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# OPTIMIZING GROWTH, IONIC, PHYSIOLOGICAL CASE AND PRODUCTIVITY OF SWEET PEPPER UNDER SALINITY CONDITIONS

**BY**

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## ABSTRACT

Salinity experiments were designed at El-Bramoon Farm, Agric. Res. Inst. during 2001 and 2002, summer seasons. To study different performances of treated sweet pepper Baladi cv. under salinity stress (3000 and 6000 ppm NaCl) and application of Ca-gluconate, ATP, K-citrate and Na-benzoate treatments for improving its growth and fruit yield.The results could be summarized as follows:

**Effect of salinity:** Increasing levels of salinity resulted in significant decline in vegetative growth, dry matter accumulation and partitioning, flowering, fruiting, and fruit yield / plant in the two seasons of growth. Total dry weight/plant and fruit yield/plant were reduced by (33.2 and 17.9%) and (39.7 and 31.6%) (compared with control) during the two seasons of growth due to irrigation with 3000 and 6000 ppm NaCl, respectively. Also, membranes integrity, permeability and selectivity were impaired (measured by $EC_1/EC_2$, K/Na values) resulted in excessive uptake and translocation of $Na^+$ and $Cl^-$ ions vs low content of N, P and K within roots and leaves.

**Effect of anti-salinity treatments:** Spraying pepper plants with Ca-gluconate, ATP, K-citrate and Na-benzoate respectively, were greatly improved N, P and K content and reduced $Na^+$ and $Cl^-$ ions uptake, shift $EC_1/EC_2$, K/Na and Na l / Na r values to be in normal case. They were respectively increased total dry weight and fruit yield by (42.4, 34.0, 26.6 and 23.1%) and (71.6, 50.7, 42.4 and 35.7%) (means of the two seasons) respectively.

**Effect of interaction:** In similar trends salinity adversely affected all the studied growth and yield parameters. On the other hand the anti-stress treatments well improved those at 3000 ppm NaCl and ameliorated the adverse effects at higher 6000 ppm NaCl salinity. In this respect, Ca-gluconate and ATP were the most effective one, they increased fruit yield by 20.3 and 4.8% at 3000 ppm NaCl and alleviated the reductions of 6000 ppm NaCl to be only 6.3 and 6.5%, respectively. Correlation values were greatly confirmed the interrelationship of the ionic and physiological case with fruit yield. That, suggested the possibility of using $EC_1/EC_2$ and K/Na values as a reliable physiological indicators/sensors and/or as adaptive behaviour under salinity.

It could be concluded that spraying salt stressed sweet pepper plants with Ca-gluconate (16% Ca) at 2 ml/L and/or commercial ATP at (50 ppm) was a suitable technique to increase its fruit yield at moderate (3000 ppm NaCl) and to alleviate yield reduction at higher (6000 ppm NaCl) salinity

## INTRODUCTION

Sweet pepper and most of the economic vegetables are categorized as salt sensitive to moderately sensitive glycophytes with developing less or no halophyte like behavior in some cases (Mass and Hoffman, 1977 and Greenway and Munns, 1980). Under low salinity, glycophytes suffer from osmotic effects and turgor declines rather than toxic one, they try to cope with such effects, but greater metabolic demand is placed upon the plant to generate organic compatible solutes, i.e. sugars, organic and amino acids for osmotic adjustment (process characteristics typically for glycophytes). At higher salinity, ion imbalances and salt ion toxic effects rather than the osmotic one was the case. Plants can not adequately adapted to control salt uptake into their sensitive tissues with less or no capability to exclude these ions away from the sensitive cytoplasm into cell vacuoles (halophytic like behavior) (Greenway and Munns, 1980; Pasternak, 1987 and Hasegawa and Bressan, 2000).

Salinity induces reductions in growth and fruit yield due to the toxic effect of salt ions (Niu *et al.*, 1995), hyperosmotic effects (Yancey *et al.*, 1982), nutritional imbalances (Liu and Zhu, 1998 and Navarro *et al.*, 2002), membrane destabilization (Hasegawa and Bressan, 2000), membrane breakdown and low K/Na and Ca/Na selectivity followed by sharp intake of Na ions (Drew and Lauchli, 1985 and Kaya and Higgs, 2003), excessive accumulation and toxic effects of Na and Cl (Greenway and Munns, 1980), depression in $CO_2$ assimilation (Nieman *et al.*, 1988), inhibition of photosynthesis (Munns and Termaat, 1985), diversion and expandature of carbohydrates and energy (ATP) pools (maintenance and protective processes (Pasternak, 1987 and Nieman *et al.*, 1988), reduction in useful ions uptake (N, P, K, Ca and Mg) vs. excessive uptake of Na and Cl (Kaya and Higgs, 2003 and Kaya *et al.*, 2003) raise in ethylene synthesis and senescence effects (El-Abd *et al.*, 1988), generation of toxic reactive oxygen species (ROS) (Maggio *et al.*, 2002).

Based on the well understanding of the above mentioned information. Some treatments were suggested as a promising agromanagement technique for amelioration of the adverse effects, consequences and the drastic internal events due to salinity. This technique depend on the frequent spraying of salt stressed pepper plants with Ca-gluconate and K-citrate (for their ion regulatory osmoregulatory, cryoprotective (detoxification), anti-oxidantal and other roles, adenosine tri-phosphate, commercial ATP as energy agent, Na-benzoate as anti-ethylene, during stressful conditions.

Herein, it could be cited the relevant information about such treatments. as calcium and its anti-salinity effects (signaling, regulatory and structural functions) (Epstein, 1988; Ferguson, 1988 and Knight, 2000)

Potassium is known as a perquisite for turgor drives solutes transport and water balance, metabolic demand for enzymes activities, photosynthesis capacity and protein synthesis (Chow *et al.*, 1990 and Marschner, 1995). Fathy *et al.*, (2003) about using K-citrate, citric acid and ATP as energy, anti-oxidantal agents during the stressful condition, Njoroge *et al.* (1998); Reymond *et al.* (1992); Fathy and Farid (2000) and Fathy *et al.* (2000) all about the anti-stress effects of ATP. About the use of Na-benzoate as anti-ethylene agent during stress conditions (Wang *et al.*, 1982; Lascaris and Deacon, 1991 and Fathy *et al.*, 2000).

The present work is an attempt to conduct an extensive analysis of the effect of salinity on different performances of sweet pepper "Baladi" cv as a reliable local model germplasm towards identifying the mechanisms by which underlying stress effects, searching about new ameliorative treatments and/or inducing some degrees of salt less sensitivity and the feasibility of using poor quality water in irrigation at economical level.

## MATERIALS AND METHODS

Two experiments were designed at El-Bramoon Experimental Station, El-Dakahlia Governorate, Hort. Res. Inst., Cairo, during 2001 and 2002 summer seasons. In order to study different responses of sweet pepper Baladi cv under the effect of different salinity (NaCl) levels and the protective anti-stress treatments and their interaction.

**Experimental procedure and cultural conditions:**

Pepper seedlings (40 day old) were transplanted into plastic polyethylene bags 25 cm in diameter, filled with clay and sand in 1:1 ratio as growth substrate. Plants were initially irrigated only with tap water during the first month to ensure best establishment. Bags were arranged in factorial experiment (3 x 5), randomized complete block design. Each treatment contained 30 bag, ten in each replicate (3 replicates).

On mid of April, one month after transplanting, plants were frequently irrigated with salinized water, three weekly successive applications up to 12 ones. Each 3 successive salt treatments were followed by one protective treatment up to 4 applications. Irrigation with NaCl salinized water was amounted to 0.5 L/bag, increased with time to 1 L/bag. In some cases tape water used for irrigation as required. Each plant monthly received 2 g NPK (20-20-20) fertilizer.

**Salinity treatments:**

Adding commercial NaCl in tap water, salt treatments were initiated at increments of around 1000 and 2000 ppm NaCl during the first 3 applications to reach the final concentrations of 3000 and 6000 ppm, respectively. Treatments were control (0 ppm NaCl, tap water only), 3000 and 6000 ppm NaCl.

