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EFFECT OF FOLIAR APPLICATION OF ASCORBIC ACID ON PLANT GROWTH, POWDERY MELDOW DISEASE, CHEMICAL COMPOSITION, FRUIT YIELD AND QUALITY OF EGGPLANT (*Solanum melongena* L.) GROWN UNDER SALINE AND NON-SALINE CONDITIONS.

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ABSTRACT

Eggplant plants were grown in pot experiment to investigate the effects of NaCl salinity and foliar application of ascorbic acid on plant growth, fruit yield and quality. Soil analysis, during experimental period, showed that all soil properties, except pH, were increased with increasing NaCl concentrations. The results showed that salt-stressed plants had less vegetative parameters, total sugar content, calcium content, potassium content and fruit yield. However, concentration of sodium in roots, shoots and fruits as well as fruit free total phenols and fruit weight loss were increased with salt. Powdery mildew disease severity decreased with salt treatments which associated with low leaf total sugar content. The results indicated that ascorbic acid sprayed plants had significantly higher root fresh weight, fruit yield, fruit free total phenols as well as shoot and fruit potassium and calcium contents, while, fruit sodium content decreased. Low powdery mildew disease rate was found in sprayed plants at high NaCl (100 mmol). These results are suggesting that the ascorbate spraying was effective in alleviating adverse effects of salinity on the parameters mentioned before. No significant differences in other vegetative growth and chemical composition were observed between sprayed and non-sprayed plants with ascorbic acid; none of these variables was improved with the foliar of ascorbic acid. Also the results indicated that fruit total phenol, potassium, calcium and sodium content were significantly increased when fruits stored under room conditions compared with fresh harvested fruits. In conclusion, results support the hypothesis that supplemental ascorbic acid would ameliorate the inhibitory effects of NaCl stress in eggplant.

Keywords: Solanum melongena, ascorbate, Vitamin C, spraying, NaCl, salinity tolerance induction, powdery mildew disease.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is one of the important vegetable crops, grown on over 1.7 million ha world-wide (FAO, 2005) and it is among the few vegetables capable of high yield in hot-wet environments. Compared with other species, eggplant is considered as a moderately salt sensitive crop. It was estimated that 6.9% reduction in eggplant fruit yield occurred when grown in soil salinity of 1 EC (Heuer *et al.,* 1986).

The term salinity refers to the total dissolved concentration of major inorganic ions (i.e. Na^+, Ca^{2+}, Mg^{2+}, K^+, HCO_3^- , SO_4^{2-} and Cl^-). Soil water salinity is determined in saturated soil extract. In this respect, (FAO, 1996) stated that the electrical conductivity of a saturated soil extract (EC_e) or individual mineral concentration in a saturated extract will eventually grow much larger than the comparable values in saline irrigation water. The inorganic salts, mainly sodium salts, that cause soil salinity, are highly mobile. Irrigation with water that has excess amounts of sodium can adversely impact soil structure making it difficult for plant growth. Generally, the saline irrigation water affects the pedogenetic processes, physical, chemical and biological soil properties (Nikos *et al.,* (2003).

Salt stress are the several environmental factors that adversely affect plant growth, development and yield of the crop. However, addition of sodium chloride reduced disease severity of powdery mildew (Elmer, 1992 & Reid *et al.*, 2001).

Approximately 6% of the total world wide land area is affected by salinity (Flowers *et al.*, 1977). Also, 19.5% of the irrigated agricultural lands are considered saline (Flowers and Yeo, 1995). Furthermore, each year there is a deterioration of 2 million ha (about 1%) of world agricultural lands due to salinity, leading to less crop productivity (Choukr-Allah, 1995). Egypt is one of the countries that suffer from severe salinity problems. Where one third of the total cultivated land area of Egypt affected by salinity (Ghassemi *et al.* 1995).

Salt stress causes stomatal closure, which reduces the CO_2/O_2 ratio in the leaves and inhibits CO_2 fixation (Epstein, 1989). These conditions increase the rate of reactive oxygen species (ROS) formation (Asada and Takahashi, 1987). It is documented that ROS causes host cell death and pathogen killing in higher concentrations (Irani *et al.*, 1997 & Irani and Goldschmidt-Clermont, 1998). To combat the toxic effect of ROS, the plants have an antioxidant defence system, which differ among different crops species in their ability to remove or scavenge ROS (Levitt, 1980).

Powdery mildew is a serious disease in eggplant plants which is caused by the obligate pathogenic fungus *Leviellula taurica*. Severe damage to the foliage results in a reduction in photosynthesis, which can lead to the appearance of necrotic spots on the leaves and eventual defoliation and plant death (Jacob *et al.*, 2007).

Recently, great attention has been focused on the possibility of using safety substances such as vitamins in order to improve plant growth, flowering, fruit setting and total yield of different plant species and to overcome the negative effects of environmental stress conditions such as drought (El-Ghinbihi and Hassan, 2007), salinity (Shaddad *et al.*, 1999), cold (Mahajan and Tuteja, 2005) and pathogen (Borbála *et. al.* 2005) stresses.

Ascorbic acid plays an important role as an antioxidant and protects the plant during oxidative damage by scavenging free radicals and reactive oxygen species that are generated during photosynthesis, oxidative metabolism and various stresses including excess light, soil water deficit, water logging, UV-B radiation, ozone and plant disease (Conklin *et al.*, 1996; 1997; Noctor and Foyer 1998; Smirnoff, 2000; Sanmartin *et al.*, 2003; Blokhina *et al.*, 2003; Hückelhoven *et al.*, 1999; Schultheiss *et al.*, 2002). Ascorbic acid also maintains the prosthetic metal groups of various enzymes in the reduced state ensuring their activity (Padh, 1990; Davey *et al.*, 2000). Recent studies indicate that ascorbic acid is involved in regulation of both cell division and expansion as well as photosynthesis process (Smirnoff, 1996 &

2000; Kato and Esaka, 1999 & 2000; Franceschi and Tarlyn, 2002; Pignocchi *et al.*, 2003; Chen and Gallie, 2006). Debolt *et al.* (2007) formulated that the L-ascorbic acid catabolism and the formation of oxalic and L-tartaric acid provide compelling evidence for a major role of L-ascorbate in plant metabolism. Moreover, the ascorbic acid redox state, controlled by ascorbate oxidase activity levels, is mainly responsible for the apoplast capability of transmitting signals related with environmental changes or defence processes (Sanmartin *et al.*, 2003; Pignocchi and Foyer, 2003).

