

AMELIORATIVE EFFECTS OF DI-POTASSIUM HYDROGEN ORTHOPHOSPHATE ON SALT-STRESSED AND NON-STRESSED EGGLANT (*Solanum melongena* L.)

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ABSTRACT

Two pot experiments were carried out with Eggplant (*Solanum melongena* L.) cv. Topaz F₁ in sand culture to investigate the effects of foliar application of 10 mM K₂HPO₄ to plants grown under NaCl concentration (50 mM) supplied via roots and in complete nutrient solution. Treatments were (1) nutrient solution (C); (2) nutrient solution + 10 mM K₂HPO₄ as foliar application (C+PK); (3) nutrient solution + 50 mM NaCl (C+S); and (4) nutrient solution + 50 mM sodium chloride + 10 mM K₂HPO₄ as a foliar application twice weekly (C+S+PK). The plants grown at NaCl had less vegetative growth, dry matter, leaf total sugar content and fruit yield than those grown in normal nutrient solution in both years, however, leaf free phenols was not changed by salinity treatment. Foliar K₂HPO₄ sprays ameliorated the negative effects of salinity on plant growth and fruit yield as well as increased leaf free phenols content. Sodium concentration in plant tissues increased in NaCl treatment and the sodium uptake was not reduced by application of K₂HPO₄, however, leaf total sugar content was decreased by spraying K₂HPO₄. Concentrations of K, Ca and P in shoots and roots were in the deficient range in plants grown at NaCl and these deficiencies were corrected by foliar application K₂HPO₄. Free phenol, potassium and calcium were increased in stored fruits under room conditions and this increase was more by pre-harvest foliar spray with K₂HPO₄ compared with fresh harvested fruits. Total sugar content was decreased in stored fruits compared with fresh harvested fruits and the application of K₂HPO₄ lowered this decrease. High fruit sodium content was found in stored fruits, however, the pre-harvest foliar spray with K₂HPO₄ lowered the sodium accumulation in fruits compared with the untreated one. In conclusion, results support the hypothesis that supplemental K₂HPO₄ would ameliorates the inhibitory effects of NaCl stress in eggplant.

Keywords: salinity, K₂HPO₄, eggplant, foliar application.

INTRODUCTION

The world population is expanding rapidly and it expected to be around 8 billion by the year 2025 (Pinstrup-Andersen *et al.*, 1999). This represents an addition of nearly 80 million people to the present population (6 billion) every year. It is forecast that the increases in world population will occur almost exclusively in developing countries, where serious nutritional problems exist at present, and population pressure on the agricultural soils is already very high. To feed the increasing world population food production must be increased by up to 100% over the next 25 years (Dyson, 1999), however, recent trends indicate that productivity and fertility of soils are globally declining due to degradation and intensive use of soils without consideration of proper soil-management practices (Cakmak, 2002).

Eggplant (*Solanum melongena* L.) is one of the most important vegetable crops, grown on over 1.7 million ha world-wide (FAO, 2005). Compared with other species eggplant is considered as a moderately salt sensitive crop (Heuer *et al.*, 1986).

Salinity is the main environmental factor accountable for decreasing crop productivity of a wide variety of crops in many areas of the world especially in arid and semi-arid regions (Ashraf and Foolad, 2007). According to Bray *et al.* (2000) the relative decreases in potential maximum crop yields with a biotic stress factors vary between 54% and 82%.

Saline water intrusion has severely damaged 30 million of the world's 237 million hectares of irrigated farmland and some 80 million hectares are deleteriously affected in varying degrees. Cultivated land area in Egypt is very low (4% of total land area), also third of the cultivated land area in Egypt were affected by salinity (Ghassemi *et al.* 1995).

Plants exposed to environmental a biotic stress factors suffer from oxidative damage catalyzed by reactive oxygen species (Asada and Takahashi, 1987). Increasing evidence suggests that improvement of potassium (K)-nutritional status of plants can greatly lower the ROS production by reducing activity of NAD(P)H oxidase and maintaining photosynthetic electron transport (reviewed by Cakmak, 2005).

Sodium is the predominant soluble cation in many of the salinity affected soils. High concentrations of Na disturb intracellular ion homeostasis (Rus *et al.*, 2004 & Ashraf, 2004). To overcome salinity problem, considerable efforts have been directed by plant breeders and physiologists toward developing cultivars and agro-management techniques to improve growth and yield of crops under saline conditions.