**Anti-salinity protective treatments:**

These treatments were commercial adenosine tri-phosphate ATP (50 ppm), Ca in organic form (Ca-gluconate 16% Ca) (2 ml/L), K in organic form K-citrate 30% K (5 g/L), Na-benzaoate (0.25 g/L). All treatments were sprayed 4 times followed each three salt applications.

**Experimental parameters:**

**Growth and dry matter:**

Ten days after the termination of all treatments, nine plants from each treatment (three from each replicate) were carefully taken with their roots, cut into shoots and roots. Plant height (cm), number of leaves and shoots were recorded. Shoots and roots were oven dried (70°C/72 hr), shoots, roots, total dry weight (TDW)/plant (g) and shoot/root (DW) ratio were determined. Relative dry weight (%) of different treatments relative to that of control (Without any treatment).

**Ionic and mineral nutrient status:**

The dried materials of leaves and roots were used for analysis of N, P and K as well as salt ions $Na^+$ and $Cl^-$. Na and K were analyzed using flame photometer, Cl was determined by titration method (Page *et al.*, 1982), N.K and P were analyzed and determined according to modified methods of Horneck and Miller (1998), Horneck and Hanson (1998) and Cotton (1954), respectively.

**Physiological indicator parameters:**

Na l / Na r was calculated from Na content of leaves divided by Na content of roots, as indicator for allocation of Na between roots and shoots. Low ratios reflected a best salt adaptive case due to the capacity of reducing the translocation of Na into sensitive shoots (Blom-Zandestra, 2000).

K/Na ratio, was calculated from K of leaves divided by their Na content, as indicator for membrane selectivity of K ions vs Na ions, higher ratios indicated less salt sensitive adaptive case (Ltifi *et al.*, 1992 and De-Pascale *et al.*, 2003). Electrolyte leakage index ($EC_1/EC_2$), determined based on values of electrical conductivity of leaf tissue sap before ($EC_1$) and after salt stress ($EC_2$). Low values associated with better membrane permeability and integrity and tolerant (Kaya and Higgs, 2003). It was determined according to methods of Fathy (2000).

**Flowering and fruit yield:**

Number of flowers and fruits and fruit yield (g) were determined all over the season from 15 plants of each treatment (5 plant each replicate), then were calculated per plant. Also, fruit length, diameter (cm) and fruit shape index (length / diameter) were determined. Relative yield %, calculated from yield of each treatment relative to that of control.

**Correlation studies:**

Fruit yield per plant was statistically correlated vs. some physiological, elemental and ionic characters to be confirmed the interrelation between yield and the plant adaptive behaviors during this work conditions.

All data were statistically analysis based on ANOVA. Different between means were statistically measured using Duncan Multiple Range test.

## RESULTS AND DISCUSSION

**Vegetative growth characters:**
**Effect of salinity:**

The data in Table (1) showed that increasing NaCl levels cause a significant declines in all growth parameters, i.e. plant height, number of leaves and shoots also dry matter accumulation and partitioning into shoots and roots and the whole plant dry weight. These parameters were severely reduced with salinity in the two seasons of study. Shoot/root ratio tended to be slightly decreased specially at moderate 3000 ppm NaCl (only significant at second season), as an adaptive modification to increase water and ions uptake for osmoregulation.

From the same data, total dry weight was reduced by 33.2 and 39.5% (mean of two seasons) at moderate and higher salinities, respectively.

Such growth sensitivity and reductions with salinity might be due to the incomplete osmotic regulation and turgor declines derived inhibition in expansion growth at moderate salinity (Yancey *et al.*, 1982) and due to the nutritional imbalances (Liu and Zhu, 1998 and Navarro *et al.*, 2002), toxic effect of salt ions (Niu *et al.*, 1995) at higher salinity.

**Table (1): Effect of salinity treatments on growth parameters of sweet pepper during the two seasons of study.**

| NaCl (ppm) | Plant height (cm) | No. of leaves / plant | No. of shoots / plant | DW of shoots (g/plant) | DW of roots (g/plant) | Total DW (g/plant) | Relative TDW (%) | Shoot / root ratio |
|---|---|---|---|---|---|---|---|---|
| 2001 | | | | | | | | |
| 0 | 69.9 a | 147.0a | 16.9a | 111.6a | 16.0a | 128.2a | 100 | 6.76a |
| 3000 | 53.7 b | 94.1b | 11.0b | 73.7b | 11.1b | 84.8b | 66.14 | 6.60a |
| 6000 | 51.0 c | 80.9c | 8.8c | 66.0c | 9.9c | 75.9c | 59.2 | 6.63a |
| 2002 | | | | | | | | |
| 0 | 70.0a | 151.0a | 16.8a | 114.2a | 16.7a | 130.9a | 100 | 6.86a |
| 3000 | 54.6b | 96.2b | 12.1b | 76.6b | 11.7b | 88.3b | 67.45 | 6.53b |
| 6000 | 50.2c | 82.8c | 9.6c | 70.4c | 10.4c | 80.8c | 61.72 | 6.79a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test in Table (1).

Additionally, it may be due to membrane destabilization (Hasegawa *et al.*, 2000), membrane breakdown and low K/Na and Ca/Na selectivity followed by sharp intake of Na ions (Drew and Lauchli, 1985 and Kaya and Higgs, 2003), depression in photosynthesis and $CO_2$ assimilation (Munns and Termaat, 1985 and Nieman *et al.*, 1988), diversion and expenditure of carbohydrates and energy pools (Pasternak, 1987 and Nieman *et al.*, 1988), inducible raise in ethylene and toxic ROS (El-Abd *et al.*, 1988 and Maggio *et al.*, 2002).

Similar results about growth reduction by salinity were (Chartzoulakis and Kalpaki, 2002; De-Pascale *et al.*, 2003 and Kaya and Higgs 2003).

Based on the results of Mass and Hoffman (1977), Greenway and Munns (1980), Mediros *et al.*, (2002), Navarro *et al.*, (2002), De-Pascale *et al.*, (2003) and the present results, it could be considered sweet pepper Baladi cv as relatively less salt sensitive at moderate (3000 ppm) NaCl and moderately sensitive at higher (6000 ppm) salinity.

**Effect of anti-salinity treatments:**

Data of Table (2) indicated that regardless of salinity spraying sweet pepper plants with Ca-gluconate, followed by ATP, K-citrate and Na-benzoate significantly improved plant height, number of leaves and shoots, dry weight of shoots, roots and the total compared with control in two seasons of study. Also, such treatments were significantly differed among them in most cases.

Shoot/root ratio was not significantly affected in first season, in second season it was significantly decreased by most treatments compared with control. From the same results, Ca-gluconate, ATP, K-citrate and Na-benzoate increased total dry weight of their plants by 142.0, 134.0, 126.9 and 123.1% (means of two seasons relative to control), respectively.

This positive effect could be attributed to effect upon membrane integrity and selectivity measured by higher K/Na ratio and lower $EC_1/EC_2$ and Na l / Na r values (Table 8), higher content of the useful nutrients (N, P and K) vs low uptake and translocation of harmful ones (Na and Cl) (Table, 5). That, logically led to improve growth and dry matter accumulation as well.

In addition, it was obvious that Ca-gluconate was of the most superior favourable effect on growth. This might be due to the different counteracting and protective roles of Ca ions and from the other hand due to the role of gluconate organic moiety in osmoregulation and protection of membrane and enzymes against adverse effects of stress (Pasternak, 1987 and Hasegawa and Bressan, 2000). The exogenously applied Ca might be participate in Ca permeable channels (flow of Ca from the higher external supply into internal compartment in which Ca is at low concentration, this involved Ca-signaling system and its role as a secondary messenger in stress signal transduction system, thereby transcription of enzymes and proteins associated with the stress adaptation (Knight, 2000). Ca ions known to be greatly controlling the severity of specific ion (Na and Cl) toxicities (Mass, 1993), improved K, Ca, Mg selectivity vs. Na ions (Navarro *et al.*, 2000), preserved the structural and functional integrity of plant membrane, stabilized cell wall structure, regulate ions transport as well as cell wall enzyme activities (Rengel, 1992 and Marschner, 1995).Moreover, it was known that Ca beneficially affected growth and development via its role as a secondary messenger, its role constitute the link between the external signal (salinity) and intercellular responses (Ferguson, 1988).