The objective of this study was to investigate the minimization of salt induced deficiency in the eggplant plants through foliar ascorbic acid application.

MATERIALS AND METHODS

1- Plant materials, treatments and growth conditions

This pot experiment was conducted in the research experimental farm of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt from May 3 to September 30, 2006 and repeated in 2007, to study the effect of foliar spray with ascorbic acid on growth characters, chemical composition, yield, disease severity of powdery mildew and shelf life fruit quality of eggplant grown under salt stress conditions.

Seeds of eggplant (*Solanum melongena*) cv. Topaz F_1 were sown in styrophom trays under glass greenhouse conditions. The trays were filled with a soil mixture (modified cornell peat-lite mixes in 1:1 ratio, Hartmann *et al.*, 1990). After emerging , they were watered with a commercial nutrient solution (19-19-19 N-P-K with micronutrient) at a dilution of 1:200. The seedlings were maintained under high humidity and with a day/night temperature of 35/25 °C for four weeks. The seedlings were transplanted at a rate of one plant per pot. The pots were filled with 4000 cm^3 washed sand (Table 1). Treatments were initiated after two weeks from transplanting, where the plants during this period irrigated with nutrient solution.

Table (1): Physical and chemical properties of the experimental soil (before cropping).

Property	Value	Property	Value
Physical analysis		**Soluble cations (meq/l)**	
Sand (%)	85.21%	Ca^{2+}	0.8
Silt (%)	11.50%	Mg^{2+}	0.6
Clay (%)	3.29%	K^+	0.3
Soil texture	**Sandy soil**	Na^+	3.0
Bulk density	1.66 gcm^{-3}		
SAR	3.59	**Soluble anions (meq/l)**	
ESP	4.34	HCO_3^-	1.6
Chemical analysis		Cl^-	3.0
ECe (dSm^-)	0.47	CO_3^-	0.0
pH	8.27	SO_4^{--}	0.1

Each experiment included 6 treatments which were all possible combinations of three salt stress (0.0, 50 and 100 mmol/l NaCl) treatments with two concentrations of ascorbic acid (0.0 and 3.0 mmol/l) as foliar spray.

The treatments were arranged as factorial experiment in randomized complete block design, with three replications each included five pots

The nutrient solution was added at a dilution of 1:50 which corresponding to an EC 2.0 mS/cm. The plants irrigated four times per week with 250 ml/pot nutrient solution plus 0.0, 50 and 100 mmol/l NaCl, which increased to 500 ml/l from the beginning of flowering (from the middle of July until the end of the experiment). Each pot from control treatment received no salt, sprayed or not sprayed with ascorbic acid, and irrigated with only nutrient solution. In salt treatment with 50 mmol/l, each pot received a total of 44.3 g/pot at the end of experiment. With regard to salt treatment with 100 mmol/l, each pot received a total of 88.56 g/pot at the end of experiment. The plants were maintained at day/night temperature of 42/20 °C outside greenhouse. The composition of nutrient solution was 19% N, 19% P_2O_5, 19% K_2O, 200 ppm Fe, 50 ppm Zn, 100 ppm Mn, 7 ppm Cu, 5 ppm Mo and 12% SO_4. Ascorbic acid solution was sprayed one time per two week on the whole shoot of plants as a foliar spray. The volume of sprayed solution ranged from 20 to 50 ml per plant each time, depending on plant size or developmental stage. Tween 20 at rate of 0.5% was used as wetting agent. De-ionized water was sprayed as a control. All sprays were done in the morning (8-9 a.m.).

2- Fruit quality during Shelf life:

Eighteen unblemished fruits from harvest number three and four of each treatment were hand-picked to study the effect of the combination of NaCl stress and foliar application of ascorbic acid on fruit quality during shelf life. Fruits were harvested at the commercial maturity stage and transferred to the laboratory within 1 h. They were stored for 12 days under room conditions (34±2 °C and 58% RH). Chemical determinations (total sugar, soluble phenols, potassium, sodium and calcium contents) were carried out after 0, 6 and 12 days after beginning of storage.

3- Measurements and Observations

Soil physical and chemical analysis: Soil samples from both seasons was mixed and homogenized together for each salt treatment, then physical and chemical analysis were done at the end of experiment.

Bulk density: Bulk densities of the calcareous, alluvial and sandy soils were determined according to Blake and Hartge (1986). *Electrical conductivity*: of the saturated soil paste extract expressed as (dSm^{-1}) were measured using conductivity meter model Jenway 3310 according to Richards (1954). *Soil pH*: the pH of soil samples was determined by bench type Beckman glass electrode pH meter, in 1:2.5 soil-water suspensions according to Page *et al.* (1982). *Soluble cations and anions*: the saturated soil paste extract was analyzed for soluble anions and cations. Sodium and K^+ were determined flamephotometerically, Ca^{2+}, Mg^{2+}, were volumetrically determined by titration with ethylene diamine tetra acetic acid (versinate), Cl^- was determined by titration with silver nitrate, HCO_3^- was determined by titration with standard sulphuric acid according Page *et al.,* (1982). *Sodium adsorption ratio (SAR)*: was calculated based on the equation $SAR = Na / (\frac{Ca + Mg}{2})^{1/2}$ where Na^+, Ca^{2+} and Mg^{2+} in $meql^{-1}$ according to

Ayers and Westcot (1994). *Exchangeable Sodium Percentage (ESP)* : was calculated using the equation of ESP % = Na_{ex} / CEC where Na_{ex} is the exchangeable sodium meq/100g soil, and CEC is the cation exchange capacity meq/100g soil according to page *et al.*, (1982).

Morphological Parameters:

Plant height and leaf number were measured for all plants after 8 weeks from transplanting. Also, a representative plants from each replicate were picked at the end of cultivation in pots for shoot and root fresh and dry weight determination.

Yield measurements included number of fruits and fruit yield/plant. During both seasons, fruits were harvested every week from the end of July to the end of September (based on nine harvest).

Fruit weight loss: After harvest, the average fruit weight for each treatment was evaluated. The weight loss during shelf life period was expressed as a percentage of the original fresh weight.