Plant nutrients are taken up both by roots and by upper plant parts (Mengel, 2002). The low availability of nutrients in the soil, fixations of potassium and phosphorus ions are high under salinity soils, also, lack of water uptake because of high osmotic potential around the plant roots as well as concomitant slower diffusion rates of nutrients.

Foliar applied nutrients have the benefit of being 4 to 30 times more efficient and there is no risk of groundwater contamination, especially under saline conditions. There is a direct link between foliar feeding and the activities of the enzymatic systems of the plant, whereas the availability of nutrients provided by foliar feeding stimulate enzymatic cycles to greater efficiency and quicker response (Kupper, 2003). For that, foliar fertilization can therefore be a complementary measure taken to provide nutrients during a critical phase, especially under salinity stress.

Potassium is the most prominent inorganic plant solute that plays important roles related to stomatal behaviour, osmoregulation, enzyme activity, protein synthesis, cell expansion, neutralization of nondiffusible negatively charged ions and membrane polarization (Elumalai *et al.*, 2002). Phosphorus is used in many metabolic reactions and activities as a component of many organic compounds and it is important in metabolic transfer processes, photosynthesis and respiration (Awad *et al.*, 1990).

The effects of salts on plant growth and physiology have been well documented in cereals, for example, rice (Lutts *et al.*, 1996) and barley

(Morales *et al.*, 1992). However, the effects of salt stress on vegetative growth and physiology are still not understood. It is well known that high salt concentrations induce P and K deficiencies in tomato (Satti and Al-Yahyai, 1995; Lopez and Satti, 1996), strawberry (Kaya *et al.*, 2001; Kaya *et al.*, 2002), pepper and cucumber (Kaya *et al.*, 2003) and melon (Kaya *et al.*, 2007). Addition of KNO_3 (Lopez and Satti, 1996; Kaya and Higgs, 2003; Kaya *et al.*, 2007), KH_2PO_4 (Kaya *et al.*, 2001 & Kaya *et al.*, 2003), K_2SO_4 (Khayyat *et al.*, 2007) to fertilizer solutions ameliorated the adverse effects of salinity on plant growth and fruit yield in tomato, pepper, cucumber, melon and strawberry. However, there little or no information is available on induction salinity tolerance by application of K_2HPO_4 , whereas, di-potassium orthophosphate (K_2HPO_4) was used before to overcome plant disease, such as Bacterial spot disease in tomato and pepper (Abbasi *et al.*, 2002) and powdery mildew in tomato (Ehret *et al.*, 2002).

In this investigation, a long-term experiment with a commercial eggplant cultivar was conducted to study the effectiveness of foliar application of another source of potassium phosphate (K_2HPO_4) for overcoming salinity stress.

MATERIALS AND METHODS

1-Plant materials, treatments and growth conditions

This pot experiment was conducted out doors at research experimental farm of the Faculty of Agriculture, Suez Canal University, Ismailia, Egypt from May 3 to September 30, 2006 and repeated in 2007.

Seeds of eggplant (*Solanum melongena*) cv. Topaz F₁ were sown in styrofoam 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 7000 cm³ washed sand. Soil texture was sandy, Ph was 8.27, EC was 0.465 dSm⁻¹, Ca was 0.8 meq⁻¹, Mg was 0.6 meq⁻¹, K was 0.3 meq⁻¹, Na was 3.0 meq⁻¹, HCO₃ was 1.6 meq⁻¹, Cl was 3.0 meq⁻¹ and SO₄ was 0.1 meq⁻¹.

Two weeks from transplanting different treatments were initiated. Treatments were (i) control: plants receiving nutrient solution, (ii) control plus 10 mmol/l K_2HPO_4 (C+KP): plants receiving nutrient solution plus K_2HPO_4 applied foliarly once a week, (iii) salinity treatment (C+S): plants receiving nutrient solution plus 50 Mm NaCl, (iv) salinity plus supplementary 10 mmol/l K_2HPO_4 (C+S+KP): plants receiving nutrient solution plus 50 mmol/l NaCl plus 10 mmol/l K_2HPO_4 applied foliarly once a week. These treatments presented all possible combinations of two salt stress (0.0 and 50 mM) treatments with two concentrations of K_2HPO_4 (0.0 and 10 mM) as foliar spray. The volume of sprayed solution ranged from 20 to 50 ml per plant each time, depending on plant size or development. The same amount of water was pulverized to the control plants. pH was measured for water and