**Table (2): Effect of anti-salinity treatments on growth parameters of sweet pepper during the two seasons of growth.**

| Amelior. Ions | Plant height (cm) | No. of leaves / plant | No. of shoots / plant | DW of shoots (g/plant) | DW of roots (g/plant) | Total DW (g/plant) | Relative TDW (%) | Shoot / root ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | 2001 | | | | |
| ATP | 64.4a | 115.1b | 13.2b | 90.9b | 13.5b | 104.4b | 136.47 | 6.76a |
| Ca-gluc. | 64.8a | 119.1a | 15.3a | 94.8a | 14.3a | 109.1a | 142.61 | 6.60a |
| K-citrate | 57.0b | 109.4c | 12.2c | 83.5c | 12.7c | 96.2c | 126.08 | 6.60a |
| Na-benz. | 57.6b | 107.3d | 10.8d | 82.9c | 12.4c | 95.3c | 124.57 | 6.69a |
| Control | 47.1c | 85.7e | 9.5c | 66.6d | 9.9d | 76.5d | 100.0 | 6.62a |
| | | | | 2002 | | | | |
| ATP | 64.2b | 117.1b | 13.5b | 91.9b | 13.8b | 105.7b | 131.63 | 6.67b |
| Ca-gluc. | 65.6c | 120.5a | 16.6a | 98.7a | 14.9a | 113.6a | 141.46 | 6.61b |
| K-citrate | 58.1c | 112.4c | 13.3b | 89.3c | 13.3c | 102.6c | 127.77 | 6.80b |
| Na-benz. | 57.0c | 109.8d | 11.2c | 85.0d | 12.7d | 97.7d | 121.66 | 6.67b |
| Control | 46.4d | 90.2e | 9.6d | 70.4e | 9.9e | 80.3e | 100.0 | 6.89a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

On the other hand, the application of ATP known to be improve growth of plants via its direct enhanceable role in energy-dependent metabolic processes, H-ATP-ase membrane (ions) transporter system, DNA regulatory and structural functions and its growth and yield promotional effects during stressful conditions (Reymond *et al.*, 1992; Njoroge *et al.*, 1998; Fathy and Farid, 2000; Fathy *et al.*, 2000 and Fathy *et al.*, 2003).

K-citrate improved growth due to the known indispensable functions of K ions and due to the osmoregulatory and anti-salt ions toxic effect, anti-oxidantal effects of organic citrate moiety (Lascaris and Deacon, 1991; Hasegawa and Bressan, 2000 and Fathy *et al.*, 2003).

K known as a pre-requisite for turgor drives solutes transport and water balance, its metabolic demand for enzymes activities, photosynthetic capacity and protein synthesis (Chow *et al.*, 1990 and Marschner, 1995). Meanwhile, Na-benzoate relatively induced growth improvement may be due to its anti-ethylene and anti-oxidantal effects, thereby alleviated the adverse senescence effects of the stress (Wang *et al.*, 1982; El-Abd *et al.*, 1988; Lascaris and Deacon, 1991; Fathy *et al.*, 2000 and Maggio *et al.*, 2002).

**Effect of interaction:**

The results presented in Table (3) showed that Ca-gluconate followed by ATP, K-citrate and to less extant Na-benzoate improved all growth parameters and dry matter accumulation and partitioning pattern of non salt stressed plants. In similar trend, they improved those at moderate salinity and to some extent at higher salinity relative to the control of non-stressed plants and highly relative to the controls of 3000 and 6000 ppm NaCl salinities.

**Table (3): Effect of interaction on growth parameters of sweet pepper during the two seasons of growth.**

| NaCl ppm | Amel. Ion | Plant height (cm) | No. of leaves /plant | No. of shoots /plant | DW of shoots (g/plant) | DW of roots (g/plant) | Total DW (g/plant) | Relative TDW (%) | Shoot/ root ratio |
|---|---|---|---|---|---|---|---|---|---|
| **2001** | | | | | | | | | |
| 0 | ATP | 78.0b | 150.0b | 18.0b | 116.1b | 17.6a | 133.7b | 113.59 | 6.57bc |
| | Ca-glu. | 80.6a | 156.3a | 20.6a | 123.0a | 18.2a | 141.2a | 119.96 | 6.74bc |
| | K-citrate | 70.6c | 144.3c | 16.0c | 109.0c | 16.9b | 125.9c | 106.96 | 6.41cd |
| | Na-ben. | 71.0c | 145.0c | 15.0cd | 106.7d | 15.6c | 122.3d | 103.90 | 6.94ab |
| | Control | 49.3gh | 139.3d | 15.0cd | 103.2e | 14.5d | 117.7e | 100 | 7.15a |
| 3000 | ATP | 59.6d | 105.0e | 11.6e | 83.2g | 11.5f | 94.7g | 80.45 | 7.23a |
| | Ca-glu. | 57.6de | 107.3e | 14.3d | 86.2f | 13.2e | 99.4f | 84.45 | 6.51bcd |
| | K-citrate | 51.3fg | 97.6f | 11.6e | 72.5i | 11.1f | 83.6i | 71.02 | 6.55bcd |
| | Na-ben. | 52.3f | 94.6g | 10.0fg | 75.1h | 11.5f | 86.6h | 73.57 | 6.49cd |
| | Control | 47.6h | 66.0k | 7.3hi | 51.8k | 8.4h | 60..2k | 51.14 | 6.12d |
| 6000 | ATP | 55.6e | 90.3h | 10.0fg | 73.5hi | 11.3f | 84.8hi | 72.04 | 6.49cd |
| | Ca-glu. | 56.3e | 93.6g | 11.0ef | 75.5h | 11.4f | 86.9h | 73.83 | 6.58bc |
| | K-citrate | 49.0gh | 86.3i | 9.0g | 68.9j | 10.0g | 78.9j | 67.03 | 6.85abc |
| | Na-ben. | 49.6gh | 82.3j | 7.6h | 67.1j | 10.1g | 77.2j | 65.59 | 6.64bc |
| | Control | 44.3i | 52.0l | 6.3i | 45.0l | 6.8i | 51.8l | 44.01 | 6.59bc |
| **2002** | | | | | | | | | |
| 0 | ATP | 79.6b | 155.7a | 17.3b | 112.9b | 18.0b | 130.9b | 109.72 | 6.2fg |
| | Ca-glu. | 82.3a | 156.7a | 21.3a | 132.7a | 18.7a | 151.4a | 126.90 | 7.1bc |
| | K-citrate | 69.3c | 150.0b | 16.6b | 113.6b | 17.7b | 131.3b | 110.05 | 6.4efg |
| | Na-ben. | 70.0c | 149.7b | 14.6c | 106.2c | 15.8c | 122.0c | 102.26 | 6.7de |
| | Control | 48.6hi | 143.0c | 14.3c | 105.9c | 13.4d | 119.3c | 100 | 7.8a |
| 3000 | ATP | 61.3d | 104.3e | 12.6d | 84.7d | 12.0ef | 96.7d | 81.05 | 7.0bcd |
| | Ca-glu. | 58.6e | 110.0d | 16.3b | 84.3d | 13.7d | 98.0d | 82.14 | 6.1g |
| | K-citrate | 54.6f | 100.0f | 13.0d | 78.2e | 11.9ef | 90.1c | 75.52 | 6.6ef |
| | Na-ben. | 52.0g | 96.0g | 10.0e | 77.3e | 11.7ef | 89.0e | 74.60 | 6.5ef |
| | Control | 46.6i | 71.0k | 8.0f | 58.6g | 9.3h | 67.9g | 56.91 | 6.3fg |
| 6000 | ATP | 51.6g | 91.3h | 10.6e | 78.2e | 11.6f | 89.8c | 75.27 | 6.7de |
| | Ca-glu. | 56.0f | 95.0g | 12.3d | 79.2e | 12.3e | 91.5e | 76.69 | 6.6ef |
| | K-citrate | 50.3gh | 87.3c | 10.3e | 76.2e | 10.3g | 86.5c | 72.50 | 7.4b |
| | Na-ben. | 49.0h | 84.0j | 8.3f | 71.6f | 10.5g | 82.1f | 68.81 | 6.7cde |
| | Control | 44.0j | 56.6l | 6.6g | 46.7h | 7.2i | 53.9h | 45.18 | 6.5efg |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

The present ameliorative and protective anti-stress effects of the applied treatments on growth behavior of the salt stressed plants (3000 and 6000 ppm NaCl) was logically true, since the same treatments improved K/Na selectively, decreased the membrane breakdown and electrolytes leakage (decreased $EC_1/EC_2$ values), decreased Na, Cl uptake and translocation into sensitive shoots, increased N, P and K content of both shoots and roots (Tables 6 & 9).