Plant chemical analysis:

Total sugar and total free phenols content determination. Total soluble sugars in fresh leaves (fifth leaves) and fresh fruits (harvest number 6) as well as stored fruits(6 or 12days) were determined according to Stewart (1974). Total soluble phenols in fresh leaves and fruits were quantitively determined by Folin and Ciocaltu colorimetric method (A.O.A.C. 1985). Sugar and phenols were measured at 620 and 640 nm using a Spectro 22 spectrophotometer (Labomed Inco, USA). The concentration of phenols was calculated from a standard curve of pyrogallol (Coseteng and Lee, 1987).

Dry weight determinations and chemical analysis. A representative plant was selected per each replicate at the end of experiment, divided into roots and shoots and dried in an oven at 70 °C for three days to determine dry weights and elemental concentrations. Ground samples were dry-ashed at 550 °C for 4 h. Potassium, Sodium and calcium in roots, shoots and fruits were determined by flame photometer according to Brown and Lilleland (1946).

Disease assessment: Powdery mildew was estimated under natural infestation with salt stress and foliar application of ascorbic acid treatments. One week after the last application, 10 plants were selected systematically from each treatment and three leaves were chosen at random on each selected plant. The numbers of visible colonies on leaves were counted. Infected leaves were categorized as follows: 0 = No symptoms; 1= Quarter of blade mildewed; 2= Half of blade mildewed; 3= Three quarter of blade mildewed; 4 = More than three quarter of blade mildewed. Percentage of disease severity was P= sum of (n X v) / 4N X 100 where: P= percentage of disease severity, n = Number of leaves in each category, v= numerical value of each category. N= Total number of leaves in sample, according to Townsend and Heuberger (1943).

4- Data analysis

Data were statistically analyzed using ANOVA/MANOVA of Statistica 6 software (Statsoft, 2001) with mean values compared using Duncanś multiple range test with a significance level of at least $p \leq 0.01$ and 0.05.

RESULTS

The results in Table (2) show that soil salinity (ECe), sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were increased progressively, relative to the control treatment, with increasing salinity levels in the irrigation water after 8 weeks and 16 weeks. These increments may be resulted from the continuous application of saline irrigation water which contains different concentrations of soluble ions such as Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, HCO_3^{-} and SO_4^{2-}.

Data presented in Tables (2) indicated that salt stress treatments at different concentrations negatively affected vegetative growth parameters of eggplant and leaf total sugar content. The obtained results showed that salt stress treatments caused significant reduction in plant height, number of leaves and leaf total sugar content compared with untreated plants. However, leaf total soluble phenols did not differed significantly.

Table (2): Effect of saline irrigation water on some physical and chemical soil properties at 8 and 16 weeks from transplanting of eggplants.

Sample date (week)	Salt conc.	ECe dSm^{-1}	pH	SAR	ESP	Cations meq^{-1}				Anions meq^{-1}			
						Ca	Mg	K	Na	CO_3	HCO_3	Cl	SO_4
8	0.0	2.19	7.62	4.20	7.18	1.0	1.8	2.3	16.8	0.0	3.8	3.2	14.9
	50	3.41	7.59	9.00	5.09	0.8	1.2	3.1	29.0	0.0	6.2	12.6	15.3
	100	4.20	7.27	0.26	6.61	1.0	1.8	3.4	35.8	0.0	7.0	17.6	17.4
16	0.0	3.86	7.00	0.76	9.32	0.8	0.6	3.1	34.1	0.0	4.6	4.4	29.6
	50	11.63	7.14	1.53	110.75	1.2	1.6	5.2	108.3	0.0	5.0	88.4	22.9
	100	15.23	7.10	143.90	174.12	1.0	1.0	6.4	143.9	0.0	2.4	140.2	9.7

Concerning the effect of ascorbic acid on eggplant growth characters as well as leaf total sugar and soluble phenols content, data demonstrate that no significant differences were found for plant height, leaf number, leaf total sugar and leaf total soluble phenols content, except number of leaves, in the second season which significantly increased when eggplant were sprayed with ascorbic acid (Table 3).

Results presented in Tables (3) indicated that the interaction between salt stress treatments and foliar application of ascorbic acid did not alleviate the harmful effects of salt stress in terms of plant height, total sugar and total soluble phenols content. However, at high NaCl concentration (100 mmol/l), number of leaves in both seasons, increased when eggplant sprayed with ascorbic acid compared with non-treated plants.

Salt stress treatments at different concentrations negatively affected shoot and root fresh (S.F.W. & R.F.W.) and dry weight (S.D.W. & R.D.W.) as well as fruit yield, however, root fresh and dry weight was not decrease when NaCl increased from 0.0 to 50 mmol/l. Root/shoot ratio was significantly higher at 50 mmol/l compared with other salt treatments (0.0 and 100 mmol/l). Concerning the effect of ascorbic acid on eggplant growth characters and fruit yield, data demonstrated that no significant differences were found for shoot fresh and dry weights as well as root/shoot ratio. However, root fresh (R.F.W.) and dry weights (R.D.W.) were increased when eggplant sprayed with ascorbic acid and this increasing was significant for root fresh weight in the first season only. On the other hand, fruit yield was increased markedly in eggplants treated with ascorbic acid compared with un-treated eggplant (Table 4). The results of interaction between salt stress treatments and foliar application of ascorbic acid, showed higher increases in the fruit yield under saline and non-saline conditions in ascorbic acid sprayed eggplant plants. The higher shoot and root fresh and dry weights were observed in plants sprayed with ascorbic acid and did not received salt treatments, however, higher root/shoot ratio observed when plants treated with 50 mmol/l NaCl and sprayed with ascorbic acid (Table 4).

Table (3): Effect of salinity stress with NaCl, foliar spraying with ascorbic acid and their interaction on plant height, leaf number, leaf total sugar and leaf total soluble phenols content of eggplant at 8 weeks from transplanting.

