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AMELIORRATIVE EFFECTS OF APPLYING PHOSPHATE, NITRATE AND CITRATE IONS ON SWEET PEPPER UNDER SALINITY STRESS CONDITIONS.

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ABSTRACT

Experiments were carried out at El-Bramoon Exper. Farm during 2001 and 2002 summer seasons, to study the effect of salinity stress (3000 and 6000 ppm NaCl) and three ameliorative anti stress substances, i.e. citrate (5 g/L citric acid), phosphate (0.35 ml/L H_3PO_4) and nitrate (0.35 ml/HNO_3) ions in irrigation water and their interaction to improve different performance of sweet pepper Baladi cv. Results indicated that:

Plant height, number of leaves and shoots, dry weight of shoots, roots and the whole plant, shoot / root ratio, number of flowers and fruits, fruit yield and quality (on plant basis) were significantly reduced in two seasons by increasing salinity. Total dry weight decreased by 26.8 and 38.3%, fruit yield decreased by 12.2 and 29.2% (means of two seasons relative to control) at 3000 and 6000 ppm NaCl, respectively. Also, along with salinity, Na and Cl were excessively accumulated vs. low N, P and K content within leaves and roots, Na and Cl in leaves increased by (100 and 129.3%), (192.8 and 292.8%), whereas K decreased by 18.5 and 38.3% at 3000 and 6000 ppm NaCl, respectively relative to control. K / Na value significantly decreased, EC_1/EC_2 and Nal/Nar were increased (impairment of membrane), increased permeability and electrolyte leakage and higher Na selectivity case).

Concerning effect of the ameliorative ions, Citrate > phosphate > nitrate were greatly improved all the mentioned characteristics, they increased total dry weight of plant by 41.2, 36.0 and 28.0%, fruit yield / plant by 56.8, 43.0 and 35.7%, respectively relative to control.

As for interaction effect, presence of the ameliorative ions in the same trend were highly improved growth, ionic, mineral and physiological performances and fully restored fruit yield to the normal case of non-stressed plants at 3000 ppm NaCl and to some extent at 6000 ppm NaCl.

Some important indicators for salinity adaptation case were P and K content (positively correlated with fruit yield), Cl content and EC_1/EC_2 value (negatively correlated with fruit yield).

It could be concluded that adding citric acid 5 gm/L (citric ion) and/or phosphoric acid (0.35 ml/L) in irrigation water 3 times during the season, to obtain the best growth and productivity of sweet pepper during similar stress conditions. Also, that Baladi sweet pepper considered as less to moderately salt sensitive plant at moderate to higher salinities.

INTRODUCTION

The quality of irrigation water is often poor in arid and semi-arid regions. In Egypt, salinity problems became more pronounced either in new and old lands or in north costal areas. This due to the limited water resources faced by great demand for the developing agricultural system, intensive cropping and fertilization, irrigation and drainage mis-management and lacking of salt tolerant gerplasm.

Sweet pepper is the most important and favourable vegetable crop. It has been classified as being from more to moderately salt sensitive, this is varied due stress degree and cultivars, with threshold value of 1.5-1.8 dsm^{-1} and yield reduction slope of 14-16% (Mass and Hoffman, 1977 and Medeiros *et al.*, 2002). In early work of Lessani and Marschner (1978), they characterized pepper crop as salt sensitive due to the excessive accumulation of harmful salt ions with less developed adaptive mechanism for salt secretion into cell vacuoles.

In recent work of De-Pascale *et al.* (2003) pepper was classified as moderately salt sensitive with reductions of dry weight and marketable yield of 46 and 24% at 4.4 dsm^{-1} and 34 and 58% at 8.8 dsm^{-1}, respectively.
Navarro *et al.* (2002) found yield reduction of 15% at 3 dsm^{-1} salinity, and that old cvs were less sensitive than new ones. Beek *et al.* (1992) indicated that sweet pepper "Baladi" cv. was less salt sensitive due to that salinity induce less reduced root system, yield only reduced by 50% at 7.6 dsm^{-1} salinity. Richter *et al.* (1999) found that the same pepper cv was salt-sensitive. Also, it was reported that some pepper cvs were of glycophytic type behavior (salt excluders), whereas others were of halophytic type behavior (salt includers) (Ferreira and Jones, 2000).