**Ionic and mineral content:**

**Effect of salinity:**

Along with increasing the severity of NaCl stress, useful nutrients, i.e. N, P and K content of leaves and roots was greatly diminished. In contrary, harmful salt ions, i.e. Na and Cl content of the same plant organs was excessively increased during the two seasons (Table 4).

The same data proved that such plants tended to accumulate more of useful nutrients in their leaves relative to roots and they slightly tended to maintain more $Na^+$ and $Cl^-$ in their sensitive shoots. This suggest to be somewhat as an adaptive behavior to decrease the harmful effects of salinity (West, 1978).

Such ions and nutrients accumulation pattern of sweet pepper as affected by salinity was confirmed by the results of Greenway and Munns (1980), Richter *et al.*, (1999), De-Pascale *et al.*, (2003), Kaya and Higgs (2003), and Kaya *et al.*, (2003). In addition, the excessive intake of Na and Cl vs the reduced uptake of N, P and K with salinity could be here due to the harmful effect of NaCl on membrane integrity and selectivity as well as the inducible more electrolyte leakage case in Table (7).

**Effect of anti-salinity treatments:**

Data in Table (5) revealed that regardless with salinity, all the applied treatments significantly improved the content of leaves and roots from the useful N, P and K mineral nutrients. At the same time, significantly decreased the allocation of the salt ions either in roots or shoots compared with the control in the two seasons. Herein, this also was expected, since these treatments in similar fashion were increased membrane selectivity of K at the expense of Na, improved their permeability and integrity case measured by the lower $EC_1/EC_2$ and higher K/Na values, decreased Na translocation into plant tip measured by low Na l / Na r values (Table 8).

The highest content of N and P and the lowest content of Na and Cl was of Ca-gluconate plants. The other treatments were also of favorable effect on the ionic and nutritional case of their plants.

Ca-gluconate via its Ca ions preserved membranes, regulate ions transport and selectivity, activated H-ATP-ase transporter enzyme system (Ferguson, 1988), also citrate as organic ions known to protect the transport membranes against salt (Hasegawa and Bressan, 2000). ATP also known to be directly involved in the active ion transporter systems (H-ATP-ase) those which allocated at membrane surfaces, thereby regulated uptake and translocation of different ions.

K-citrate, known to be of enhancable effect on mineral uptake and translocation via its citrate moiety involvement in energy metabolism (Fathy *et al.*, 2003), also due to the direct activator effects of K on the transporter enzymes and its ions regulatory functions (Marschner, 1995).

**Table (4): Effect of salinity on ions and mineral nutrients content of leaves and roots of sweet pepper during the two seasons of growth.**

| NaCl (ppm) | N (%) | | P (%) | | K (%) | | Na (%) | | Cl (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Leaves | Roots | Leaves | Roots | Leaves | Roots | Leaves | Roots | Leaves | Roots |
| 2001 | | | | | | | | | | |
| 0 | 2.7 a | 2.2 a | 0.250 a | 0.238 a | 4.2 a | 2.5 a | 1.05 c | 1.20 c | 3.25 c | 4.20 c |
| 3000 | 2.4 b | 2.0 b | 0.213 b | 0.203 b | 3.1 b | 2.2 b | 2.18 b | 2.37 b | 11.4 b | 11.8 b |
| 6000 | 2.1 c | 1.8 c | 0.201 b | 0.191 c | 2.3 c | 1.8 c | 2.490 a | 2.49 a | 14.54 a | 14.0 a |
| 2002 | | | | | | | | | | |
| 0 | 2.6 a | 2.2 a | 0.251 a | 0.239 a | 4.3 a | 2.58 a | 1.04 c | 1.19 c | 2.89 c | 4.1 c |
| 3000 | 2.4 b | 2.0 b | 0.220 b | 0.203 b | 3.1 b | 2.22 b | 2.12 b | 2.22 b | 10.55 b | 11.0 b |
| 6000 | 2.1 c | 1.8 c | 0.204 c | 0.189 c | 2.4 c | 1.85 c | 2.32 a | 2.36 a | 13.55 a | 13.4 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

**Table (5): Effect of anti-salinity treatments on ions and mineral nutrients content of leaves and roots of sweet pepper during the two seasons of growth.**

| Ameliorative Ions | N (%) | | P (%) | | K (%) | | Na (%) | | Cl (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Leaves | Roots | Leaves | Roots | Leaves | Roots | Leaves | Roots | Leaves | Roots |
| 2001 | | | | | | | | | | |
| ATP | 2.5 b | 2.1 b | 0.255 a | 0.244 a | 3.3 c | 2.3 b | 1.84 b | 1.94 b | 8.30 d | 7.00 d |
| Ca-gluconate | 2.7 a | 2.2 a | 0.250 a | 0.239 a | 3.1 d | 2.2 c | 1.73 b | 1.81 d | 5.97 e | 5.90 e |
| K-citrate | 2.4 c | 2.1 b | 0.215 b | 0.204 b | 3.6 a | 2.5 a | 1.82 b | 1.95 b | 10.13 c | 10.80 b |
| Na-benate | 2.3 d | 2.0 c | 0.220 b | 0.212 b | 3.4 b | 2.2 d | 1.85 b | 1.89 c | 10.67 b | 10.60 c |
| Control | 2.0 e | 1.6 d | 0.165 c | 0.155 c | 2.4 e | 1.6 e | 2.14 a | 2.15 a | 13.71 a | 15.50 a |
| 2002 | | | | | | | | | | |
| ATP | 2.6 b | 2.0 b | 0.262 a | 0.239 a | 3.4 b | 2.3 b | 1.77 c | 1.91 b | 7.43 d | 6.70 c |
| Ca-gluconate | 2.7 a | 2.2 a | 0.250 a | 0.236 a | 3.2 c | 2.2 c | 1.65 d | 1.80 c | 5.56 e | 5.60 d |
| K-citrate | 2.4 c | 2.1 b | 0.221 b | 0.203 b | 3.7 a | 2.5 a | 1.79 bc | 1.91 b | 9.15 c | 10.30 b |
| Na-benate | 2.3 d | 2.0 b | 0.222 b | 0.210 b | 3.4 b | 2.2 c | 1.83 b | 1.88 b | 9.85 b | 10.50 b |
| Control | 2.0 e | 1.7 c | 0.171 c | 0.163 c | 2.5 d | 1.7 d | 2.10 a | 2.10 a | 12.98 a | 14.50 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

**Table (6): Effect of interaction on ions and mineral nutrients content of leaves and roots of sweet pepper during the two seasons of growth.**