Treatments		Plant height (cm)		Number of leaves		Leaf total sugar (mg/100g F.W.)		Leaf free phenols (mg/100g F.W.)	
NaCl (mmol/l)	Ascorbic acid (mmol/l)	2006	2007	2006	2007	2006	2007	2006	2007
0.0		51.30 a	52.50 a	23.77 a	24.44 a	1001.3 a	1042.8 a	143.3 a	145.9 a
50		42.87 b	42.94 b	20.00 b	19.72 b	767.5 b	818.0 b	165.5 a	172.5 a
100		28.60 c	30.00 c	12.13 c	13.22 c	615.5 c	634.5 c	157.9 a	167.1 a
	0.0	43.87 a	44.09 a	20.14 a	19.04 b	786.2 a	829.8 a	156.6 a	160.4 a
	3.0	42.92 a	44.27 a	19.74 a	21.64 a	803.3 a	833.7 a	154.6 a	169.3 a
0.0	0.0	51.53 a	53.33 a	22.73 a	22.89 ab	1052.0 a	1120.0 a	138.9 a	145.6 a
	3.0	51.07 a	51.67 a	24.80 a	26.00 a	950.7 ab	965.5 b	147.7 a	164.3 a
50	0.0	42.93 b	43.00 b	19.73 b	19.67 bc	702.3 cd	754.5 cd	155.9 a	166.3 a
	3.0	42.80 b	42.89 b	20.27 ab	19.78 bc	832.7 bc	881.5 bc	175.2 a	178.7 a
100	0.0	27.63 c	29.40 c	10.25 d	11.00 d	604.3 d	615.0 d	160.1 a	169.4 a
	3.0	29.71 c	30.75 c	14.29 c	16.00 c	626.7 d	654.0 d	155.7 a	164.7 a

Means of three replicates with the same letter in each column are not significantly different (Duncan's *p ≤ 0.05).

Sodium concentration in shoot and root was significantly higher in salt stressed plants compared with control plants. However, potassium and calcium content in shoots and roots were decreased significantly at salt stress treatments compared with un-treated plants. Foliar spraying eggplant plants with ascorbic acid did not show any significant differences between treated or un-treated plants in terms of shoot and root sodium and calcium content as well as root potassium content. However, shoot potassium content was significantly increased when eggplant sprayed with ascorbic acid. As for the combined effect of salt stress and the addition of ascorbic acid, results revealed that in both saline and non-saline conditions, spraying eggplants with ascorbic acid improved significantly shoot potassium content in both seasons. However the foliar application of ascorbic acid mostly did not significantly change sodium and calcium content in shoots and roots of eggplant, except for the foliar application of ascorbic acid which increased sodium content in shoots at high salt stress (100 mmol/l NaCl), in summer 2006. Also sodium content was increased markedly in roots under high salt stress, in summer 2007 (Table 5).

Table (4): Effect of salinity stress with NaCl, foliar spraying with ascorbic acid and their interaction on fresh and dry matters of shoots and roots, root/shoot ratio and fruit yield of eggplant during the two seasons of 2006 and 2007.

Treatments: NaCl (mmol/l)	Treatments: Ascorbic acid (mmol/l)	Shoot Fresh Weight (S.F.W.) (g)	Shoot Dry Weight (S.D.W.) (g)	Root Fresh Weight (R.F.W.) (g)	Root Dry Weight (R.D.W.) (g)	Root/ shoot ratio	Fruit weight (g) / plant	Fruit number/ plant
				2006				
0.0		125.18 a	35.78 a	92.01 a	17.59 a	0.48 b	3405.00 a	51.17 a
50		74.30 b	17.74 b	70.50 ab	14.74 ab	0.85 a	1483.00 b	31.00 b
100		64.85 b	14.64 b	50.27 b	8.49 b	0.58 b	295.27 c	7.00 c
	0.0	91.23 a	23.24 a	63.27 b	13.02 a	0.62 a	1600.70 b	27.78 b
	3.0	90.82 a	24.22 a	83.75 a	15.47 a	0.67 a	1855.00 a	31.67 a
0.0	0.0	116.36 a	32.88 a	65.03 b	13.03 b	0.39 c	3269.40 b	49.00 b
	3.0	133.99 a	38.68 a	133.98 a	25.84 a	0.57 abc	3540.60 a	53.33 a
50	0.0	83.28 b	18.93 b	69.56 b	15.18 ab	0.83 ab	1350.40 d	28.67 d
	3.0	65.32 b	16.55 b	71.44 b	14.30 ab	0.86 a	1655.70 c	33.33 c
100	0.0	65.39 b	15.25 b	51.19 b	9.74 b	0.64 abc	222.23 f	5.67 e
	3.0	64.32 b	14.03 b	49.35 b	7.235 b	0.52 bc	368.73 e	8.33 e
				2007				
0.0		122.75 a	36.60 a	86.43 a	15.41 a	0.42 b	3410.70 a	51.00 a
50		74.80 b	17.26 b	65.99 ab	14.15 a	0.84 a	1512.90 b	31.25 b
100		63.50 b	14.00 b	49.25 b	7.88 b	0.56 b	353.95 c	9.50 c
	0.0	90.75 a	22.96 a	61.77 a	12.80 a	0.62 a	1632.80 b	28.17 b
	3.0	83.30 a	22.28 a	72.68 a	12.17 a	0.59 a	1885.60 a	33.00 a
0.0	0.0	124.00 a	36.00 a	69.38 b	14.66 a	0.40 b	3294.00 b	49.00 b
	3.0	121.50 a	37.20 a	103.48 a	16.16 a	0.44 b	3527.50 a	53.00 a
50	0.0	84.24 b	18.39 b	65.95 b	14.73 a	0.84 a	1351.20 d	28.50 d
	3.0	65.40 b	16.13 b	66.05 b	13.58 ab	0.84 a	1674.70 c	34.00 c
100	0.0	64.00 b	14.50 b	50.00 b	9.00 bc	0.63 ab	253.25 e	7.00 f
	3.0	63.00 b	13.50 b	48.50 b	6.75 c	0.50 ab	454.65 e	12.00 e

Means of three replicates with the same letter in each column are not significantly different (Duncan's $^{*}p \leq 0.05$).

Table (5): Effect of salinity stress with NaCl, foliar spraying with ascorbic acid and their interaction on sodium, potassium and calcium content in shoots and roots of eggplant during the two seasons of 2006 and 2007.

