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Optimization of Sweet Pepper Productivity in Greenhouse under Natural Salinity Stress

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ABSTRACT

Planted sweet pepper crop under greenhouse is subjected to salt stress which leads to a decline in overall performance of the crop. The purpose of these experiments was to see how Moringa oleifera leaf extract (1:30 v/v MLE to tap water) and salicylic acid (SA; 1mM) affected the growth, physiochemical attributes, and yields of sweet pepper (*Capsicum annuum* L.) plants grown in greenhouses with saline soil (EC= 2.41 dSm^{-1}) and irrigation water (EC= 2.01 dSm^{-1}). In sweet pepper plants, MLE or SA applied as a seedling spray or plant foliar spray improved growth characteristics (i.e., plant height, number and area of leaves per plant, and plant dry weight) as well as physiochemical attributes (i.e., total chlorophylls, total soluble sugars, free proline and ascorbic acid, and N, P, and K contents). In addition, early and total yields were improved when compared with the controls (seedlings and plant foliar spray with tap water). Combined treatments of MLE and SA (i.e., seedlings spray with MLE + plant foliar spray with MLE, seedlings spray with MLE + plant foliar spray with SA, seedlings spray with SA + plant foliar spray with MLE and seedlings spray with SA + plant foliar spray with SA) significantly increased all abovementioned parameters compared to the control. The combined treatment of seedlings spray with MLE + plant foliar spray with MLE then seedlings spray with MLE + plant foliar spray with SA gave the highest results of the growth and yields of sweet pepper plants by mitigation the injury of salinity stress (soil and irrigation water).

Keywords: Pepper, growth, yield, salinity, salicylic acid, *Moringa oleifera* extract.

INTRODUCTION

Growing vegetables in greenhouses is becoming increasingly popular around the world (Grafiadellis, 1999). However, after several years of continuous high fertilizer inputs in intensive agricultural systems, such as greenhouse vegetable production, soil chemical and biological characteristics may alter substantially (Gao *et al*., 2000 and Zhu *et al*., 2005). Recent trends show that soil productivity and fertility are dropping globally as a result of soil degradation and misuse without effective soil management practices (Cakmak, 2002). Excess salt in the soil solution can harm plant growth by inhibiting osmotic water uptake by roots or causing specific ion effects (Greenway and Munns, 1980). Salinity stress induces oxidative stress in plants, resulting in the production of reactive oxygen species (ROS) and oxidative damage can be reduced by antioxidant defences that scavenge or inhibit ROS production (Ashraf and Harris, 2004).

Pepper (*Capsicum annuum*) is a popular vegetable crop in the Solanaceae family. It is a high-value crop that is rich in vitamins A and C, as well as proteins and minerals (Temu and Temu, 2005).

Salicylic acid (SA) is a plant hormone that promotes growth, development, and ultimately yield in a variety of crops under both normal and stressful environmental conditions (Ahmad *et al*., 2013). SA produces defensive reactions in crop plants and protects them from high temperatures when they are stressed (Pan *et al*., 2006).

Aside from synthetic growth enhancers like SA, plant-based natural growth enhancers such as moringa leaves extract (MLE) are crucial as low-cost sources of plant growth stimulation (Nimbal *et al*., 1996 and Yasmeen *et al*., 2013). Zeatin, a naturally occurring cytokinin, is abundant in the leaves, as are other growth-promoting components such as ascorbates, vitamin E, phenolics, and minerals (Foidl *et al.*, 2001 and Nagar *et al*., 2006). Moringa leaf extracts (MLE) foliar spraying accelerates plant development, improves stress resistance, and increases crop production (Foidl *et al*., 2001; Fahey, 2005 and Marcu, 2005).

The aim of this study was to see how well the exogenous application of MLE and/or SA affected growth, yields, and endogenous physio-chemical components in Capsicum annum L. plants exposed to natural soil salt stress (EC = 2.41 dS/m). This study also sought to demonstrate a link between changes in pepper physio-chemical components and the degree of tolerance in terms of improved growth and yields. Exogenous treatments of MLE and/or SA employed as seedling spray and/or plant foliar spray will raise the level of antioxidants and osmoprotectants that will overcome the stress caused by salinity stress, according to the hypothesis tested.

MATERIALS AND METHODS

The experiment was carried out under greenhouse conditions at Kaha Horticultural Research Station, Agriculture Research Center, Ministry of Agriculture, in order to investigate the effect of using foliar application of moringa leaf extract and salicylic acid on pepper seedlings and plants for overcome salinity stress.