| NaCl ppm | Amel. Ion | N (%) Leaves | N (%) Roots | P (%) Leaves | P (%) Roots | K (%) Leaves | K (%) Roots | Na (%) Leaves | Na (%) Roots | Cl (%) Leaves | Cl (%) Roots |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | | | | | | | | | | | |
| 0 | ATP | 2.69 bc | 2.21 cd | 0.283 a | 0.270 a | 4.3 b | 2.6 b | 1.10 g | 1.30 h | 3.00 jk | 3.90 j |
| | Ca-glu. | 3.02 a | 2.38 a | 0.248 bc | 0.261 a | 4.1 c | 2.4 d | 0.97 h | 1.00 i | 2.60 k | 3.10 k |
| | K-citr. | 2.66 bcd | 2.29 b | 0.244 bc | 0.228 bc | 4.6 a | 2.8 a | 1.05 gh | 1.20 h | 3.50 ij | 4.66 i |
| | Na-ben. | 2.55 ef | 2.11 ef | 0.241 bc | 0.217 cd | 4.2 c | 2.5 c | 1.10 g | 1.30 h | 3.60 i | 4.56 i |
| | Control | 2.61 cde | 2.13 def | 0.233 c | 0.210cde | 3.8 d | 2.4 d | 1.10 g | 1.30 h | 3.50 ij | 4.73 i |
| 3000 | ATP | 2.48 fg | 2.20 cd | 0.245 bc | 0.236 b | 3.1 f | 2.3 d | 2.16 ef | 2.20 de | 10.0 f | 8.66 g |
| | Ca-glu. | 2.72 b | 2.26 bc | 0.246 bc | 0.239 b | 3.0 g | 2.4 d | 2.08 f | 2.10 g | 6.40 h | 5.80 h |
| | K-citr. | 2.52 ef | 2.16 de | 0.211 d | 0.194 ef | 3.6 e | 2.5 bc | 2.06 f | 2.20 de | 11.80 e | 13.10 e |
| | Na-ben. | 2.40 g | 2.05 f | 0.213 d | 0.213 cd | 3.8 d | 2.2 e | 2.21 de | 2.10 f | 11.70 e | 11.43 f |
| | Control | 1.94 i | 2.60 h | 0.148 f | 0.132 g | 2.0 l | 1.5 h | 2.41 b | 2.40 b | 17.20 b | 20.00 b |
| 6000 | ATP | 2.40 g | 1.95 g | 0.236 c | 0.223bcd | 2.6 i | 1.9 f | 2.30 cd | 2.20 de | 11.80 e | 8.48 g |
| | Ca-glu. | 2.54 def | 2.10 ef | 0.257 b | 0.216 cd | 2.4 j | 1.9 f | 2.20 ef | 2.30 d | 8.80 g | 8.80 g |
| | K-citr. | 2.06 h | 1.95 g | 0.191 e | 0.187 f | 2.8 h | 2.3 e | 2.35 bc | 2.36 c | 15.00 d | 14.83 d |
| | Na-ben. | 1.97 hi | 1.90 g | 0.205 de | 0.206 de | 2.2 k | 1.8 g | 2.30 cd | 2.20 e | 16.60 c | 16.00 c |
| | Control | 1.46 j | 1.20 i | 0.133 g | 0.123 g | 1.5 m | 1.1 i | 2.90 a | 2.70 a | 20.40 a | 21.90 a |
| 2002 | | | | | | | | | | | |
| 0 | ATP | 2.72 b | 2.26 b | 0.297 a | 0.271 a | 4.40 b | 2.66 b | 1.05 f | 1.24 f | 2.60 ij | 3.85 j |
| | Ca-glu. | 3.00 a | 2.40 a | 0.238 bc | 0.251 b | 4.20 c | 2.50 d | 0.940 g | 1.00 g | 2.20 j | 3.05 k |
| | K-citr. | 2.56 c | 2.25 bc | 0.243 b | 0.240 bc | 4.60 a | 2.80 a | 1.03 f | 1.21 f | 3.10 hi | 4.51 hij |
| | Na-ben. | 2.60 c | 2.06 ef | 0.238 bc | 0.215 de | 4.20 c | 2.53 cd | 1.09 f | 1.25 f | 3.10 hi | 4.36 ij |
| | Control | 2.48 def | 2.18 bcd | 0.240 bc | 0.216 de | 3.90 d | 2.41 e | 1.10 f | 1.23 f | 3.40 h | 4.75 hi |
| 3000 | ATP | 2.47 ef | 1.96 g | 0.248 b | 0.226 cd | 3.10 g | 2.35 f | 2.00 de | 2.21 d | 9.20 e | 8.13 g |
| | Ca-glu. | 2.75 b | 2.22 bc | 0.256 b | 0.242 bc | 3.00 g | 2.35 f | 1.97 e | 2.08 e | 6.20 g | 5.21 h |
| | K-citr. | 2.53 cde | 2.17 cd | 0.223 cd | 0./188 fg | 3.60 f | 2.58 c | 2.11 d | 2.22 d | 10.50 d | 11.83 e |
| | Na-ben. | 2.42 f | 2.12 de | 0.221 cd | 0.214 de | 3.70 e | 2.26 g | 2.11 d | 2.12 e | 10.50 d | 11.10 f |
| | Control | 2.00 h | 1.66 i | 0.149 f | 0.141 h | 2.00 l | 1.54 j | 2.38 b | 2.45 b | 16.20 b | 18.73 b |
| 6000 | ATP | 2.55 cd | 1.96 g | 0.240 bc | 0.219 d | 2.60 i | 2.01 h | 2.23 c | 2.27 cd | 10.50 d | 8.21 g |
| | Ca-glu. | 2.48 ef | 2.11 def | 0.254 b | 0.213 de | 2.40 j | 1.94 i | 2.05 de | 2.31 c | 8.30 f | 8.47 g |
| | K-citr. | 2.13 g | 1.86 h | 0.195 e | 0.180 g | 2.80 h | 2.28 g | 2.24 c | 2.31 c | 13.70 c | 14.50 d |
| | Na-ben. | 2.00 h | 2.03 fg | 0.206 de | 0.200 ef | 2.30 k | 1.92 i | 2.30 bc | 2.28 cd | 15.90 b | 16.03 c |
| | Control | 1.60 i | 1.23 j | 0.122 g | 0.129 h | 1.60 m | 1.13 k | 2.79 a | 2.62 a | 19.20 a | 19.97 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

Na-benzoate might be protected membrane and improved their transporter systems via its role as anti-oxidant agent (Lascaris and Deacon, 1991).

**Effect of interaction:**

Data in Table (6) clearly show that at moderate salinity, most of the applied protective treatments improved leaves and roots content from the useful nutrients (N, P and K) relative to the normal non-stressed plants and extremely relative to the salt-stressed controls. Meanwhile, they mitigated the excessive accumulation of Na and Cl.

At higher NaCl level (6000 ppm), these treatments maintained similar ameliorative enhanceable effects, but to less extent relative to the normal plants and pronouncedly compared with the stressed controls.

The same data revealed that in many cases the most effective treatment of many counteracting anti-stress effects was Ca-gluconate followed by ATP, K-citrate and Na-benzoate in the two seasons. This could be explained based on their preservation and protective effects on the membranes and their binding enzymes and proteins, the key site of ion transportation and regulation measured by the suitable values of $EC_1/EC_2$ and K/Na of these treatments relative to those of control (Table 9).

As mentioned above Ca-gluconate and K-citrate may evoked their anti-stress regulatory effects due to the direct antagonistic and detoxic effects of Ca and K ions against Na and its distribution within plant. Added to their indispensable metabolic involvements. Meanwhile, their organic moiety gluconate and citrate might induced additional protective and osmoregulatory effects (Marschner, 1995; Navarro *et al.*, 1999 Hasegawa and Berssan, 2000, and Knight, 2000).

The regulatory and protective effects of the applied ATP and Na-benzoate were previously mentioned.

**Physiological indicator parameters:**
**Effect of salinity:**

It was obvious from Table (7) that increasing the intensity of salt stress resulted in significant decrease in K/Na value, increased $EC_1/EC_2$ and Na l / Na r values in two seasons.

**Table (7): Effect of salinity on some physiological indicator parameters of sweet pepper during the two seasons of growth.**

| NaCl | 2001 | | | 2002 | | |
|---|---|---|---|---|---|---|
| (ppm) | K/Na | $EC_1/EC_2$ | Na l/Na r | K/Na | $EC_1/EC_2$ | Na l/Na r |
| 0 | 3.79a | 0.65 c | 0.84 c | 4.16 a | 0.64 c | 0.87 b |
| 3000 | 1.43 b | 0.93 b | 0.97 b | 1.48 b | 0.90 b | 0.95 a |
| 6000 | 0.98 c | 1.02 a | 1.01 a | 1.04 c | 1.02 a | 0.98 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

This suggested that moderate salinities at 3000 ppm NaCl and greatly at 6000 ppm NaCl were impaired the membranes integrity and permeability. Thereby, induced more electrolytes leakage measured by $EC_1/EC_2$ higher values vs. lower values of control. Such harmful effects of salinity also impaired membranes selectivity lead to sharp inclusion and accumulation of Na ions vs K ions measured by low K/Na values. On the other hand, the allocation of Na between leaves and roots was adversely affected by salinity (higher Na l/Na r values), specially at the first season. Stressed Plants translocated more Na into their shoots.