Treatments		Concentrations in shoots						Concentrations in roots					
NaCl (mmol)	Ascorbic acid (mmol)	Na^+ 2006	Na^+ 2007	K^+ 2006	K^+ 2007	Ca^{2+} 2006	Ca^{2+} 2007	Na^+ 2006	Na^+ 2007	K^+ 2006	K^+ 2007	Ca^{2+} 2006	Ca^{2+} 2007
0.0		0.30 c	0.33 c	1.76 a	1.79 a	1.97 a	2.02 a	0.46 c	0.49 c	0.72 a	0.75 a	1.07 a	1.09 a
50		0.92 b	0.95 b	1.18 b	1.20 b	1.69 b	1.74 b	1.01 b	1.03 b	0.59 b	0.62 b	0.85 b	0.89 b
100		1.67 a	1.72 a	1.13 b	1.11 b	1.56 c	1.59 c	1.38 a	1.43 a	0.39 c	0.42 c	0.85 b	0.89 b
	0.0	0.85 a	0.98 a	1.27 b	1.26 b	1.75 a	1.77 a	0.90 a	0.98 a	0.59 a	0.59 a	0.95 a	0.97 a
	3.0	0.90 a	1.03 a	1.50 a	1.48 a	1.72 a	1.80 a	0.89 a	0.98 a	0.59 a	0.60 a	0.92 a	0.95 a
0.0	0.0	0.27 d	0.29 c	1.60 b	1.63 b	2.00 a	2.00 a	0.46 c	0.49 e	0.76 a	0.80 a	1.07 a	1.07 a
	3.0	0.34 d	0.37 c	1.93 a	1.95 a	1.93 a	2.04 a	0.47 c	0.50 e	0.68ab	0.70 ab	1.08 a	1.11 a
50	0.0	0.93 c	0.98 b	1.12 d	1.12 c	1.76 b	1.67 c	1.05 b	1.08 c	0.56 b	0.57 b	0.95ab	0.99 a
	3.0	0.91 c	0.93 b	1.24 c	1.25 c	1.62bc	1.81 b	0.96 b	0.98 d	0.63 b	0.68 ab	0.76 c	0.80 c
100	0.0	1.61 b	1.66 a	1.00 e	0.96 d	1.50 c	1.64cd	1.34 a	1.39 b	0.37 c	0.42 c	0.79 c	0.84 bc
	3.0	1.73 a	1.78 a	1,25 c	1.25 c	1.62bc	1.55 d	1.43 a	1.48 a	0.41 c	0.42 c	0.90bc	0.95 ab

Means of three replicates with the same letter in each column are not significantly different (Duncan's $^{*}p \leq 0.05$

Data presented in Table (6) showed that the reduction percentages of disease severity were decreased by addition NaCl at different concentrations. NaCl at 50 mmol caused reduction of powdery mildew on eggplant plants by 30.9% and 41.99 %, however, at 100 mmol the reduction of powdery mildew was 64.4% and 65.74%, in both seasons, compared with the control (0.0 mmol). Whereas, plants treated with ascorbic acid at concentration 3 mmol showed more efficiency in controlling the disease incidence. Ascorbic acid caused increasing in the disease reduction by the rate of 30 % and 23.35 %. It is clear that significantly the highest disease reduction percentage was found when salt stress at 100 mmol interacted with spraying of ascorbic acid (73.9% and 84.77%, in both seasons) compared with other treatments.

Table (6): Effect of NaCl and ascorbic acid on controlling powdery mildew in eggplant plants during the two seasons of 2006 and 2007.

Treatments		Disease severity %	
NaCl (mmol/l)	Ascorbic acid (mmol/l)	2006	2007
0.0		15.917 a	15.083 a
50		11.000 b	8.750 b
100		5.667 c	5.167 c
	0.0	12.778 a	10.944 a
	3.0	8.944 b	8.389 b
0.0	0.0	18.333 a	15.000 a
	3.0	13.500 b	15.167 a
50	0.0	12.000 b	9.167 b
	3.0	10.000 bc	8.333 b
100	0.0	8.000 c	8.667 b
	3.0	3.333 d	1.667 c

Means of three replicates with the same letter in each column are not significantly different (Duncans $^{*}p \leq 0.05$).

Data presented in Table (7&8) show the effect of salt stress and spraying with ascorbic acid and their combined effect on fruit quality during storage. Significantly the highest fruit weight loss% and fruit total phenols content were achieved at high NaCl concentration (100 mmol/l). Regarding fruit total content of sugar, results showed that zero salt treatment had the highly significant total content of sugar, however, the treatment of 50 mmol/l NaCl had the lower significant fruit sugar content, in both seasons. Fruit potassium and calcium content were decreased with NaCl increase, however, fruit sodium content was increased. Foliar spraying with ascorbic showed significant decrease in fruit weight loss% and fruit total sugar content, however, fruit free phenols increased significantly in sprayed eggplant compared with non-sprayed plants. Sprayed plants with ascorbic acid contained significantly low sodium, in both seasons, however, significantly high calcium and potassium contents were observed in sprayed eggplant, in the second season. Concerning the effect of storage duration on fruit quality, results showed that higher fruit weight loss% in both years and fruit total soluble phenols in the second year were noticed at the late storage period

(12 days), whereas, significant higher phenols, in the first, season, was observed at middle storage period (6 days). However, fruit total sugars content were significantly decreased by storage duration, in both seasons. Also, results indicated that significantly higher sodium, potassium and calcium content in the fruits were observed mostly when eggplant fruits stored in room temperature for 12 days compared with fresh harvest fruits. The interaction among salt stress, spraying with ascorbic acid and storage duration at room temperature are presented in Table (7&8). During storage for 6 and 12 days, fruit weight loss were increased for all salt and ascorbic acid treatments compared with fresh harvest fruits. The highest weight loss was mostly noticed after 12 days of storage for all treatments.

Table (7): Effect of salinity stress with NaCl, foliar spraying with ascorbic acid and their interaction on fruit weight loss, total sugar and total soluble phenols contents of eggplant fruits during shelf life period.