The Moringa leaf extract (MLE) was prepared as follows: fresh leaves harvested from fully matured *Moringa oleifera* trees were dried in shade for 7 days. Dried leaves were grinded and extracted. For extraction, 1 L ethyl alcohol

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(70%) was added to 100 g of leaf powder and the mixture was kept aside for 72 h with occasional stirring (Nikkon *et al*., 2003). The solution was filtered twice through Whatman No. 1 filter paper after the stirring procedure. Filtered solution was subjected to a rotary evaporator to fully evaporate the alcohol. The residue of the extract was diluted to 30 times and used to seedlings and foliar spray applications. The extract can be stored in the refrigerator at 4°C until use.

Sweet pepper seeds, Gedion F_1 hybrid were sown (on 20 of August in 2016 and 2017) in seedling trays (209 holes) that were filled with mixture of peatmoss, vermiculite and fertilizers. The weight of peatmoss, vermiculite and mineral nutrients and penlet was applied according to the guidelines of Ministry of Agriculture. Seedlings at 5 true leaves stage grown in the above mentioned conditions were sprayed one time with one of the following treatments:

A: Untreated seedlings (control); seedlings were sprayed with tap water as ordinary and used as a control.
B: Seedlings were sprayed with moringa leaf extract (MLE).
C: Seedlings were sprayed with salicylic acid (SA) (1 mM) .

Seedlings were transplanted at the same time (on 18 of October in 2016 and 2017) under plastic house conditions of an area 360 m^2 (40 m long × 9 m width × 3 m height). The soil texture of the experimental field was loamy clay as presented in Table (1-I). Seedlings were planted on the two sides of each ridge (Zigzag pattern) at 50 cm apart. Each treatment was assigned to the two ridges, 7 m long and 1 m width with 3 replicates. Other agricultural practices as harrowing and irrigation were carried out as commonly practiced for the conventional pepper planting. The irrigation water analysis was represented in Table (1-II) as follow:

Table 1-I. Physical and chemical properties of the soil under study*.

a. Physical properties.

Water field capacity (%)	Organic matter (%)	Total $CaCO_3$ (%)	Texture class
32.8	1.2	1.70	Clayey

b. Chemical properties.

pH 1 : 2.5 soil : water ratio	E.C dSm^{-1}	Available (mg/kg soil)			Soluble ions (meq / 100 gm soil)							
					Cations				Anions			
		N	P	K	Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	HCO_3^-	$CO_3^=$	$SO_4^=$
7.70	2.41	123	1.18	171	11.21	5.59	8.68	0.93	7.54	1.42	–	17.45

Table 1-II. Analysis of irrigation water*.

PH	E.C dSm^{-1}	Soluble ions (meq / 100 gm soil)								Elements (mg/L)							
		Cations				Anions											
		Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	NH_4^+	NO_3	B	Cu	Fe	Mn	P	Zn
7.20	2.01	3.97	10.59	8.0	0.23	–	4.53	5.40	12.87	2.0	11.0	0.046	0.047	0.007	0.610	0.29	0.037

*** The soil and irrigation water were analyzed at soils, water and environment unit, Agricultural Research Center.**

Threshold salinity of pepper is 1.5 dS/m

After seedlings establishment, (50 days after transplanting) foliar spray of water, MLE or SA was done at early morning with a sprayer (vol. 20 L) to run off four times, at 50, 65, 80 and 95 days after transplanting. To ensure optimal penetration into leaf tissues, 0.1% (v/v) Tween-20 was added to the foliar sprays as a surfactant. Treatments in the greenhouse were 9 treatments (3 in the nursery x 3 in the greenhouse) as following:

1- Tap water + Tap water = control
2- Tap water + Moringa leaf extract = Tap water + MLE
3- Tap water + Salicylic acid = Tap water + SA
4- Salicylic acid +Tap water = SA + Tap water
5- Salicylic acid + Moringa leaf extract = SA + MLE
6- Salicylic acid + Salicylic acid = SA + SA
7- Moringa leaf extract + Tap water = MLE + Tap water
8- Moringa leaf extract + Moringa leaf extract = MLE + MLE
9- Moringa leaf extract + Salicylic acid = MLE + SA

The experimental design was a four-replication randomised complete block design.

Six days after seedlings spray, pepper seedlings were taken from trays as sample and the following measurements were recorded: seedlings height, seedling stem diameter, dry matter of seedling and leaves total chlorophyll.

The plant sample was taken at 105 days after transplanting (55 days after treatments initiation) of the nine treatments, then the plants were dissected into different organs and the following measurements were recorded: root length, plant height, number of branches, number of leaves / plant, diameter of stem, dry weight of roots, stems, leaves and fruits (fruits that found on plant at the time of the sample) and leaf area / plant.

Yield and its components were also determined as follows: the pepper fruits were harvested every 7 days. Early yield is the first four harvests (number and weight), total yield (throughout the entire harvesting season) (number and weight) and average fruit weight.