K₂HPO₄ solution and it was 6.5 and 7.7 respectively. All these sprays were done in the morning (8-9 a.m.). The treatments were arranged as factorial experiment in randomized complete block design. Each treatment was replicated three times and each replicate included 7 pots. The plants were irrigated four times per week with 500 ml/pot from the nutrient solution plus 0.0 and 50 mmol/l NaCl, which increased to 1000 ml/l from the beginning of flowering (from the middle of July until the end of the September). Each pot from control treatment without salt received none NaCl, only nutrient solution, however, salt treatment with 50 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% P₂O₅, 19% K₂O, 200 ppm Fe, 50 ppm Zn, 100 ppm Mn, 7 ppm Cu, 5 ppm Mo and 12% SO₄. The nutrient solution was added at a dilution of 1:50 which corresponding to an EC 2.0 dSm⁻¹.

2- Measurements and Observations

2.1. 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.

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 flamephotometrically, Ca²⁺, Mg²⁺, were volumetrically determined by titration with ethylene diamine tetra acetic acid (versinate), Cl⁻ was determined by titration with silver nitrate, HCO₃⁻ was determined by titration with standard sulphuric acid according Page *et al.*, (1982). *Sodium adsorption ratio (SAR):* was calculated based on the equation $SAR = Na / \left(\frac{Ca + Mg}{2} \right)^{1/2}$ where Na⁺, Ca²⁺ and Mg²⁺ in meq/l 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).

2.2. Plant growth. Plant height, leaf number and branch number were measured at 8 weeks from transplanting. Harvesting of fruits started from the end of July on a weekly basis and continued for 9 weeks. The yield was determined in terms of fruit number and fruit weight. After the last harvest, plants were uprooted and the fresh weight of plant roots and shoots were taken.

2.3. Total sugar and total free phenols content determination. Extract solution of 10 grams from fresh leaves (fifth leaves) in Ethanol (80%) was used to determined total soluble sugars according to Stewart (1974). Also, in the same extract solution, free soluble phenols were quantitatively 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).

2.4. Dry weight determinations and chemical analysis. Three plants per replicate were divided into shoots and roots 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. 0.5 gm of powdered material was digested separately using a mixture of H₂SO₄ and H₂O₂ and then brought to a final volume of 50 ml with distilled water. Potassium, Sodium and calcium in roots and shoots were determined by flame photometer according to Brown and Lilleland (1946). P was analyzed by a vanadate-molybdate method at 660 nm using a Spectro 22 spectrophotometer (Chapman and Pratt, 1982).

3- Fruit quality during Shelf life:

Eighteen unblemished fruits from harvest number six from each treatment in this investigation were hand-picked to study the effect of the combination of salt stress with NaCl 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 6 or 12 days under room conditions (34±2 °C and 58% RH).

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.

Fruit chemical composition: Chemical determinations (total sugar, free phenols, potassium, sodium and calcium content) were carried out after 0, 6 and 12 days beginning of storage. Ten fresh grams from three fruits per replicate in each storage stage were used to determine total sugar content and free soluble phenols, however the rest of fruits were dried and digested to measure Na, K and Ca. The methods previously described.

4- Data analysis

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

RESULTS

All soil chemical properties (EC, K, Na, SO₄, Cl, SAR and ESP) were higher in the soils received nutrient solution and NaCl compared with soils received only nutrient solution, except the soil pH which was decreased. It is clear that the increase in K and SO₄ were less than other chemicals (Fig. 1).

Salt stress treatment with 50 mmol/l NaCl negatively affected plant height, leaf number, fruit yield, leaf and fruit total sugar, different organs calcium and potassium content (root, shoot and fruit), shoot phosphorus content. On the other hand, root/shoot ratio, different organs sodium content (root, shoot and fruit), root phosphorus content and fruit free phenols were increased significantly under salt stressed eggplants compared with unstressed plants.