Treatments			Fruit weight loss%		Total sugar (mg/100 g.F.W.)		Fruit total soluble phenols (mg/100g F.W.)	
NaCl mmol/l	Ascorbic acid mmol/l	Storage duration (day)	2006	2007	2006	2007	2006	2007
0.0			11.15 c	15.63 c	1036.70 a	1028.60 a	132.38 c	142.05 c
50			14.76 b	15.89 b	710.13 c	766.23 c	133.61 b	143.10 b
100			15.89 a	27.09 a	872.33 b	808.59 b	152.92 a	153.87 a
	0.0		15.11 a	20.42 a	915.72 a	878.75 a	131.28 b	139.90 b
	3.0		12.76 b	18.65 b	830.40 b	856.88 b	148.00 a	152.78 a
		0.0	0.00 c	0.00 c	927.45 a	910.85 a	118.66 c	127.54 c
		6.0	17.95 b	28.26 b	875.72 b	880.39 b	153.41 a	145.90 b
		12.0	23.85 a	30.35 a	816.01 c	812.18 c	146.85 b	165.58 a
0.0	0.0	0	0.00 j	0.00 m	1192.30 a	1169.10 a	101.07 n	102.16 o
		6	16.77 g	18.25 k	1071.10 b	1070.40 c	148.10 i	160.30 f
		12	18.26 f	38.04 c	951.34 h	950.21 g	162.33 e	174.13 c
	3.0	0	0.00 c	0.00 m	1039.30 c	1091.10 b	101.30 n	116.13m
		6	13.92 i	10.07 l	981.34 g	963.38 d	152.44 g	130.13 l
		12	17.95 f	27.3 g	985.00 f	927.46 h	129.04 k	169.44 d
50	0.0	0	0.00 c	0.00 m	755.41 n	761.34 l	101.10 n	111.30 n
		6	17.16 g	22.97 h	560.21 r	959.29 e	123.44 l	112.24m
		12	27.04 b	19.14 j	722.46 o	615.21 q	106.04 m	173.44 c
	3.0	0	0.00 c	0.00 m	756.34 m	744.29 m	155.00 f	132.17 k
		6	20.28 e	21.30 i	770.21 l	798.16 k	149.00 h	152.17 i
		12	24.08 cd	31.93 e	696.13 p	719.09 p	167.10 d	177.30 b
100	0.0	0	0.00 c	0.00 m	1037.30 d	742.04 n	124.04 l	148.45 j
		6	24.46 c	57.07 a	1036.40 e	900.00 j	169.13 c	164.10 e
		12	32.30 a	28.30 f	915.00 i	741.13 o	146.24 j	113.00 l
	3.0	0	0.00 c	0.00 m	784.19 k	957.25 f	129.44 k	155.00 h
		6	15.08 h	39.90 b	835.00 j	591.13 r	178.33 a	156.45 g
		12	23.49 d	37.24 d	626.13 q	920.00 i	170.37 b	186.20 a

Means of three replicates with the same letter in each column are not significantly different (Duncanś *$p \leq 0.05$).

Table (8): Effect of salinity stress with NaCl, foliar spraying with ascorbic acid and their interaction on sodium, potassium and calcium contents of eggplant fruits during shelf life period.

Treatments			Na^+		K^+		Ca^{2+}	
NaCl mmol/l	Ascorbic acid (mmol/l)	Storage duration (day)	2006	2007	2006	2007	2006	2007
0.0			0.317 c	0.290 c	1.741 a	1.742 a	1.798 a	1.782 a
50			0.511 b	0.546 b	1.667 b	1.687 b	1.757 b	1.782 a
100			0.604 a	0.630 a	1.653 b	1.643 c	1.652 c	1.707 b
	0.0		0.506 a	0.518 a	1.691 a	1.667 b	1.739 a	1.712 b
	3.0		0.449 b	0.462 b	1.682 a	1.713 a	1.732 a	1.801 a
		0.0	0.428 c	0.462 c	1.564 b	1.563 c	1.612 c	1.615 c
		6.0	0.491 b	0.488 b	1.741 a	1.719 b	1.753 b	1.797 b
		12.0	0.513 a	0.520 a	1.755 a	1.788 a	1.842 a	1.858 a
0.0	0.0	0	0.335 l	0.345 k	1.640 f	1.645 h	1.700 ef	1.680 f
		6	0.400 k	0.305 l	1.840 c	1.825 c	1.800 bcde	1.760 e
		12	0.425 j	0.375 j	1.920 b	1.865 b	1.940 a	1.820 cd
	3.0	0	0.245 n	0.225 n	1.440 h	1.445 k	1.690 ef	1.680 f
		6	0.210 o	0.225 n	1.795 cd	1.865 b	1.760 cdef	1.860 bc
		12	0.285 m	0.285 m	1.810 cd	1.805 de	1.900 ab	1.890 b
50	0.0	0	0.465 i	0.505 h	1.700 e	1.735 f	1.600 gh	1.550 h
		6	0.565 e	0.595 ef	1.980 a	1.795 e	1.700 efg	1.580 gh
		12	0.505 g	0.545 g	1.380 i	1.445 k	1.840 abc	1.900 b
	3.0	0	0.435 j	0.485 i	1.490 g	1.555 j	1.720 def	1.780 de
		6	0.480 h	0.500 h	1.600 f	1.685 g	1.820 bcd	1.900 b
		12	0.615 c	0.645 c	1.850 c	1.905 a	1.860 abc	1.980 a
100	0.0	0	0.585 f	0.625 d	1.480 gh	1.375 m	1.400 i	1.380 l
		6	0.625 c	0.700 a	1.495 g	1.415 l	1.840 abc	1.980 a
		12	0.645 b	0.665 b	1.785 d	1.905 a	1.830 abc	1.760 e
	3.0	0	0.505 g	0.585 f	1.635 f	1.625 i	1.560 h	1.620 g
		6	0.665 a	0.605 e	1.735 e	1.730 f	1.600 gh	1.700 f
		12	0.600 d	0.605 e	1.785 d	1.805 de	1.680 f	1.800 de

Means of three replicates with the same letter in each column are not significantly different (Duncans $^*p \leq 0.05$).