In addition, fruit quality was also determined as follow:

Random samples of 5 marketable fruits were taken from each plot, and the flowing data were recorded: fruit length, fruit diameter, flesh thickness, total soluble solids (TSS) , dry matter content (%), and ascorbic acid content was determined using the 2,6, dichlorophenol indophenol dye and oxalic acid as extractor (A.O.A.C.,1965).

Chemical composition in leaves

The following chemical constituents were determined in dried ground leaves taken at time of plant sampling.

1) Total nitrogen was determined by micro Kjeldahl method, as described by Pergel (1945).
2) Total phosphorus was determined using the method described by Chapman and Pratt (1961).
3) Potassium was determined photometrically using the Elmar-flame photometer Model 149.
4) Total soluble sugars content in leaves was determined by taking 0.1 gm dry weight then adding 10 ml of 80% ethanol and then was leaved the mixture for 10 days in the refrigerator, afterword it filtrated through a sintered glass silica-filter. Total sugars determination was carried out by using the phenol-sulphoric-- method according to Dubois *et al.* (1956)
5) Proline determination
The rapid colorimetric method was used to determine the proline content of sweet pepper leaves of Bates *et al.* (1973).

Statistical analysis

The data were subjected to the proper analysis of variance and the significance of differences between treatments was determined by least significant difference (Steel and Torrie, 1981).

RESULTS AND DISCUSSION

A. Seedlings growth parameters

Data in Table (2) show that the growth parameters of sweet pepper seedlings, i.e., dry matter of seedlings and total chlorophyll were significantly increased by seedlings spray with moringa leaf extract (MLE) before transplanting time during the two seasons, while the increment was significant in dry matter of seedlings by seedlings spray with salicylic acid (SA) in the second season only compared to the control (seedlings spray with tap water). These findings are consistent with Khan *et al.* (2003). Fariduddin *et al.* (2003) also found that when lower salicylic acid concentrations were sprayed on *Brassica juncea,* dry matter accumulation was significantly increased. Similar finding was recorded by Abou El-Yazied (2011). Rady and Mohamed (2015) indicated that seed soaking or foliar spraying with SA or MLE enhanced total chlorophyll in bean plants. Spraying common bean plants with MLE significantly increased the photosynthetic pigments as compared with stressed plants (Latif and Mohamed, 2016). Additionally, photosynthetic pigments (total chlorophyll and carotenoids) of geranium leaves were improved due to MLE application (Ali *et al*., 2018). In addition, Khan *et al.* (2019) mentioned that, biochemical parameters were significantly affected by both priming seeds of wheat and foliar application of MLE alone and blended MLE ($p < 0.05$). Maximum chlorophyll a contents were measured in MLE sprayed wheat (alone and blended form) in both sowing dates while minimum chlorophyll a contents in control.

The present investigation also revealed that seedlings sprayed with MLE produced significantly more dry matter and chlorophyll than those sprayed with SA. Moreover, foliar MLE spraying may induce early cytokinin production, preventing premature leaf senescence and resulting in larger leaf area with higher photosynthetic pigments (Rehman and Basra, 2010).

It is obvious from results presented in Table (2) that both pre-treatments (seedlings spray with moringa leaf extract or salicylic acid) decreased significantly seedling height than the control while the reduction in seedling diameter by using MLE was significant in the first season only.

Table 2. Effect of some protective treatments on some growth parameters of sweet pepper seedlings during both seasons

Treatments	2016 season				2017 season			
Seedlings spray	Seedling height (cm)	Seedling stem diameter (cm)	Dry matter of seedling (%)	Leaves total chlorophyll (SPAD)	Seedling height (cm)	Seedling stem Diameter (cm)	Dry matter of seedling (%)	Leaves total chlorophyll (SPAD)
Tap water	15.5	0.31	29.06	46.21	15.5	0.31	28.87	46.07
Salicylic	13.95	0.30	29.07	46.81	13.8	0.30	29.28	46.76
Moringa*	13.3	0.27	33.35	49.55	13.2	0.28	33.32	48.05
LSD at 0.05	0.583	0.013	0.504	0.936	0.692	N.S.	0.233	0.921

*** Moringa leaf extract**

B. Vegetative growth

Data in Table (3) show that using MLE or SA as seedlings spray or plant foliar spray enhanced all growth characteristics (significantly or insignificantly) when compared to the control. When compared to the control, seedlings sprayed with SA + plant foliar spray with SA, seedlings sprayed with SA + plant foliar spray with MLE, seedlings sprayed with MLE + plant foliar spray with SA, and seedlings sprayed with MLE + plant foliar spray with MLE significantly improved all growth characteristics. Seedlings spray with MLE + plant foliar spray with MLE or SA treatments were determined to be the most effective treatments in improving root length, plant height, number of branches/plant, number of leaves/plant, and stem diameter in the two seasons when compared to the control.