These physiological parameters are considered important indicators for salinity effects and the degree of adaptation under this conditions (Ltifi *et al.*, 1992; De-Pascale *et al.*, 2003 [K/Na indicator]; Kaya and Higgs, 2003 [$EC_1/EC_2$ indicator] and Ltifi *et al.*, 1992 [Na l / Na r indicator]).

**Effect of anti-salinity treatments:**

The results of Table (8) indicated that all the sprayed materials significantly decreased $EC_1/EC_2$ values (improved membranes case). they increased K/Na values, improved uptake and translocation of K at the expense of Na. Also, to some extent decreased Na l / Na r values, mitigated the translocation of Na from outer medium and roots into shoots. The most protective one was Ca-gluconate followed by ATP, K-citrate and at last Na-benzoate.

**Table (8): Effect of anti-salinity treatments on some physiological indicator parameters of sweet pepper during the two seasons growth.**

| Ameliorative Ions | 2001 | | | 2002 | | |
|---|---|---|---|---|---|---|
| | K / Na | $EC_1 / EC_2$ | Na l / Na r | K / Na | $EC_1 / EC_2$ | Na l / Na r |
| ATP | 1.81 ab | 0.77 d | 0.93 ab | 2.32 b | 0.79 b | 0.91 b |
| Ca-gluconate | 2.27 a | 0.61 e | 0.95 a | 2.39 ab | 0.58 c | 0.92 b |
| K-citrate | 2.43 a | 0.83 c | 0.91 b | 2.49 a | 0.85 b | 0.92 b |
| Na-benzate | 2.21 ab | 0.88 b | 0.96 a | 2.21 c | 0.85 b | 0.96 ab |
| Control | 1.62 a | 1.25 a | 0.95 a | 1.66 d | 1.21 a | 0.97 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

These results were similar in two seasons. Herein, the effective protective influence of Ca-gluconate might be due to the direct antagonistic effect of Ca vs Na within plant tissues, its preservator effect on membranes structure, function and its activator role on membrane binding enzymes (Ferguson, 1988 and Navarro *et al.*, 2002). Maintaining of an adequate supply of Ca under salinity is an important factor in controlling the severity of specific ion (Na & Cl) toxicities (Mass, 1993).

**Effect of interaction:**

The data of Table (9) revealed that interaction significantly affected the mentioned physiological parameters in two seasons and the applied Ca-gluconate. ATP, K-cirtrate and Na-benzoate improved such parameters of non-stressed plants. they also similarly mitigated the adverse effects of 3000 ppm salinity and to some extent at 6000 ppm NaCl. Ca-gluconate was the most superior one in all cases.

**Flowering and Fruit yield:**

**Effect of salinity:**

It was clear from the results of Table (10) that number of flowers and fruits, fruit yield and quality (fruit length and diameter) were significantly declined with salinity in the two seasons of study. Fruit shape index was not significantly affected. Fruit yield of the stressed-plants was reduced with salinity in parallel to the reduction in number of flowers and fruits.

**Table (9): Effect of interaction on some physiological indicator parameters of sweet pepper during the two seasons of growth.**

| NaCl ppm | Amel. Ion | 2001 K/Na | 2001 $EC_1/EC_2$ | 2001 Na l/Na r | 2002 K/Na | 2002 $EC_1/EC_2$ | 2002 Na l/Na r |
|---|---|---|---|---|---|---|---|
| 0 | ATP | 2.86 b | 0.66 k | 0.82 f | 4.22 b | 0.730 e | 0.846 f |
| | Ca-glu. | 4.28 a | 0.45 l | 0.94 de | 4.77 a | 0.433 f | 0.933bcde |
| | K-citr. | 4.37 a | 0.68 j | 0.83 f | 4.500 a | 0.736 e | 0.846 f |
| | Na-ben. | 3.93 a | 0.72 h | 0.82 f | 3.87 c | 0.653 e | 0.870 ef |
| | Control | 3.51 ab | 0.74 g | 0.80 f | 3.56 d | 0.676 e | 0.890 def |
| 3000 | ATP | 1.43 cd | 0.71 hi | 0.96 cde | 1.55 f | 0.680 e | 0.910cdef |
| | Ca-glu. | 1.43 cd | 0.68 j | 0.97 cde | 1.55 f | 0.653 e | 0.950bcde |
| | K-citr. | 1.73 c | 0.88 f | 0.93 e | 1.71 ef | 0.867 d | 0.950bcde |
| | Na-ben. | 1.72 c | 0.95 d | 1.01 bc | 1.76 e | 0.913 cd | 0.996 abc |
| | Control | 0.82 cd | 1.43 b | 0.97 cde | 0.856 i | 1.403 b | 0.970 bcd |
| 6000 | ATP | 1.14 cd | 0.95 d | 1.00 bcd | 1.183 g | 0.973 c | 0.987 abc |
| | Ca-glu. | 1.10 cd | 0.70 ij | 0.94 de | 1.170 gh | 0.676 e | 0.890 def |
| | K-citr. | 1.19 cd | 0.91 e | 0.98 cde | 1.27 g | 0.940 cd | 0.960 bcd |
| | Na-ben. | 0.97 cd | 0.99 c | 1.04 ab | 1.00 hi | 0.980 c | 1.00 ab |
| | Control | 0.52 d | 1.58 a | 1.08 a | 0.58 j | 1.55 a | 1.10 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

**Table (10): Effect of salinity on flowering, fruit yield and quality of sweet pepper during the two seasons of growth.**

| NaCl (ppm) | No. of flowers / plant | No. of fruits / plant | Fruit yield / plant (g) | Relative yield (%) | Fruit length (cm) | Fruit diameter (cm) | Fruit shape index |
|---|---|---|---|---|---|---|---|
| **2001** | | | | | | | |
| 0 | 52.6 a | 23.6 a | 565.6 a | 100 | 8.1 a | 3.6 a | 2.26 a |
| 3000 | 45.6 b | 19.8 b | 459.3 b | 81.21 | 6.7 b | 2.7 b | 2.39 a |
| 6000 | 37.7 c | 16.7 c | 383.1 c | 67.73 | 5.0 c | 2.4 c | 2.33 a |
| **2002** | | | | | | | |
| 0 | 53.8 a | 21.6 a | 582.2 a | 100 | 7.9 a | 3.7 a | 2.1 a |
| 3000 | 46.9 b | 20.3 b | 482.6 b | 82.89 | 6.2 b | 2.8 b | 2.2 a |
| 6000 | 38.8 c | 17.4 c | 401.6 c | 68.97 | 4.8 c | 2.4 c | 2.1 a |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

The same data show that fruit yield reduced by 17.9 and 31.6% (means of the two seasons relative to control) at 3000 and 6000 ppm NaCl, respectively. These yield reductions suggested that sweet pepper Baladi cv. considered as a less salt sensitive at moderate salinity and moderate sensitive at higher salinity. This was greatly in agreement with results obtained by Mass and Hoffman (1977), Richter *et al*., (1999) Mediros *et al*., (2002), Navarro *et al*., (2002) and De-Pascale *et al*., (2003).

The present results of salinity effects on flowering, fruiting and fruit yield were in accordance with those of Navarro *et al*. (20002); De-Pascale *et al*. (2003) and Kaya and Higgs (2003).

Herein, these results were expected based on the similar adverse effects of salinity on growth and dry matter partitioning (Table 1), the ionic and elemental content (Table 4), the physiological status (Table 7). Also, it might be due to the toxic effect of salt ions (Niu *et al*., 1995), hyperosmotic effects of salinity (Yancey *et al*., 1982), nutritional imbalances (Liu and Zhu, 1998), Navarro *et al*., (2002), membranes breakdown and destabilization (Hasegawa and Bressan, 2000), diversion and expenditure of carbohydrates and energy pools away from growth and yield activities (Pasternak, 1987 and Nieman *et al*., 1988).

**Effect of the anti-salinity treatments:**

The results in Table (11) revealed that in the two seasons, all the tested treatments significantly improved number of flowers and fruits, thereby increased fruit yield of sweet pepper plants relative to the control, also they improved fruit quality, in most cases. Regardless of salinity, fruit yield was increased by 71.6, 50.7, 42.4 and 35.6% as a result of spraying plants with Ca-gluconate, ATP, K-citrate and Na-benzoate, respectively (means of two seasons relative to the control).