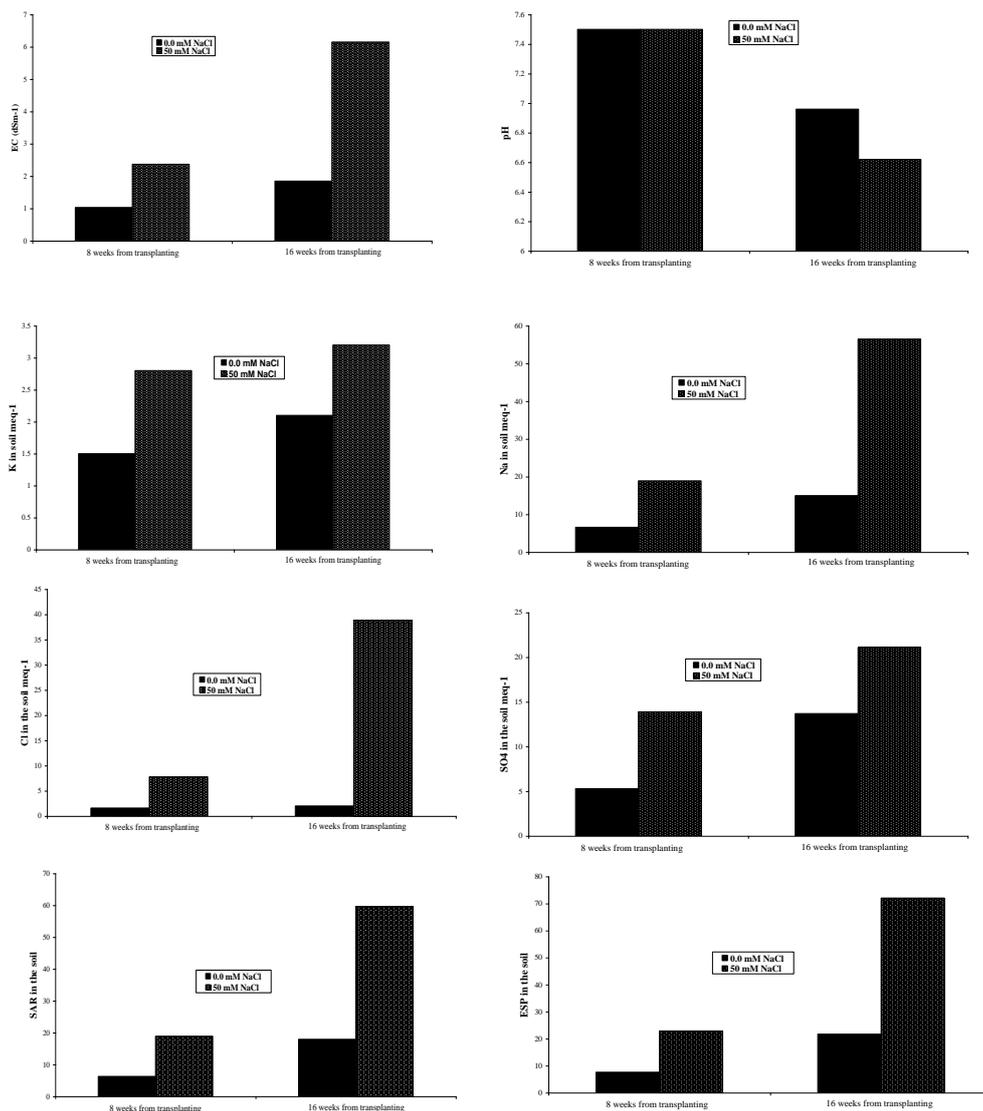


Fig. (1): Effect of NaCl-treatments on some chemicals properties in the soil substrate at 8 and 16 weeks from transplanting of eggplants.

Leaf free phenols content was slightly affected. Foliar spraying eggplant plants with 10 mmol/l K_2HPO_4 enhanced significantly plant height, leaf number, fruit yield, leaf and fruit free phenols content, K, Ca and P in roots and shoots, fruit calcium and potassium content as well as root sodium content. This enhancement was mostly significant especially under salt stress. In some cases stressed-plants which sprayed with potassium phosphate have been reached nearly the same values of control plants in some parameters (plant height, leaf number, fruit yield, shoot and root calcium content as well as shoot phosphorus content). Moreover, other parameters such as leaf and fruit free phenols content in addition to root P content reached more values than control plants. Shoot and fruit sodium content were decreased in sprayed plants under saline conditions and this decrease was significantly in sodium fruit content. The reduction of leaf total sugar content by stress was increased when plants sprayed with K_2HPO_4 , however, the decreasing of fruit total sugar content by salinity stress was improved significantly when plants treated with K_2HPO_4 (Tables 1, 2, 3, 4 and 5)

Fruit weight loss, fruit free phenols, sodium, potassium and calcium were increased markedly in stored fruits compared with fresh harvested fruits. Free weight loss, fruit free phenols content and fruit sodium were increased in fruits harvested from stressed-plants, however, fruit total sugar, potassium and calcium content were less in fruits harvested from stressed-plants. Application of potassium phosphate improved fruit free phenols, total sugar, potassium and calcium content especially in plants under salt stress conditions, however, weight loss percentage and fruit sodium content were decreased in fruits which harvested from plants treated with K_2HPO_4 . Fresh harvested fruits came from control I plants had high sugar content, however, high free phenols content was found in stored fruits (12 days) which harvested from stressed-plants and sprayed with K_2HPO_4 (C+S+KP).