Data in Table (4) indicate that the increment in dry weight of different organs of sweet pepper plant, dry weight of entire plant and leaf area / plant was obtained by using seedlings spray and / or plant foliar spray with SA and / or MLE. Generally, the application of seedlings spray and / or foliar spray of plants with MLE produced the highest all the values then using seedlings spray and / or plant foliar spray with SA, while the control produced the lowest values under the salinity conditions of soil and irrigation water. These results are true in both seasons.

These findings are confirmed with the results of Khan *et al.* (2003), Elwan and El-Hamahmy (2009), Abou El-Yazied (2011), Culver *et al.* (2012) and Howladar (2014). In addition, Rady and Mohamed (2015) observed that the combination treatment of common bean seed soaking in SA + foliar spray with MLE was the most effective in increasing shoot length, leaf area / plant, number of leaves / plant, and plant dry weight among all the combined treatments. Also, Latif and Mohamed (2016) showed that, foliar spray of stressed and unstressed plants with MLE significantly improved all plant growth parameters of common bean plants as compared with stressed plants without MLE under all environmental stresses [salt stress (200 mM), high temperature (45°C) and gamma rays (200 Gy)]. Similarly, Matthew (2016) revealed that foliar application of MLE, two weeks interval, at a concentration of 1:20 gave the best results in terms of pepper growth attributes. Furthermore, Nour El-Din *et al.* (2018) found that foliar application of moringa leaf extract improved stem thickness, plant length, number of leaves, and leaf area/plant in cherry tomato. The fact that salicylic acid and other salicylates are known to influence different biochemical and physiological processes of plants and may play a vital role in regulating their growth and productivity could explain these findings (Arberg, 1981).

Exogenous administration of salicylic acid prevented IAA and cytokinin levels from declining in salinity-stressed wheat plants, resulting in improved cell division in the root apical meristem and increased plant growth and production (Shakirova *et al.*, 2003).The same authors also reported that the pre-treatment with SA resulted in the accumulation of ABA which might have contributed to the pre-adaptation of seedlings to salinity stress as ABA induces the synthesis of wide range of anti-stress proteins, thereby providing protection to the plants. Further, the treatment also lowered the level of active oxygen species and therefore, the activities of superoxide dismutase (SOD) and peroxidase (POX) were also lowered in the roots of young wheat seedlings (Shakirova *et al*., 2003). These findings indicate that salicylic acid regulates the activity of these antioxidant enzymes, which protects against salt stress either directly or indirectly (Sakhabutdinova *et al.*, 2004). Fariduddin *et al*. (2003) found that the exogenous application with salicylic acid (SA) in *Brassica juncea* increase net photosynthetic rate, carboxylation efficiency, and activities of nitrate reductase and carbonic anhydrase over the control. Thereby improved the growth of salinity stressed barley plants by exogenous application of salicylic acid enhanced the photosynthetic rate and also maintained the stability of membranes (El-Tayeb, 2005). *M. oleifera* leaves are abundant in zeatin, as well as other growth-promoting chemicals such as ascorbates, phenolic acids, and minerals such as Ca, K, and Fe, making it a great crop growth enhancer (Anjorin e*t al*, 2010). Moringa leaf extract is the most commonly used plant growth promoter (Phiri and Mbewe, 2010). Another explication could be based on the presence of essential macro and micronutrients such as Mg, Ca, P, K, Fe, Mn, Zn, and Cu in MLE analysis. MLE also contains osmoprotectants like amino acids, proline, total soluble sugars and K, as well as antioxidants such as soluble phenolics, proline, total carotenoids, and ascorbic acid. It also contains phytohormones such gibberellins, indole-3-acetic acid, and the cytokinin zeatin. MLE's diverse composition shows that it could be used as a plant biostimulant (Rady and Mohamed, 2015). Also, Foidl *et al*. (2001) showed that the extract obtained from the leaves of moringa in 80% ethanol contains growth enhancing principles (i.e. hormones of the cytokine type). To speed up the growth of young plants, the extract can be used as a foliar spray. The use of a growth hormone spray will also make the plants firmer and more resistant to pests and disease. Plants sprayed with this growth hormone spray will also produce more and larger fruit, resulting in a higher yield when harvest time arrives. In addition, Szepesi *et al*. (2005) showed that pre-treatment of plants with SA enhanced antioxidant enzyme activities in concentration dependent manner and increased the stress tolerance of tomato seedlings. Improved acclimation of SA-pretreated plants to salt stress was dependent on the activation of antioxidative enzymes and accumulation of ionic and non-ionic osmolytes prior to the stress, but increased resistance to non-ionic osmotic stress was possible in plants with lower antioxidative enzyme activities at the start of the stress. The possible role of osmotic adaptation and oxidative protective mechanisms during long-term pre-treatment of tomato plants with low concentrations of SA.

