	0.044	0.055	25.464	11.664	3.074	3.238

Yield and yield components

The Data in Table 6 reported the effect of SWI and MLE treatments and their inter action on yield and its components of cotton plant in two seasons 2020 and 2021. Considering the SWI treatments, the data indicated that increasing SWI concentration reduced significantly yield and its components (number of opened bolls/plant, boll weight, seed index and seed cotton yield g/pot), while lint percentage was significantly increasing in both seasons. The cotton plants irrigated by SWI at concentration of 0 ppm, obtained the highest means of number of opened bolls/plant (17.79 and 16.99), boll weight (1.80 and 1.76g), seed index (10.40 and 10.12g) and seed cotton yield (31.99 and 29.91g/pot) in the first and second seasons, respectively. On the other hand, Cotton plants irrigated by SWI at concentration of 10000 ppm obtained the lowest means of number of opened bolls/plant (11.93 and 11.07), boll weight (1.31 and 1.28g), seed index (9.04 and 8.85g) and seed cotton yield (15.71 and 14.31g/pot) in the first and second seasons, respectively. That might be attributed to salinity stress decreases the availability of assimilates led toreduce number and weight of bolls and finally seed cotton yield. In this connection, Hanafy et al. (2013) and Zhang et al. (2014) deduced that salinity conditions reduced cotton yield by reducing leaf area duration in the development stages caused to loss flowers, bolls and yield. Similar results are in harmony with those found by Rady *et al.* (2013) on wheat, Rady et al. (2015), Zaki & Rady (2015) on common bean and Taha (2017) on sunflower plants.

As MLE treatments, the data reveal that yield and its components were positively responded to MLE foliar application. Spraying cotton plants by MLE at concentration of 30% gave the best results of number of opened bolls/plant, boll weight, seed index and seed cotton yield about (15.3, 15.27, 6.55 and 31.36%) in the first season, respectively, and the similar trend for the second season, whereas the untreated cotton plants exhibited the lowest values of yield and its components in both seasons. The positive effect of MLE application on cotton yield and its components might be attributed to its effect on growth, chemical constituents and activity of enzymes as reported before (Tables 3, 4 and 5), where increased osmolyte compounds content, phytohormones, enzymes activity, production of fruiting branches and leave area resulted in more productivity of flower and boll, also it increased carbohydrate supplying during productivity stage into bolls to increase bolls weight, bolls numbers and gave high quality yield. These results are harmony with Yasmeen et al. (2018) and Arif et al. (2019) found that foliar application of MLE prevents the abscission of squares and bolls, then increasing bolls number and weight stimulating the mobilization and storage of photosynthesis in new formed bolls. As well as, Rady et al. (2015), Zaki & Rady (2015) on common bean, Taha (2016) on sunflower, Abusuwar & Abohassan (2017) on canola and Hanafy (2017) on soybean under stress conditions.

The results of analysis of variance stated that yield and its components were significantly affected by the interaction between SWI and MLE treatments, except lint percentage did not affected significantly in the both 2020 and 2021 seasons. Foliar application of MLE concentration 30% gave the highest statistically valuesof yield and its component under different SWI levels in both seasons. On the other hand, untreated plants gave the lowest values of yield and its component under different SWI levels in both seasons. This means that MLE application decreased the harmful effects of salinity stress on cotton plant. These results are in line with those noticed by Taha (2016) on sunflower and Hanafy (2017) on soybean under stress conditions.

Fiber properties

Data in Table 6 inducted that SWI and MLE treatments and their interactions affected insignificantly on fiber quality properties (fiber length, micronaire reading and fiber strength) of cotton. That may be due to other parameters like chlorophyll content, number of fruiting branch/plant, number of open boll, boll weight, seed index, lint % and seed cotton yield have a negative relation with the fiber properties. These results are agreement with Yasmeen et al. (2018) and Arif et al. (2019), who noted that micronaire value, have a negative relation with seed cotton yield, but MLE treatments increased insignificantly cotton fiber quality as compared to untreated plants.