Fruit total soluble phenols were increased during storage for 6 or 12 days compared with fresh harvest fruits for all salt or ascorbic acid treatments and this increasing was mostly at significant level. Also the significant high total soluble phenols was observed in fruits harvested from the plants received high salt concentration (100 mmol/l), when the fruits stored for 6 days in the first season and the fruits which stored for 12 days in the second season. Higher fruit total sugar content was achieved when the fruits were not stored and came from eggplant plants that were not treated with salt or ascorbic acid, in both seasons. In the other hand, fruit sodium content increased significantly in treatments contained salt compared with no salt treatments, especially at salt treatment with 50 mmol/l which combined with the storage duration for 12 days in some cases and in other cases combined with 6 days storage duration. In general, fruit potassium content was slightly affected by the application of salt treatments or the foliar spraying with 3 mmol/l ascorbic acid. However, fruit potassium content was increased during storage at room temperature. Although significantly the highest potassium content was observed in fruits harvested from eggplants treated with salt (50 mmol NaCl), in both seasons, high potassium values were observed in eggplant treated with no NaCl, and sprayed or not with ascorbic acid and stored for 6 or 12 days, compared with fresh harvest fruits. The behavior of fruit calcium content was in most cases similar with the potassium content, except that calcium content was less affected by salt treatments than potassium content (Table 8).

DISCUSSION

Excess salinity within the plant rootzone has a general deleterious effect on plant growth. The hypothesis that best seems to fit observation is that excessive salinity reduces plant growth primarily because it increases the energy that must be expended to acquire water from the soil of the rootzone and to make the biochemical adjustments necessary to survive under stress. This energy is diverted from the processes which lead to growth and yield (Rhoades *et al.,* 1992).

Salinity stress induced lower biomass production, total sugar content, shoot and root potassium and calcium contents and fruit yield of eggplant. This is in accordance with the previous findings in cucumber (Kaya *et al.* 2003) and melon (Kaya *et* al. 2007). As suggested by Bernstein (1963), suppression of plant growth under saline conditions may either be due to osmotic reduction in water availability or excessive ion (Na and Cl) accumulation in plant tissues (Gunes *et al.* 1995). On the other hand, with the increasing of concentration of cell sap, in terms of osmotic pressure, caused by NaCl the incidence of disease decreased markedly which was accompanied by a decrease in total sugar content of the leaves. This result was supported by Hegde and Karande (1978) who demonstrated that powdery mildew disease is considered one of the most plant disease affected by the concentration of total sugar content.

Foliar spray of ascorbic acid significantly enhanced fruit yield in both non-stressed and stressed conditions. These positive results with ascorbic acid were associated with root fresh and dry weights increasing under non-saline conditions. The obtained results are in agreement with those achieved by Shaddad *et al.* (1990) in faba bean, Arisha (2000) in potato and Gaballah *et al.* (2007) in sunflower. The improved effect of ascorbic acid may be due to enhancing cell division and expansion as well as enhancing the plant nutritional status (Smirnoff, 1996; Kato and Esaka, 1999; 2000; Shalata and Neumann, 2001; Pignocchi *et al.*, 2003 and Mostafa, 2004). Also, results indicated that the foliar spray with ascorbic acid alleviated the toxic effects of salt stress on shoot and fruit potassium and calcium content as well as fruit yield of eggplant. These results are in agreement with Khan *et al.* (2006) who indicated that supplemental ascorbic acid ameliorate the inhibitory effect of sea salt in some halophytes. The positive results with regard to fruit yield, potassium and calcium content may be because of the fact that ascorbic acid plays a protecting role in plants under salt treatments, against the oxidative damage caused by scavenging free radicals and reactive oxygen species that are generated during salt stress (Conklin *et al.*, 1996; 1997; Noctor and Foyer

1998; Smirnoff, 2000; Sanmartin *et al.*, 2003; Blokhina *et* al., 2003). Application of 3 mmol ascorbic acid improved potassium and calcium content and this effect could be due to the effect of ascorbic acid on increasing the efficiency of potassium uptake and also, it might be true because ascorbic acid has a positive role in photosynthesis process. In addition, potassium is very important in the opening of stomatal system and for more CO_2 fixation (Franceschi and Tarlyn, 2002), as well as potassium is necessary for the translocation of sugars and formation of carbohydrates as reported previously in pepper (El-Ghinbihi and Hassan, 2007). Calcium was increased in shoots and fruits of eggplant sprayed with ascorbic acid, there is may be two reasons for that, (1) there is now strong evidence that wall ascorbate and ascorbate oxidase have links with wall metabolism, photosynthesis and cell division which need more calcium uptake, (2) ascorbate is the major precursor of oxalate and could be linked to calcium homeostasis and free calcium levels (Smimoff, 2000 & Debolt *et* al., 2007). Calcium has been shown to ameliorate adverse effects of salinity on plants (Ehret et al., 1990 & Kaya *et al.*, 2002). Also, calcium is well known to have regulatory roles in metabolism (Cramer *et al.*, 1986). Sodium ions may compete with calcium ions for membrane-binding sites. Therefore, it has been hypothesized that high calcium levels can protect the cell membrane from the adverse effects of salinity (Busch, 1995).

Eggplant plants sprayed with ascorbic acid at high salt stress decreased disease severity at significant level. These results are supported by Nicholas (1996) and Borbála *et. al.* (2005) who reported that the pathogen is arrested by an active plant response (antioxidants) which increased especially in cell-wall. Ascorbate occurs in the cell wall where it is a first line of defense against biotic stress. Cell wall ascorbate and cell wall-localized ascorbate oxidase have been implicated in control of pathogen growth which prevent the biotrophic fungus from establishing the nutrition organs (haustoria).

Foliar spray of ascorbic acid appeared to increase fresh and dry matters accumulation in roots under non-saline condition. The proportion of dry weight allocated to roots was increased with increasing NaCl to 50 mmol/l, then again decreased at 100 mmol/l, as shown from data on root/shoot ratio, were the increas were approx. 54% and 21% in salt treatments with 50 mmol/l NaCl none-sprayed and sprayed with ascorbic acid, respectively. However, it was approx. 32% and 12 % in salt treatments with 100 mmol/l, compared with treatments without salt. Previous studies carried out with cotton and prosopis (Meloni et al., 2001, 2004), soybean and alfalfa (Bernstein and Ogata, 1966 & Kant *et al.*, 1994) and with cowpea (Murillo-Amador *et al.*, 2006) showed that shoot growth was inhibited by NaCl more than root growth.