C. Yield and its components

Data presented in Table (5) show that increases in early yield (number and weight) of sweet pepper plants were existed with using all treatments compared to the control. This increment was significant in the second season only.

Over the two seasons, salicylic acid (SA) and/or Moringa leaf extract (MLE) had a strong effect on total yield (number and weight) and average fruit weight of sweet pepper plants. The results in Table (5) reveal that applying SA or MLE alone, as a seedling spray or foliar application of plants, enhanced these parameters significantly or insignificantly when compared to the controls. The combination treatments achieved the best results, particularly seedlings spray with MLE + plant foliar spray with MLE treatment, which came in top, followed by seedlings spray with MLE + plant foliar spray with SA.

Table 3. Effect of some protective treatments on root length, plant height, number of branches / plant, number of leaves / plant and stem diameter of sweet pepper plants under natural salinity stress during both seasons

Treatments		2016 season					2017 season				
Seedlings spray	Plant foliar spray	Root length (cm)	Plant height (cm)	No. of branches /plant	No. of leaves / plant	Stem diameter (cm)	Root length (cm)	Plant height (cm)	No. of branches /plant	No. of leaves / plant	Stem diameter (cm)
Tap water	Tap water	16.0	52.5	13.25	215.3	1.74	14.4	48.0	14.3	224.3	1.47
	Moringa	17.3	54.7	17.0	230.0	1.90	15.0	51.0	20.0	340.0	1.70
	Salicylic	17.0	54.0	17.5	236.0	1.75	14.8	48.7	11.0	177.0	1.60
Slicylic	Tap water	16.0	55.3	9.7	237.2	1.73	16.0	52.0	14.5	283.0	1.65
	Moringa	17.6	58.1	12.2	262.7	1.89	17.4	57.3	16.7	281.3	1.70
	Salicylic	16.3	55.3	11.3	297.3	1.77	16.8	55.0	16.0	323.0	1.60
Moringa*	Tap water	17.3	57.3	10.0	221.3	1.73	16.5	54.5	17.5	302.0	1.75
	Moringa	19.7	64.8	9.5	322.5	1.90	18.0	58.0	18.0	305.5	1.75
	Salicylic	19.3	63.0	12.7	274.0	1.90	17.5	57.5	20.5	383.0	1.75
LSD at 0.05		N.S	5.414	N.S	40.766	N.S	1.169	3.496	3.222	55.585	0.130

*** Moringa leaf extract**

Table 4. Effect of some protective treatments on dry weight and leaf area of sweet pepper plants under natural salinity stress during both seasons

Treatments		2016 season						2017 season					
Seedlings spray	Plant foliar spray	Vegetative growth dry weight			Fruits dry weight at sampling date	Plant dry weight	Leaf area	Vegetative growth dry weight			Fruits dry weight at sampling date	Plant dry weight	Leaf area
		Roots	Stems	Leaves				Roots	Stems	Leaves			
Tap water	Tap water	3.97	23.48	24.09	19.73	71.27	0.3894	3.17	15.38	19.68	14.12	52.36	0.2544
	Moringa	3.87	24.26	28.02	27.63	83.79	0.4766	4.18	23.72	28.54	12.11	68.55	0.4460
	Salicylic	4.44	25.72	27.80	16.51	74.47	0.4358	2.30	15.52	19.87	20.04	57.73	0.2802
Salicylic	Tap water	4.12	25.22	26.27	23.90	79.18	0.4071	4.52	23.88	29.08	26.61	84.08	0.4442
	Moringa	4.18	34.02	37.66	34.70	110.55	0.5908	4.47	26.55	29.76	37.19	97.96	0.4728
	Salicylic	4.55	30.96	31.47	25.67	92.31	0.5014	4.17	25.52	28.84	30.68	89.21	0.4599
Moringa*	Tap water	4.57	27.06	26.61	20.78	79.01	0.4025	3.74	27.24	31.36	35.29	97.62	0.4572
	Moringa	5.85	39.17	58.29	33.80	137.11	0.9565	5.20	31.81	34.03	34.38	105.12	0.5401
	Slicylic	5.69	32.60	34.21	42.16	114.64	0.5296	4.22	31.64	35.68	30.22	101.79	0.5222
LSD at 0.05		1.087	6.889	12.241	N.S	22.028	0.260	0.753	5.379	3.057	7.997	12.219	0.0610

*** Moringa leaf extract**

Table 5. Effect of some protective treatments on early and total yield and average fruit weight of sweet pepper under natural salinity stress during both seasons