TABLE 6. Effect of salinity water irrigation concentrations, moringa leaves extract applications and the interaction between them on yield, its components and fiber properties of cotton during 2020 and 2021 seasons

Treatments		No. of open bolls/plant		Boll Weight (g)		Seed Index (g)		Lint %		Cotton seed yield/plant (g)		Fiber length (mm)		Micronaire reading		Fiber strength	
Salinity water conc. (A)	**MLE application (B)**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
0 ppm	Control	16.84	15.90	1.70	1.67	10.20	9.84	39.24	39.10	28.56	26.23	33.80	33.60	4.40	4.40	10.50	10.40
	10%	17.46	16.73	1.77	1.72	10.35	9.95	39.88	39.66	30.79	28.72	34.30	33.90	4.40	4.40	10.70	10.50
	20%	18.15	17.35	1.85	1.82	10.40	10.27	40.32	40.08	33.48	31.48	34.50	34.10	4.50	4.50	10.70	10.50
	30%	18.73	18.00	1.88	1.85	10.65	10.45	40.34	40.42	35.15	33.23	34.60	34.40	4.60	4.50	10.80	10.70
Mean		**17.79**	**16.99**	**1.80**	**1.76**	**10.40**	**10.12**	**39.94**	**39.81**	**31.99**	**29.91**	**34.30**	**34.00**	**4.47**	**4.45**	**10.67**	**10.52**
6000 ppm	Control	14.47	13.85	1.46	1.44	9.45	9.15	40.88	40.93	21.02	19.87	32.70	32.50	4.20	4.30	10.40	10.30
	10%	15.35	14.26	1.54	1.50	9.55	9.35	41.12	41.06	23.87	21.30	33.10	32.80	4.30	4.30	10.40	10.30
	20%	16.18	14.97	1.61	1.58	10.17	9.47	41.55	41.32	25.92	23.54	33.30	32.90	4.40	4.40	10.50	10.50
	30%	16.63	15.54	1.67	1.63	10.25	9.61	41.84	41.65	27.72	25.26	33.70	33.20	4.50	4.50	10.60	10.60
Mean		**15.65**	**14.65**	**1.57**	**1.53**	**9.85**	**9.39**	**41.34**	**41.24**	**24.63**	**22.49**	**33.20**	**32.85**	**4.35**	**4.37**	**10.47**	**10.42**
10000 ppm	Control	10.64	9.63	1.17	1.12	8.73	8.64	41.89	41.83	12.40	10.75	31.80	31.40	4.10	3.90	10.30	10.20
	10%	11.82	10.46	1.26	1.24	8.95	8.85	42.26	42.24	14.92	12.89	32.20	31.60	4.30	4.10	10.40	10.30
	20%	12.27	11.85	1.39	1.37	9.14	8.91	42.71	42.36	16.95	16.16	32.60	31.80	4.30	4.20	10.40	10.40
	30%	13.00	12.37	1.44	1.42	9.35	9.01	42.85	42.55	18.57	17.46	32.90	32.30	4.40	4.30	10.40	10.40
Mean		**11.93**	**11.07**	**1.31**	**1.28**	**9.04**	**8.85**	**42.42**	**42.24**	**15.71**	**14.31**	**32.37**	**31.77**	**4.27**	**4.12**	**10.37**	**10.32**
General mean of MLE application (B)	Control	13.98	13.12	1.44	1.41	9.46	9.21	40.67	40.62	20.66	18.95	32.76	32.50	4.23	4.20	10.40	10.30
	10%	14.87	13.81	1.52	1.48	9.61	9.38	41.08	40.98	23.19	20.97	33.20	32.76	4.33	4.26	10.50	10.36
	20%	15.53	14.72	1.61	1.59	9.90	9.55	41.52	41.25	25.45	23.72	33.46	32.93	4.40	4.36	10.53	10.46
	30%	16.12	15.30	1.66	1.63	10.08	9.69	41.67	41.54	27.14	25.31	33.73	33.30	4.50	4.43	10.60	10.56
LSD at 0.05 of	A	0.094	0.368	0.019	0.005	0.104	0.018	0.255	0.417	0.235	0.265	N.S	N.S	N.S	N.S	N.S	N.S
	B	0.141	0.292	0.012	0.012	0.103	0.046	0.643	0.554	0.207	0.385	N.S	N.S	N.S	N.S	N.S	N.S
	A x B	0.244	0.506	0.021	0.022	0.178	0.081	N.S	N.S	0.358	0.667	N.S	N.S	N.S	N.S	N.S	N.S