Table (1): Effect of NaCl and NaCl plus the foliar application of dipotassium phosphate on plant height, leaf number, leaf total sugar and leaf total soluble phenols content of eggplant at 8 weeks from transplanting during the two seasons of 2006 and 2007.

Treatments	Plant height (cm)		Number of leaves		Leaf total sugar (mg/100g F.W.)		Leaf total soluble phenols (mg/100g F.W.)	
	2006	2007	2006	2007	2006	2007	2006	2007
C	54.40 b	54.57 a	27.50 b	25.20 b	958.00 a	908.00 a	145.60 b	150.38 c
C+KP	57.82 a	58.70 a	38.64 a	41.00 a	658.00 c	621.33 c	160.36 a	161.00 b
C+S	45.46 c	45.70 b	22.36 c	23.14 b	754.50 b	733.50 b	139.60 b	140.90 d
C+S+KP	53.09 b	54.43 a	36.46 a	36.00 a	603.33 c	632.50 c	166.30 a	167.50 a

Means of three replicates and each replicate includes five plants. The same letter in each column are not significantly different (Duncan's $*p \leq 0.05$). C: Plants receiving nutrient solution; C+PK; nutrient solution plus 10 mmol K_2HPO_4 foliarly supplemented; C+S: nutrient solution plus 50 mmol NaCl; C+S+PK: nutrient solution plus 50 mmol NaCl and sprayed with 10 mmol K_2HPO_4 .

Table (2): Effect of NaCl and NaCl plus the foliar application of di-potassium phosphate on fresh and dry matter of shoots and roots, root/shoot ratio and fruit yield of eggplant during the two seasons of 2006 and 2007.

Treatments	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							
C	130.50 b	37.25 b	72.00 b	14.90 b	0.40 b	4487.50 b	71.00 a
C+KP	157.50 a	50.20 a	116.09 a	23.97 a	0.53 b	5994.30 a	76.50 a
C+S	79.55 c	18.50 c	66.05 b	12.57 b	0.69 a	2327.50 c	41.50 b
C+S+KP	92.45 c	22.73 c	68.40 b	12.46 b	0.55 ab	4736.60 b	76.50 a
2007							
C	135.50 b	38.00 b	73.50 b	15.25 b	0.41 b	4810.00 b	76.00 ab
C+KP	162.50 a	50.95 a	106.90 a	22.41 a	0.62 a	5754.20 a	71.50 b
C+S	84.55 c	19.25 c	71.05 b	12.72 b	0.66 a	2325.00 c	43.00 c
C+S+KP	94.95 c	23.23 c	70.80 b	12.65 b	0.55 ab	4842.00 b	79.50 a

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

Table (3): Effect of NaCl and NaCl plus the foliar application of di-potassium phosphate on sodium, potassium, calcium and phosphate content in roots and shoots of eggplant during the two seasons of 2006 and 2007.

Treatments	Concentrations in shoots				Concentrations in roots			
	Na ⁺	K ⁺	Ca ²⁺	P	Na ⁺	K ⁺	Ca ²⁺	P
2006								
C	0.30 b	1.95 a	2.04 a	0.45 b	0.53 c	0.83 b	1.17 b	1.30 d
C+KP	0.33 b	1.97 a	2.12 a	0.68 a	0.59 c	1.01 a	1.37 a	1.53 c
C+S	0.88 a	1.14 c	1.64 b	0.23 c	1.00 b	0.42 c	1.05 c	1.85 b
C+S+KP	0.83 a	1.36 b	1.96 a	0.43 b	1.20 a	0.46 c	1.14 b	2.05 a
2007								
C	0.29 b	1.90 a	2.00 a	0.53 b	0.51 c	0.88 a	1.22 b	1.32 d
C+KP	0.35 b	2.02 a	2.13 a	0.73 a	0.54 c	1.06 a	1.41 a	1.58 c
C+S	0.93 a	1.19 c	1.69 b	0.28 c	1.08 b	0.40 b	1.15 b	1.93 b
C+S+KP	0.88 a	1.40 b	2.00 a	0.48 b	1.23 a	0.48 b	1.15 b	2.15 a

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

High fruit sodium and potassium content was achieved in stored fruits (12 days) and associated with treatment C+S for sodium and C and C+KP for potassium content. However high calcium content was found in stored fruits (6 or 12 days) and came from all treatments under this study (Tables 4&5).