Salinity tolerance of crop species depends on its ability to limit Na^+ absorption by the roots and maintain low levels of sodium in leaves (Tadano, 1983 & Yamanouchi, 1995). Concentrations of Ca^{2+} and K^+ in roots, shoots and fruits were decreased in the presence of NaCl as reported in previous studies (Lutts *et al.*, 1999; Siveritepe *et al.*, 2003 and Murillo-Amador *et al.*, 2006), and the mechanism of the differences in nutrient uptake under salinity is still unclear. However, the possible causes in eggplants could be related to the concentration of ions in the external solution (i.e., Na^+ and Cl^-), which if taken up at high rates, may lead to excessive accumulation in the tissue. These ions may inhibit the uptake of other ions into the root (i.e., K^+ or Ca^{2+}) and their transport into the shoot through the xylem, eventually leading to deficiency in the tissue. The data on ion concentrations in this study clearly showed that foliar spray with ascorbic acid increased concentrations of nutrients (Ca^{2+} and K^+) in shoots to mitigate the adverse effects of salinity on eggplants, however the ascorbate application did not decrease sodium concentrations in shoots and fruits, even sodium concentration increased significantly in some cases in sprayed eggplant. These results are similar to the results in other species (Shaded *et al.*, 1990; El-Ghamriny *et al.*, 1999; El-Ghinbihi and Hassan 2007).

As for fruit shelf life on room temperature, a good positive correlation was found between fruit weight loss and total fruit phenols. The reason for this increase in fruit total phenols compound was not only due to the increasing weight loss, but because of increasing salt level. Also, results showed negative correlations between fruit total sugar and calcium and sodium contents. Salinity may induce an increase in the respiration rate of plants and the energy issued from respiration processes could be allocated to growth or to the maintenance of normal metabolic functions. For that, it is possible that the stressed plants required high energy for usual normal metabolism than non-stressed plants(Kasai *et al.* 1998). Although shoot total sugar was increased in ascorbate sprayed eggplant, but total sugar content in harvested fruits decreased in sprayed eggplant. This might be due to ascorbate degradation caused by harvesting, which seems to induce serious damage to the plant cell after harvest, as reported before in broccoli (Lee and Kader, 2000 & Nishikawa *et al.*, 2003). Fruit total phenols, sodium, potassium and calcium were increased in stored fruits than in un-stored fruits. These results are in agreement with those found by Manganaris *et al.* (2007). This increasing may be attributed to the creation of channels of discontinuity and openings for total phenols, potassium, calcium and sodium penetration, as a result of their ripening after 12 days of shelf life, in relation to fresh harvest fruits.

Accordingly, it can be concluded that salt-induced reduction in yield and nutrient components can be improved by the exogenous application of ascorbic acid. Also, fruit nutrient value was improved during shelf life.

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تأثير الرش بحامض الاسكوربيك على النمو ودرجة الإصابة بمرض البياض الدقيقي والمحتوى الكيماوي والمحصول وجودة الثمار لنباتات الباذنجان النامية تحت ظروف الإجهاد الملحي والظروف الطبيعية

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أجريت هذة الدراسة في تجربتي أصص بالمزرعة التجريبية بكلية الزراعة-جامعة قناة السويس- الإسماعيلية خلال الموسمين الزراعيين ٢٠٠٦ و ٢٠٠٧ وذلك لدراسة التأثيرات الفسيولوجية لمعاملات الإجهاد الملحي على صفات النمو الخضري والتركيب الكيماوي والمحصول وجودة الثمار لنباتات الباذنجان هجين توباز وكذلك دراسة تأثير الرش بحامض الاسكوربيك بتركيز ٣ مليمول كمحاولة لتقليل الآثار الضارة لزيادة نسبة الملوحة. وقد عرضت نباتات الباذنجان للإجهاد الملحي وذلك برى النباتات بمستويات ملحية من محلول كلوريد الصوديوم بتركيزات صفر- ٥٠ - ١٠٠ مليمول وقد أوضحت النتائج المتحصل عليها ما يلي:-

أظهر تحليل التربة زيادة كل القياسات المأخوذة على التربة فيما عدا ال pH الذي انخفض مع زيادة أضافة ملح كلوريد الصوديوم وأظهرت النتائج أن ايون الصوديوم والكلوريد تراكما في التربة خلال فترة الزراعة.

أدى تعرض نباتات الباذنجان لمعاملات الإجهاد الملحي إلى حدوث نقص معنوي في صفات النمو الخضري المتمثلة في ارتفاع النبات وعدد الأوراق والوزن الخضري والجاف للمجموع الخضري والجذري وكذلك المحصول الكلي.

أظهرت الدراسة أيضا أن معاملة نباتات الباذنجان بمستويات ملوحة مختلفة أدت إلى انخفاض ملحوظ في درجة الإصابة بالبياض الدقيقي والتي تواكبت مع انخفاض مستوى الأوراق من السكريات الكلية.

أظهرت الدراسة أن معاملات الملوحة أدت إلى حدوث نقص معنوي في تركيز السكريات الذائبة الكلية وكذلك انخفض تركيز كل من البوتاسيوم والكالسيوم في أوراق وثمار الباذنجان معنويا في حين أن محتوى الفينولات الذائبة والصوديوم في الأوراق والثمار ازداد معنويا مع زيادة تركيز الملوحة في التربة.

أثر رش نباتات الباذنجان بحامض الاسكوربيك تأثير ايجابيا على التركيب الكيماوي والمحصول وجودة الثمار بالإضافة إلى أن معاملة الرش أدت إلى حدوث زيادة معنوية في تركيز محتوى المجموع الخضري والثمار من البوتاسيوم والكالسيوم وكذلك محتوى الثمار من الفينولات في حين أن محتوى الثمار من الصوديوم انخفض مقارنة بالنباتات الغير معاملة بحامض الاسكوربيك.

أثبتت النتائج أن نسبة الإصابة بمرض البياض الدقيقى انخفضت معنويا في النباتات المعاملة بحامض الاسكوربيك تحت أعلى مستوى ملوحة.

أشارت الدراسة أن محتوى ثمار الباذنجان من البوتاسيوم و الكالسيوم و الصوديوم وكذلك الفينولات ازداد بتخزينها تحت ظروف الغرفة في حين أن السكريات الكلية انخفضت بالتخزين.

وعلى ذلك يمكن التوصية برش نباتات الباذنجان بحامض الاسكوربيك حيث أن النتائج المتحصل عليها تؤكد أن حامض الاسكوربيك لة دور فعال في تقليل الأثر الضار للملوحة على نباتات الباذنجان.