Conclusion

It could be recommended that using MLE as bio-stimulant and eco-friendly fertilizer for cotton plant under normal and stress conditions. Spraying cotton plants with MLE at concentration of 30% was the best application to obtain the highest values of growth, yield and its components as well as chemical constituents in the leaves well as enzymes activity of CAT, POD, SOD and GR. Moreover it can by spraying MLE for three times during the productivity stages (squaring, beginning and top flowering), to improve cotton plant tolerance under salinity conditions by increasing the content of osmolyte compounds, enzymes activity and growth that due to finally to increase cotton plant productivity and yield.

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تحسين الآثار الضارة لإجهاد الملوحة بإستخدام المورنجا المنشط الحيوي علي نبات القطن

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الملوحة من أكبر صور الإجهاد البيئي التي تحد من إنتاجية المحاصيل. يعتبر مستخلص أوراق المورينجا منشط حيوي وسماد صديق للبيئة، فهو غني بالأحماض الأمينية والمعادن وهرمونات النمو. نفذت التجربة بتصميم قطع منشقه مره واحده بثلاثة مكررات فى صوبة بقسم فسيولوجيا النبات، معهد بحوث القطن، مركز البحوث الزراعية، الجيزة، مصر خلال موسمى 2020 و2021 على التوالى لصنف قطن جيزه 97 فى الأصيص، حيث قسمت القطع الرئيسيه إلى ثلاث مجموعات من تركيزات الري بالماء الملحي (0، 6000 و10000 جزء في المليون)، بينما كانت القطع الفرعية عشوائية بتركيزات مستخلص أوراق المورنجا (10، 20 و30٪) وتم الرش ثلاث مرات (مراحل الوسواس، بداية وقمه التزهير) لمعرفه التركيز الامثل من مستخلص أوراق المورنجا على المكونات الكيميائية والنمو والمحصول وخصائص الألياف تحت تركيزات من الري بالماء الملحي على صنف قطن جيزة 97. أدي رش مستخلص أوراق المورنجا بشكل ملحوظ إلى تحسين المكونات الكيميائية ونشاط الإنزيمات والنمو والمحصول وخصائص الألياف مقارنة بالنباتات غير المعالجة تحت تركيزات مختلفة من الري بالماء الملحي. تم تسجيل أفضل النتائج عن طريق رش مستخلص أوراق المورنجا بتركيز 30٪ حوالي (15.30 و16.61٪) لعدد اللوز المفتح / نبات، (15.27 و 10.56٪) لوزن اللوز و(31.36 و 33.56٪) لمحصول بذور القطن بالمقارنة للنباتات غير المعالجة في كلا الموسمين على التوالي. من ناحية أخرى، أدت ظروف الملوحة إلى انخفاض معنوي للنباتات القطن في محتويات الأصباغ ونموها وإنتاجيتها. ومع ذلك، فقد تسبب في زيادة كبيرة في نشاط المركبات الأسمولية والإنزيمات. أثر التفاعل بين معاملات الري بالماء الملحي والرش بمستخلص أوراق المورنجا بشكل كبيرعلى المكونات الكيميائية ونشاط الإنزيمات والنمو وخصائص المحصول، بينما لم يؤثر بشكل كبير على خصائص الألياف.