Table (4): Effect of NaCl and NaCl plus the foliar application of di-potassium phosphate on fruit weight loss, total sugar and total soluble phenols content of eggplant fruits during shelf life period.

Treatments	Storage duration (day)	Fruit weight loss %		Total sugar (mg/100 g F.W.)		Fruit free phenols (mg/100g F.W.)	
		2006	2007	2006	2007	2006	2007
C	0	0.00 h	0.00 h	1092.30 a	1069.10 b	104.90 j	106.16 i
	6	17.77 f	19.24 g	1060.60 b	1020.40 c	120.20 h	140.04 e
	12	19.26 d	35.04 a	926.34 e	930.21 f	149.65 cd	160.26 b
C+KP	0	0.00 h	0.00 h	998.34 c	1109.70 a	111.07 i	128.94 f
	6	13.22 g	19.96 f	945.50 de	891.34 g	140.10 f	155.30 c
	12	23.15 c	32.43 b	890.16 f	890.50 g	160.33 b	170.13 a
C+S	0	0.00 h	0.00 h	855.41 g	959.29 e	123.94 g	115.30 h
	6	18.16 e	23.50 e	822.46 h	761.34 j	146.90 e	122.24 g
	12	28.04 a	30.00 c	660.21 i	615.21 k	150.24 c	151.17 d
C+S+KP	0	0.00 h	0.00 h	955.50 d	969.84 d	120.04 h	132.10 f
	6	19.02 d	26.54 d	947.84 de	813.66 h	149.24 d	154.20 cd
	12	23.93 b	30.44 c	895.34 f	771.00 i	169.63 a	170.44 a

Means of three replicates and each replicate includes three fruits. The same letter in each column are not significantly different (Duncan's $*p \leq 0.05$).

Table (5): Effect of NaCl and NaCl plus the foliar application of di-potassium phosphate on sodium, potassium and calcium content of eggplant fruits during shelf life period.

Treatments	Storage duration (day)	Na ⁺		K ⁺		Ca ²⁺	
		2006	2007	2006	2007	2006	2007
C	0	0.280 g	0.280 h	1.725 e	1.545 d	1.775 e	1.755 ef
	6	0.255 h	0.295 gh	1.815 d	1.755 bc	1.890 c	2.050 a
	12	0.305 f	0.305 g	2.000 ab	1.895 a	1.880 c	1.860 bcd
C+KP	0	0.290 fg	0.305 g	1.710 e	1.690 c	1.770 e	1.810 cde
	6	0.295 fg	0.295 gh	1.890 d	1.910 a	1.895 c	1.805 de
	12	0.355 e	0.400 d	2.050 a	1.965 a	2.050 a	1.910 b
C+S	0	0.485 c	0.525 b	1.480 g	1.425 e	1.450 f	1.480 h
	6	0.525 b	0.500 c	1.665 ef	1.590 d	1.850 cd	1.860 bcd
	12	0.545 a	0.565 a	1.905 c	1.695 c	1.965 b	1.800 bc
C+S+KP	0	0.455 d	0.355 e	1.615 f	1.600 d	1.800 de	1.690 g
	6	0.455 d	0.405 d	1.815 d	1.590 d	1.905 c	1.745 fg
	12	0.485 c	0.335 f	1.966 b	1.805 b	1.910 bc	1.895 b

Means of three replicates and each replicate includes three fruits. The same letter in each column are not significantly different (Duncan's $*p \leq 0.05$).

DISCUSSION

Vegetative growth parameters, total sugar and shoots as well as fruits mineral contents were affected markedly under salinity stress treatment except sodium content which increased. This is in accordance with the previous findings in strawberry (Kaya *et al.*, 2001), cucumber (Kaya *et al.*,

2003), pepper (Kaya and Higgs, 2003) and melon (Kaya *et al.*, 2007). It's well known that saline conditions suppressed plant growth because of osmotic reduction in water availability or to excessive ion (Na and Cl) accumulation in plant tissues (Gunes *et al.*, 1995).