**Table (11): Effect of anti-salinity treatments on flowering, fruit yield and quality of sweet pepper during the two seasons of growth.**

| Ameliorative Ions | No. of flowers/ plant | No. of fruits / plant | Fruit yield / plant (g) | Relative yield (%) | Fruit length (cm) | Fruit diamete r (cm) | Fruit shape index |
|---|---|---|---|---|---|---|---|
| **2001** | | | | | | | |
| **ATP** | 47.3 b | 20.8 b | 501.5b | 149.34 | 6.9 a | 2.9 b | 2.37 ab |
| **Ca-gluconate** | 52.4 a | 25.2 a | 580.1a | 172.75 | 6.7 ab | 2.9 b | 2.34 ab |
| **K-citrate** | 45.5 c | 20.2 c | 478.6c | 142.52 | 6.1 c | 2.6 b | 2.41 a |
| **Na-benate** | 43.6 d | 18.7 d | 450.5d | 134.16 | 6.1 c | 3.4 a | b1.94 b |
| **Control** | 38.2 e | 15.2 e | 335.8e | 100 | 6.3 bc | 2.6 b | 2.56 a |
| **2002** | | | | | | | |
| **ATP** | 48.4 b | 21.6 b | 528.8 b | 152.04 | 6.7 a | 3.1 b | 2.2 a |
| **Ca-gluconate** | 54.0 a | 26.0 a | 593.2 a | 170.55 | 7.1 a | 3.1 b | 2.3 a |
| **K-citrate** | 46.7 c | 21.2 b | 495.0 c | 142.32 | 6.0 bc | 2.7 c | 2.3 a |
| **Na-benate** | 44.4 d | 19.3 c | 479.3 d | 137.00 | 6.1 b | 3.4 a | 1.8 b |
| **Control** | 38.8 e | 16.0 d | 347.8 e | 100 | 5.6 c | 2.6 c | 2.2 c |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

Such yield increments were as a result to the beneficial effect of these treatments on growth behavior and dry matter accumulation and partitioning pattern (Table 2), higher content of the useful nutrients, N, P and K vs lower content of the toxic salt ions, Na and Cl of shoots and roots (Table 5) and the inducible physiological adaptive behaviour (Table 8). All were interrelated with fruit yield and this confirmed by the correlation values (Table 13).

Similar results about the use and effects of these treatments during stressful conditions were reported by Subbarao *et al.*, (1990) and Navarro *et al.*, (1999 & 2000) [Calcium]; Njoroge *et al.*, (1998); Fathy and Farid (2000) and Fathy *et al.*, (2000) [ATP]; Fathy *et al.*, (2003) [K-citrate and ATP]; Lascaris and Deacon (1991) and Fathy and Farid (2000) [Na-benzoate].

**Effect of interaction:**

It was obvious from the results of Table (12) that all treatments induced a significant protective effect on flowering and productivity of sweet pepper either at moderate or higher salinities during the two seasons. They also improved fruit quality in term of fruit length, diameter and shape index in most cases compared with those of non-stressed and stressed controls in both seasons. They restored fruit yield at 3000 ppm NaCl plants near the normal value (non-stressed control plants) or above. Meanwhile, this was greatly recovered at higher salinity as affected by these treatments.

In this respect, fruit yield was reduced by 38.6 and 45.3% at moderate and higher salinity, respectively. Ca-gluconate and ATP were shifting this drastic case, they increased fruit yield by 4.8 and 20.3%, mitigated its severe reduction at higher salinity to be only 6.5 and 6.3%, respectively.

Meanwhile, K-citrate and Na-benzoate alleviated such yield reductions to be only 0.62 and 5.70% at moderate salinity, 16.4 and 18.5% at higher salinity, respectively.

In this respect known that salinity stress adversely induce toxic, hyperosmotic, nutritional imbalances effects, impair membranes structure and function, depress photosynthesis and protein synthesis, deplete and divert carbohydrates and energy pools, raise ethylene and toxic ROS levels as previously reviewed. Thereby impaired flowering and fruiting activities.

Applying the mentioned treatments greatly protect the stressed plants against such adverse effects. Induce a reversal suitable nutritional and physiological adaptive status (Table 3, 6 and 9). Also, such protective effects and interrelations were confirmed by the correlation values (Table 13).

Finally, it could be concluded that spraying sweet pepper with Ca in organic form of Ca-gluconate and commercial ATP considered as a promising agro-management technique to ameliorate salinity harmful effects, obtaining normal fruit yield at moderate 3000 ppm NaCl salinity and less yield reductions at higher 6000 ppm NaCl salinity. Also, that applying K in organic form of K-citrate and Na-benzoate were of beneficial ameliorative effects during salinity stress.

**Table (12): Effect of interaction on flowering, fruit yield and quality of sweet pepper during the two seasons of growth.**

| NaCl ppm | Amel. Ion | No. of flowers / plant | No. of fruits / plant | Fruit yield / plant (g) | Relative yield (%) | Fruit length (cm) | Fruit diameter (cm) | Fruit shape index |
|---|---|---|---|---|---|---|---|---|
| | | | | 2001 | | | | |
| 0 | ATP | 53.6b | 23.6c | 560.0c | 112.51 | 8.03 b | 3.2 bcd | 2.5 bc |
| | Ca-glu. | 61.0a | 29.3a | 698.3a | 140.30 | 9.1 a | 4.3 a | 2.1 bcd |
| | K-citr. | 50.3d | 23.0c | 552.3c | 110.97 | 7.9 b | 3.1 bcd | 2.5 bc |
| | Na-ben. | 50.0d | 21.6d | 519.7d | 104.42 | 7.2 bc | 3.8 ab | 1.9 cd |
| | Control | 48.3e | 20.3ef | 497.7e | 100 | 8.1 b | 3.6 abc | 2.2 bc |
| 3000 | ATP | 47.6b | 20.0fg | 502.3e | 100.92 | 7.5 b | 3.7 abc | 2.0 bcd |
| | Ca-glu. | 52.6c | 25.0b | 587.7b | 118.08 | 6.3 cd | 2.5defg | 2.5 bc |
| | K-citr. | 46.6f | 20.3ef | 481.3f | 96.70 | 5.5 de | 1.9 gh | 2.9 ab |
| | Na-ben. | 44.6g | 19.0g | 442.0h | 88.80 | 6.2 cd | 2.6 def | 2.6 bc |
| | Control | 38.0k | 15.0i | 283.3k | 56.92 | 5.5 de | 2.9 cd | 1.8 cd |
| 6000 | ATP | 40.6i | 19.0g | 442.3h | 88.86 | 5.3 de | 1.9 fgh | 2.6 bc |
| | Ca-glu. | 43.6h | 21.3de | 454.3g | 91.27 | 4.8 e | 2.0efgh | 2.3 bc |
| | K-citr. | 39.6j | 17.3h | 402.3i | 80.83 | 4.8 e | 2.7 de | 1.8 cd |
| | Na-ben. | 36.3l | 15.6i | 390.0j | 78.36 | 5.0 e | 3.8 ab | 1.3 d |
| | Control | 38.3m | 10.3j | 266.7l | 45.54 | 5.1 e | 1.4 h | 2.6 a |
| | | | | 2002 | | | | |
| 0 | ATP | 54.6 b | 24.3 c | 586.0 b | 121.14 | 7.4 b | 3.2 cd | 2.3 bcd |
| | Ca-glu. | 62.6 a | 31.0 a | 721.7 a | 149.20 | 8.8 a | 4.5 a | 1.9 de |
| | K-citr. | 51.6 c | 24.6 bc | 573.3 c | 118.52 | 8.0 b | 3.4 c | 2.3abcd |
| | Na-ben. | 50.3 d | 23.0 d | 546.7 d | 113.02 | 7.5 b | 3.9 b | 1.9 de |
| | Control | 49.3 de | 21.0 e | 483.7 g | 100 | 7.9 b | 3.5 cd | 2.3 cd |
| 3000 | ATP | 48.6 ef | 21.0 e | 526.0 e | 108.74 | 7.8 b | 4.0 b | 1.9 de |
| | Ca-glu. | 54.0 b | 25.6 b | 593.0 b | 122.59 | 6.4 c | 2.7 de | 2.4abcd |
| | K-citr. | 47.6 f | 21.0 e | 493.7 f | 102.06 | 5.6 de | 2.0 fg | 2.8 ab |
| | Na-ben. | 45.3 g | 19.0 fg | 482.3 g | 99.71 | 6.0 cd | 2.7 d | 2.1 cde |
| | Control | 39.0 i | 15.0 h | 318.3 k | 65.80 | 5.2 def | 2.7 d | 1.9 de |
| 6000 | ATP | 42.0 h | 19.6 f | 474.7 g | 98.13 | 5.0 ef | 2.1 f | 2.4abcd |
| | Ca-glu. | 45.3 g | 21.3 e | 465.0 h | 96.13 | 6.0 cd | 2.2 ef | 2.8 a |
| | K-citr. | 41.0 h | 18.3 g | 418.0 i | 86.41 | 4.5 fg | 2.7 de | 1.7 ef |
| | Na-ben. | 37.6 j | 16.0 h | 409.0 j | 84.55 | 4.9 ef | 3.6 bc | 1.3 f |
| | Control | 28.0 k | 12.0 i | 241.7 l | 49.96 | 3.8 g | 1.5 g | 2.5 abc |