Treatments		2016 season					2017 season				
Seedlings spray	Plant foliar spray	Early yield / plant		Total yield / plant		Average fruit weight (g)	Early yield / plant		Total yield / plant		Average fruit weight (g)
		No.	Weight (kg)	No.	Weight (kg)		No.	Weight (kg)	No.	Weight (kg)	
Tap water	Tap water	9.5	0.897	27.1	2.245	98.8	9.1	0.856	25.6	2.142	121.7
	Moringa	10.0	0.895	28.5	2.393	104.7	10.4	0.927	29.3	2.468	129.3
	Salicylic	10.1	0.907	27.3	2.261	103.6	10.0	0.900	27.3	2.252	127.0
Salicylic	Tap water	9.6	0.898	29.2	2.548	109.1	9.3	0.867	28.1	2.467	124.7
	Moringa	10.3	0.909	30.2	2.733	111.6	11.2	0.985	29.9	2.720	130.1
	Salicylic	10.2	0.896	29.5	2.629	110.2	10.2	0.892	28.3	2.544	129.1
Moringa*	Tap water	10.0	0.963	32.3	2.791	111.5	9.5	0.875	29.5	2.465	132.77
	Moringa	11.3	1.043	36.3	3.129	119.7	12.5	1.156	35.7	2.431	134.37
	Salicylic	11.1	1.090	32.5	2.850	113.9	10.7	1.046	30.4	2.733	133.00
LSD at 0.05		N.S	N.S	3.369	0.365	4.568	0.964	0.125	1.611	0.240	4.121

*** Moringa leaf extract**

The highest significant increase of total plant fruit weight over the control was recorded by using the combination of seedlings spray with MLE + plant foliar spray with MLE and it was 39.4% and 60.2% in the first and second season, respectively. The second significant increase of total plant fruit weight over the control was recorded by using seedlings spray with MLE + plant foliar spray with SA and it was 26.9% and 27.6% in the first and second season, respectively.

Increases in yield and its components as a result of SA and/or MLE treatments could be related to their effect on enhancing vegetative growth parameters (Tables 2, 3 and 4) and, as a result, productivity. This fact provided an explanation for the role of exogenous salicylic acid treatment to stressed plants, which can potentially reduce the adverse consequences of salt. Wheat seedlings produced from salicylic acid-soaked grains showed increased resistance to salinity stress (Hamada and Al-Hakimi, 2001).

Fariduddin *et al.* (2003) indicated that the number of pods and the seed yield of *Brassica juncea* increased by 13.7 and 8.4% over the control by spraying the plants with the lowest concentration (10^{-5}M) of SA. In a similar study, Elwan and El-Hamahmy (2009) indicated that SA application at low concentration (10^{-6}M) positively increased fruit number, average fruit weight and fruit yield of pepper grown in a moderately salt-stressed greenhouse. Also, Abo El-Yazied (2011) indicated that significant increases in early and estimated total yield of sweet pepper were existed with foliar application with 50 or 100 ppm of SA or 50 & 100 ppm of chelated zinc compared to the control treatment. Furthermore, Foidl *et al.* (2001) observed that moringa spray causes young plants to grow faster. Growth hormone spray causes plants to be firmer, more resistant to pests and disease, produce more fruit, larger fruit, and increase yield by 20–35 percent. In addition, Culver *et al.* (2012) found that spraying tomato plant with moringa extract at two weeks after transplanting (M1), at two weeks and four weeks after transplanting (M2), and every two weeks until physiological maturity (M3) increased tomato fruit weight by 43, 84, and 141 percent, respectively. Similarly, Rady and Mohamed (2015) noticed that combining SA and MLE treatments (i.e., seed soaking in SA + foliar spray with SA, seed soaking in SA + foliar spray with MLE, seed soaking in MLE + foliar spray with SA, and seed soaking in MLE + foliar spray with MLE) significantly increased green pod and dry seed yields of *Phaseolus vulgaris* L. plants grown on a saline soil. By reducing the inhibitory effects of soil salinity stress, the combination seed soaking in SA + foliar spray with MLE treatment was found to be highly successful in enhancing bean plant yields. In addition, Matthew (2016) mentioned that, foliar application of MLE at a concentration of 1:20, tow weeks interval, resulted in the greatest values of pepper yield parameters, and is thus recommended for pepper farmers.

When sprayed as an extract from fresh moringa leaves, Fuglie (2000) confirmed that one of the active substances in Zeatin: a plant hormone from the cytockinines group increased crop (bell pepper, onions, soya, sorghum, maize, coffee, tea, melon, chilli, etc.) yields.

D. Fruit quality

It is obvious from results presented in Table (6) that all treatments increased all tested characters (length, diameter, thickness, TSS, dry matter and V.C) of sweet pepper fruits compared to the control, but the increment was not significant in all characters except V.C. Fruit V.C content increased significantly by using all treatments compared to the control in two studied seasons under the salinity conditions of the soil and irrigation water. Among all combined treatments, seedlings spray with MLE + plant foliar spray with MLE (MLE + MLE) was found to be highly effective at improving V.C content of sweet pepper content then combined treatments, seedlings spray with MLE + plant foliar spray with SA (MLE + SA) or seedlings spray with SA + plant foliar spray with MLE (SA + MLE).