Ameliorate the adverse effects of salinity stress on plant growth by application of potassium phosphate nutrient solution well documented before by (Kaya *et al.*, 2001) in strawberry,(Kaya *et al.*, 2003) in cucumber,(Kaya and Higgs, 2003) in pepper and (Kaya *et al.*, 2007) in melon. The previous reports on the effect of potassium on improving salinity damages were done mostly on vegetative stage except Kaya *et al.* (2003 & 2007) who examined the effects of potassium phosphate until fruit maturity in cucumber, pepper and melon. From the previous reports on strawberry, cucumber, pepper and melon, there is only a report in which mono-potassium phosphate was applied as foliar spraying (Kaya *et al.*, 2001). It's well known that the foliar applied nutrients is more benefit than soil fertilizers especially under salinity stress (Kupper, 2003) because the low availability of nutrients in the soil, fixations of potassium and phosphorus ions under such condition. Also, it is accepted that competition exists between Na and K leading to a reduced level of internal K at high external NaCl concentration (Asch *et al.*, 1999; Rus *et al.*, 2004). Kaya *et al.* (2007) reported that the melon fruit yield reduced by 35.7% under stress treatment and the application of potassium phosphate in nutrients solution lowered this reduction to 16.8%. Also, Kaya *et al.* (2003) reported that the cucumber and pepper fruit yield reduction were 39% and 46.7% respectively under salinity treatment, however, these reduction was lowered to 7.5% and 7.11%, respectively due to addition of mono-potassium phosphate. Comparing to that, our results showed that the reduction in eggplant fruit yield under stress was more than 48 % and 51%, in both years respectively, however, the application of di-potassium phosphate as foliar spray minimized this reduction to approx. -5.5% and -0.66 in both years. This results supported that the foliar applied nutrients is more benefit than soil fertilizers especially under stress conditions (Kupper, 2003).

Stress environmental conditions, such as salinity lead to reduced availability of the nutrient, especially K (Liebersbach *et al.*, 2004; Kaya *et al.*, 2007). Environmental stress factors that enhance the requirement for K also cause oxidative damage to cells by inducing formation of ROS especially during photosynthesis (Foyer *et al.*, 1994). The reason for the enhanced need for K by plants suffering from environmental stresses appears to be related to the fact that K is required for maintenance of photosynthetic CO₂ fixation. For example, environmental stress is associated with stomatal closure and thereby with decreased CO₂ fixation. Also, potassium is moved through the phloem towards the growing regions of plant, therefore, potassium in plant roots produces a gradient of osmotic pressure that draws water into the roots and potassium in young plant leaves is associated with stomatal opening and thereby with increase transpiration rate and CO₂ fixation. Although in this study the potassium is supplemented to plants as foliar spray, however not only leaf potassium content increased but also root potassium content increased. These results were supported by the previous findings which

confirmed that potassium moved through the phloem towards the growing regions of plant.

The favourable effects of foliar spraying of potassium phosphate on plant growth, shoot and root mineral content and phenols content as well as fruit yield might be due to that potassium is a major plant macro-nutrient that plays important roles related to stomatal behaviour, osmoregulation, enzyme activity, cell expansion, neutralization of nondiffusible negatively charged ions and membrane polarization (Hsiao and Läuchi, 1986; Maathuis and Sanders, 1996; Elumalai *et al.*, 2002). Aslo, potassium has a crucial role in the energy status of the plant, translocation and storage of assimilates, maintenance of tissue water relation and stimulates root growth (Imas and Bansal 1999). Fruits present large sinks for phosphorus and potassium (Buwalda and Lenz, 1992) due to their role in metabolism and translocation of carbohydrates (Marschner, 1995), which supported our results regarding the favourable effect of spraying potassium phosphate on fruit potassium under saline and non-saline conditions. It is well-documented that when compared to plants supplied adequately with K, there is a several-fold increase in sucrose concentration in leaves of the K-deficient plants. These findings are consistent with results showing that deficiency causes a severe decrease in phloem export of sucrose from source leaves (reviewed by Cakmak, 2005). These findings supported our results regarding low leaf total sugar and high fruit total sugar content.

Application of potassium phosphate did not decrease sodium uptake, but decrease translocation of sodium from shoots to fruits. Enhancing plant growth by application of potassium phosphate is due to improvement in nutritional status of plants by more nutrients uptake than lowering sodium uptake, also, potassium plays a key role of crop quality by decreasing translocation of potassium from shoots to fruits.

For fruit shelf life on room temperature, in spite of the good positive correlation was found between fruit weight loss and total fruit phenols, however, a negative correlation also was found between fruit weight loss and fruit total sugar content. This result might be because of salinity 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). Fruit total phenols, sodium, potassium and calcium were increased in stored fruits and fruits harvested from sprayed plants with K_2HPO_4 than un-stored fruits and did not receive K_2HPO_4 , except sodium was lower in sprayed plants with K_2HPO_4 than un-sprayed plants. These result are supported by the finding of Manganaris *et al.* (2007) who confirmed that this increase 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 shelf life in relation to fresh harvest fruits.