Means followed by the same letter(s) within each column do not significantly differ using Duncan's Multiple Range Test.

**Correlation studies:**

The results of Table (13) revealed that N, P and K content, as well as K/Na and shoot/root ratios were positively correlated with fruit yield / plant in the two seasons. Whereas, Na and Cl content as well as $EC_1/EC_2$ and Na l / Na r values were negatively correlated in two seasons too. Such correlations greatly confirmed the previously discussed, interrelated and interoperated results under present work conditions.

**Table (13): Correlation coefficient of fruit yield / plant vs. some chemical and physiological parameters during the two seasons of growth.**

| Characters | Fruit yield / plant (g) | |
|---|---|---|
| | 2001 | 2002 |
| N (%) | 0.946 | 0.953 |
| P (%) | 0.843 | 0.804 |
| K (%) | 0.791 | 0.802 |
| Na (%) | -0.780 | -0.784 |
| Cl (%) | -0.942 | -0.881 |
| K / Na | 0.687 | 0.741 |
| Shoot / root ratio | 0.234 | 0.050 |
| $EC_1$ / $EC_2$ | -0.942 | -0.908 |
| Na l / Na r | -0.525 | -0.561 |

Also, it may be suggested that $EC_1/EC_2$ and K/Na values as well as N, P, K, Na and Cl contents could be considered as an important nutritional and physiological indicators/sensor for salinity effects and the protective adaptive effects of the applied treatments.

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## تحسن النمو والحالة الأيونية والفسيولوجية والإنتاجية لنباتات الفلفل الحلو تحت ظروف الملوحة

**السعيد لطفى السيد فتحى**
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أجريت تجارب ملوحة بمزرعة البرامون (الدقهلية) التابعة لمعهد بحوث البساتين بالجيزة خلال الموسم الصيفي لعامى ٢٠٠١ ، ٢٠٠٢ لدراسة تأثير شدة الإجهاد الملحى والتأثيرات المخففة والواقية لرش بعض المواد ذات التأثيرات المضادة للملوحة (جلوكونات الكالسيوم، أدينوزين تراى فوسفات وسترات البوتاسيوم وبنزوات الصوديوم) لتحسين الأداء الأيونى والفسيولوجي والنمو والإنتاجية لمحصول الفلفل (الصنف البلدى). وكانت أهم النتائج:-

**تأثير الملوحة:** أدت زيادة شدة الإجهاد الملحى إلى حدوث نقص معنوى للنمو وتراكم وتوزيع المادة الجافة وفى الإزهار والإثمار ومحصول الثمار / نبات وكان النقص فى تراكم المادة الجافة الكلية / نبات بمقدار (٣٣,٢ ، ٣٩,٧%) وفى محصول الثمار / نبات (١٧,٩ ، ٣١,٦%) (متوسط الموسمين بالنسبة للكنترول) عند الملوحة المتوسطة (٣٠٠٠ جزء فى المليون والملوحة العالية (٦٠٠٠ جزء فى المليون) كلوريد صوديوم بمياه الرى على التوالى. وكان ذلك راجع لحدوث ضرر بالأغشية البلازمية وزيادة النفاذية والتسرب الأيونى مقاسة بقيم مرتفعة ($EC_1/EC_2$)وضعف إختيارية إمتصاص ونقل البوتاسيوم بالنسبة للصوديوم وقيم منخفضة (بوتاسيوم / صوديوم) وتراكم أيونات الصوديوم والكلوريد ونقص محتوى العناصر المفيدة (نتروجين وفوسفور وبوتاسيوم) بأنسجة النبات المختلفة. كما حدثت زيادة فى صبغات البناء الضوئى راجعة لنقص النمو . وكان الضرر على تراكم المادة الجافة أكثر منه على محصول الثمار .

**تأثير المعاملات المضادة للملوحة:** أدى رش جلوكونات الكالسيوم يليها أدينوزين تراى فوسفات ثم سترات البوتاسيوم وفى النهاية بنزوات الصوديوم إلى تخفيف التأثيرات الضارة للملوحة على النمو وتراكم المادة الجافة والمحصول والحالة الفسيولوجية والأيونية وتقليل تراكم الأيونات الملحية وزيادة محتوى العناصر المفيدة وصبغات البناء الضوئى فى كلا الموسمين وحدثت زيادة فى تراكم المادة الجافة / نبات ، محصول الثمار / نبات بتأثير المعاملات المذكورة مقدارها (٤٢,٠ ، ٣٤,٠ ، ٢٦,٦ ، ٢٣,١%) ، (٧١,٦ ، ٥٠,٧ ، ٤٢,٤ ، ٣٥,٦%) (متوسط الموسمين بالنسبة للمقارنة) على التوالى.

**تأثير التفاعل:** حدث نقص معنوى فى كل صفات النمو والمحصول وضرر فى الأداء الفسيولوجى والمحتوى المعدنى نتيجة تراكم الصوديوم والكلوريد بأنسجة النبات وكان النقص فى تراكم المادة الجافة مقداره (٤٥,٩ ، ٥٥,٤%) ، وفى محصول الثمار مقداره (٣٨,٦ ، ٥٢,٣%) عند ٣٠٠٠ ، ٦٠٠٠ جزء فى المليون كلوريد صوديوم على التوالى. وأدت معاملتى جلوكونات الكالسيوم وأدونيزين تراى فوسفات إلى تخفيف هذا النقص فى المادة الجافة ليصبح ( ١٦,٧ ، ٢٤,٧%) ، (١٩,٢ ، ٢٦,٣%) على التوالى. وزيادة المحصول عند ملوحة ٣٠٠٠ جزء فى المليون بمقدار ٢٠,٣ ،

٤,٨% وتخفيف النقص عند الملوحة العالية ليصبح فقط ٦,٣ ، ٦,٥% على التوالى وكان لسترات البوتاسيوم وبنزوات الصوديوم أيضا تأثيرات مفيدة.

وأكدت نتائج الإرتباط الإحصائى على أهمية الأداء الأيونى والفسيولوجى وإنعكاسه على حالة النمو والمحصول وأهمية قيم (بوتاسيوم / صوديوم) ، ($EC_1/EC_2$) وإمكانية إستخدامها كدلائل فسيولوجية على حالة التأقلم أو الحساسية للملوحة،

فى النهاية نوصى تحت ظروف ملوحة مماثلة فى مياه الرى (٣٠٠٠ ، ٦٠٠٠ جزء فى المليون كلوريد صوديوم) يمكن رش نباتات الفلفل بجلوكونات الكالسيوم ١٦% (٢ مل / لتر) أو أدينوزين تراى فوسفات تجارى (٥٠ جزء فى المليون) (٤ مرات خلال الموسم) لتقليل أضرار الملوحة وزيادة المحصول عند الملوحة المتوسطة وتخفيف النقص بدرجة كبيرة عند الملوحة العالية.