These results are confirmed with Elwan and El-Hamahmy (2009), who found that SA application at low concentration (10^{-6}M) positively increased fruit vitamin C content of pepper grown in a moderately salt-stressed greenhouse. In this respect, Abo El-Yazied (2011) indicated that spraying SA at 50 or 100 ppm increased physical characters (diameter, length and flesh thickness) and TSS and vitamin C contents of sweet pepper fruits. Also, Nour El-Din *et al.* (2018) investigated that foliar application with moringa leaf extract exhibited a positive influence on fruit diameter, vitamin C and TSS in cherry tomato fruits.

E. Mineral, total sugars and free proline contents in leaves

Concerning the effect of foliar application of pepper seedlings and plants by using SA and MLE on N, P and K contents of sweet pepper leaves, data in Table (7) in both seasons show that leaf N, P and K contents (%) were higher in leaves of plants received combination of SA and MLE i.e., MLE + MLE, MLE + SA, SA + MLE or SA + SA than other treatments. Also, it could be noticed that the treatment MLE + MLE was superior in this respect. These results are in accordance with those obtained by Abou El-Yazied (2011) on sweet pepper, Rady and Mohamed (2015) on bean plants and El-Saady and Omar (2017) on head lettuce.

Table 6. Effect of some protective treatments on fruit physical and chemical characters of sweet pepper under natural salinity stress during both seasons

Treatments		2016 season						2017 season					
Seedlings spray	Plant foliar spray	Fruit length (cm)	Fruit diameter (cm)	Flesh thickness (cm)	TSS (%)	Dry matter (%)	V.C (mg/100 g fresh weight)	Fruit length (cm)	Fruit diameter (cm)	Flesh thickness (cm)	TSS (%)	Dry matter (%)	V.C (mg/100 g fresh weight)
Tap water	Tap water	9.9	5.7	0.43	4.1	6.08	52.22	10.3	6.3	0.56	3.9	6.37	45.73
	Moringa	10.5	5.9	0.47	4.3	6.22	70.17	10.6	6.4	0.58	4.0	6.54	59.00
	Salicylic	10.0	5.9	0.47	4.2	6.37	68.20	10.4	6.3	0.57	3.9	6.44	49.90
Salicylic	Tap water	10.3	5.8	0.50	4.2	6.29	52.60	10.5	6.3	0.60	4.0	6.58	56.41
	Moringa	10.9	6.0	0.53	4.4	6.37	78.80	11.0	6.5	0.60	4.1	6.92	67.10
	Salicylic	10.6	5.9	0.50	4.3	6.39	74.82	10.6	6.4	0.60	4.1	6.70	63.50
Moringa*	Tap water	10.5	6.1	0.53	4.2	6.36	60.17	11.0	7.0	0.58	4.1	6.80	59.50
	Moringa	11.1	6.2	0.53	4.5	6.78	87.05	11.6	7.1	0.58	4.3	7.07	80.00
	Salicylic	10.7	5.9	0.50	4.4	6.44	76.13	11.3	6.9	0.58	4.1	6.85	69.35
LSD at 0.05		N.S	N.S	N.S	N.S	N.S	3.956	N.S	N.S	N.S	N.S	N.S	1.847

*** Moringa leaf extract**

The data in Table (7) proved that generally, high total sugars and free proline were recorded in sweet pepper leaves treated with the combination of treatment applications of SA and MLE. The highest values were obtained by using seedlings spray with MLE + plant foliar spray with MLE or seedlings spray with SA + plant foliar spray with MLE. SA maximally enhanced free proline while total sugars by MLE. Somewhat, similar results were obtained by Yusuf *et al.* (2008), who reported that the effects of salinity stress on growth, photosynthetic characteristics, and enzyme activities (nitrate reductase and carbonic anhydrase) in *B. juncea* were reversed when salicylic acid was sprayed on the foliage at the 30-day stage. During the two seasons, however, foliar spraying with the two concentrations of SA and Zn produced the best value of total sugars content in sweet pepper plant leaves at 100 days after transplanting. High content of total sugars and some bioconstituents may be a direct result of high rates of photosynthesis with high efficiency in this respect (Abou El-Yazid, 2011). Also, Howlader (2014) found that spraying *Phaseolus vulgaris* plants which were grown in the presence of NaCl and / or $CdCl_2$ with moringa leaf extract (MLE) increased proline content and antioxidant enzyme activity significantly. In addition, Rady and Mohamed (2015) reported that in bean plants, SA or MLE applied as seed soaking or foliar spray increased physiochemical characteristics (total soluble sugars and free proline). In comparison to the control, seed soaking in SA + foliar spray with MLE was the most effective combination treatment. However, Afzal *et al.* (2019) found that MLE increased total soluble sugars whereas SA increased free proline in two wheat cultivars.