In conclusion, the results given here signify the role of di-potassium orthophosphate in regulating the salt stress response of eggplant and suggest that K_2HPO_4 could be used as a osmoprotection to improve plant growth and nutrient utilization under salt stress.

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التأثيرات المحسنة للرش بفوسفات البوتاسيوم الثنائية على النمو والمحتوى الكيماوي والمحصول وجودة الثمار لنباتات الباذنجان النامية تحت ظروف الإجهاد الملحي والظروف الطبيعية

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أجريت تجربتي أصص بالمزرعة التجريبية بكلية الزراعة-جامعة قناة السويس- الإسماعيلية خلال الموسمين الزراعيين 2006 و 2007 وذلك لدراسة التأثيرات الفسيولوجية لمعاملات الإجهاد الملحي على صفات النمو الخضري والتركيب الكيماوي والمحصول وجودة الثمار لنباتات الباذنجان هجين توباز وكذلك دراسة تأثير الرش بفوسفات البوتاسيوم الثنائية بتركيز 10 مليمول كمحاولة لتقليل الأثر الضار لزيادة نسبة الملوحة. وقد عرضت نباتات الباذنجان للإجهاد الملحي وذلك برى النباتات بمستويات ملحية من ملح كلوريد الصوديوم بتركيزات صفر و 50 مليمول وكانت المعاملات كالتالي:- 1- محلول مغذى 2- محلول مغذى بالإضافة للرش بفوسفات البوتاسيوم الثنائية 3- محلول مغذى مضافا إليه ملح كلوريد الصوديوم 4- محلول مغذى مضافا إليه ملح كلوريد الصوديوم بالإضافة للرش بفوسفات البوتاسيوم الثنائية وقد أوضحت النتائج المتحصل عليها ما يلي:-

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 و المحصول الكلى وكذلك تركيز السكريات الذائبة الكلية في الأوراق في حين أن الفينولات في الأوراق لم تتأثر بالملوحة.

أظهرت الدراسة أن الرش بفوسفات البوتاسيوم الثنائية حسنت من التأثير الضار نتيجة المعاملة بالملوحة على النمو الخضري والمحصول الكلى بالإضافة إلى زيادة تركيز الفينولات الكلية في الأوراق.

أدت المعاملة الملحية بكلوريد الصوديوم إلى زيادة تركيز الصوديوم في السيقان ولم تقلل المعاملة بفوسفات البوتاسيوم الثنائية من تراكم الصوديوم في المجموع الخضري في حين أن محتوى الأوراق من السكريات الكلية انخفضت في النباتات التي تم رشها بفوسفات البوتاسيوم الثنائية.

أظهرت النتائج أن تركيزات البوتاسيوم و الكالسيوم والفوسفور انخفض في النمو الخضري والجذور في النباتات التي عرضت للإجهاد الملحي في حين أن الرش بفوسفات البوتاسيوم الثنائية صححت هذا الانخفاض.

أظهرت الدراسة أن بتخزين ثمار الباذنجان زاد محتواها من الفينولات و عنصرى البوتاسيوم والكالسيوم وهذه الزيادة كانت أكثر في الثمار التي جمعت من النباتات التي تم رشها بفوسفات البوتاسيوم الثنائية.

تركيز السكريات الكلية في الثمار المخزنة كانت أقل من تركيزها في الثمار التي لم تخزن وباستخدام الرش بفوسفات البوتاسيوم الثنائية قللت من هذا الانخفاض الذي سببه تخزين ثمار الباذنجان تحت ظروف الغرفة.

أظهرت النتائج أن الثمار التي تم تخزينها احتوت على نسبة صوديوم أعلى من الثمار التي لم تخزن في حين أن الرش بفوسفات البوتاسيوم الثنائية خفضت من تراكم الصوديوم في الثمار مقارنا بالثمار التي جمعت من النباتات التي لم ترش بفوسفات البوتاسيوم الثنائية

وعلى ذلك يمكن التوصية برش نباتات الباذنجان بفوسفات البوتاسيوم الثنائية حيث أن النتائج المتحصل عليها تؤكد أن لها دور فعال في تقليل الأثر الضار للملوحة على نباتات الباذنجان.