Table 7. Effect of some protective treatments on chemical composition of sweet pepper leaves under natural salinity stress during both seasons

Treatments		2016 season					2017 season				
Seedlings spray	Plant foliar spray	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Total sugars (mg/g DW	Free proline (mg/g DW)	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Total sugras (mg/g DW)	Free proline (mg/g DW)
Tap water	Tap water	2.94	0.473	1.872	14.98	0.570	3.22	0.494	2.001	14.86	0.573
	Moringa	3.22	0.508	1.968	15.03	0.768	3.64	0.513	2.193	14.95	0.758
	Salicylic	3.17	0.500	1.959	14.94	0.601	3.50	0.502	2.217	14.92	0.636
Salicylic	Tap water	3.31	0.482	1.930	15.02	0.681	3.27	0.502	1.904	14.93	0.644
	Moringa	3.64	0.520	1.982	15.06	0.784	3.75	0.518	2.308	15.04	0.872
	Salicylic	3.50	0.517	2.154	14.98	0.745	3.68	0.510	2.231	14.96	0.735
Moringa*	Tap water	3.55	0.446	1.873	15.02	0.566	3.45	0.466	2.013	14.93	0.656
	Moringa	3.84	0.533	2.622	15.11	0.875	3.92	0.528	2.333	15.05	0.831
	Salicylic	3.65	0.469	1.923	14.98	0.632	3.71	0.497	2.186	14.92	0.725
LSD at 0.05		0.415	0.031	0.123	0.045	0.037	0.296	0.013	0.076	N.S	0.044

*** Moringa leaf extract**

CONCLUSION

The study conclude that the exogenous application with *Moringa oleifera* leaf extract and / or salicylic acid can be recommended for sweet pepper crop due to high productivity, high nutritive value to alleviate the inhibitory effects of soil or irrigation water salinity stress.

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تحسين إنتاجية الفلفل الحلو داخل الصوب الزراعية تحت إجهاد الملوحة الطبيعية

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تتعرض بعض زراعة محصول الفلفل الحلو تحت الصوب لضرر الملوحة والذي يُؤدي إلى انخفاض في أداء المحصول. الغرض من هذه التجارب هو معرفة تأثير استخدام مُستخلص أوراق المورينجا (1 مُستخلص : 30 ماء عادي) وحمض الساليسيليك (1 مللي مولر) على النمو والصفات الفسيولوجية والكيميائية والمحصول لنباتات الفلفل الحلو النامي تحت ظروف الصوب من ملوحة للتربة (EC = 2.41 dSm^{-1}) وماء الري (EC = 2.01 dSm^{-1}). فى نباتات الفلفل الحلو وجد أن استخدام مُستخلص أوراق المورينجا أو حمض الساليسيليك رشاً على الشتلات أو رشاً على النباتات يُحسِّن صفات النمو (مثل ارتفاع النبات، عدد ومساحة الاوراق للنبات، والوزن الجاف للنبات) فضلا عن الصفات الكيميائية (محتوى الاوراق من الكلوروفيل، السكريات الكلية الذائبة، والبرولين وفيتامين ج والنسة المئوية لكلا من النيتروجين و الفوسفور و البوتاسيوم). بالإضافة إلى التحسُّن في كلٍ من المحصول المُبكر والمحصول الكُلِّي مُقارنةً بالكنترول (رش الشتلات ورش النباتات بالماء العادي). وأوضحت النتائج أن توليفة المُعاملات من المورينجا و حمض الساليسيليك أسيد (على سبيل المثال: رش الشتلات بمُستخلص أوراق المورينجا + رش النباتات بمُستخلص أوراق المورينجا، رش الشتلات بمُستخلص أوراق المورينجا + رش النباتات بالساليسيليك أسيد، رش الشتلات بالساليسيليك أسيد + رش النباتات بمُستخلص أوراق المورينجا، رش الشتلات بالساليسيليك أسيد + رش النباتات بالساليسيليك أسيد) تعمل على زيادة كل الصفات السابق الإشارة إليها معنويا مُقارنةً بالكنترول. وتجمل النتائج أن أعلى تأثير على تحسُّن النمو والمحصول لنباتات الفلفل الحلو تم الحصول عليه مع استخدام التوليفة من رش الشتلات بمُستخلص أوراق المورينجا + رش النباتات بمُستخلص أوراق المورينجا ثم التوليفة من رش الشتلات بمُستخلص أوراق المورينجا + رش النباتات بالساليسيليك أسيد وذلك بتخفيف الضرر الناتج من ملوحة التربة وماء الري.