Salinity induce reduction in growth and yield are generally caused by salt ion direct specific toxic effects. (Niu *et al.*, 1995), ion and nutritional imbalances (Liu and Zhu, 1998) paralleled with membrane destabilization (Hasegawa *et al.*, 2000), hyperosmotic stress (Yancey *et al.*, 1982) followed by turger declines lead to suppression of cell division, elongation and less expansion growth and reduced photosynthesis (Pastemak, 1987).

Excessive Na^+ and Cl^- accumulation were more toxic to sensitive CO_2 assimilation and protein synthesis (Greenway and Munns, 1980).
Low energy (ATP) case resulted from either lower PO_4 intake or from expenditure of ATP for salt transport and adaptive regulatory processes diverted the carbohydrates and ATP pools from growth and yield activities (Pasternak, 1987 and Nieman *et al.*, 1988). This low energy case due to salinity resulting in membrane breakdown, impairment of their ion selectivity, sharp increase in Na uptake and transport to shoots and much lower K/Na selectivity (Drew and Lauchli, 1985). Moreover, electrolyte leakage, low K/Na and higher EC_1/EC_2 ratios (associated with membrane damage), reduced N, P, K, Ca and PO_4 uptake vs. excessive accumulation of Na and Cl all typically occurred under salinity stress (De-Pascale *et al.*, 2003 and Kaya and Higgs, 2003).

In some cases, certain adaptive behavior could be involved to protect plants against adverse effects of salinity, but it was at the expense of growth and yield declines. Those such as inclusion of salts for osmotic adjustment (Richter *et al.*, 1999), modification of shoot / root ratio as ions, K/Na and water uptake regulatory functions (Dalton *et al.*, 1997; Chartzoulakis and Klapaki, 2000 and De-Pascale *et al.*, 2003), regulation of Na accumulation and distribution within plant (maintaining it within roots or secreting into outer media, reduced its translocation into sensitive shoots) (Blom-Zandestra, 2000 and Chartzoulakis and Klapaki, 2002).

Herein an agro-management technique (nutritive approach) was suggested to ameliorate and protect sweet pepper against salinities. By supplying citrate, phosphate and nitrate ions in irrigation water. To hinder the uptake and minimize the toxic effects of harmful ions (Na^+ and Cl^-) based on the antagonistic effect of such useful ions (Citrate, phosphate and nitrate) vs salt ions (Na and Cl) at root surfaces and within plant tissue. Presence of such ions would hinder Cl^- uptake, also preferentially increase the uptake of K^+ and Ca^{++} (as complementary ions), in turn hinder the uptake of Na^+ too.

Meanwhile, added to their ionic regulatory role phosphate and nitrate are participate in energy metabolism, protein synthesis and the whole plant metabolism. Citrate involve in energy metabolism, safe osmoregulation and cryoprotection of sensitive enzymes and membranes against salt toxicities, thereby they were probably recovered the stressed plants and improve their different performances (Kafkafi *et al.*, 1982; Kent and Lauchli, 1985; Pasternak, 1987 (nitr. & phos.); Navarro *et al.*, 2002; and Kaya and Higgs, 2003 (nitr.). About citrate uses and roles (Mansour *et al.*, 1998 and Fathy *et al.*, 2003).

The present work aimed to conduct an extensive analysis for the effect of salinity on different performances of sweet pepper "Baladi" cv as an reliable local model germplasm towards decisive identification and characterization of its probable adaptive behavior underlying plant / salinity interactions. Also, to investigate the ameliorative effect of phosphate, nitrate and citrate ions supplied in irrigation water against stress effects and the feasibility of using poor quality water for irrigation of sweet pepper.

MATERIALS AND METHODS

Present work was conducted at El-Bramoon Experimental Station, El-Dakahlia Governorate of Hort. Res. Inst., Egypt, during summer seasons of 2001 and 2002. In order to study the effect of different salinities and the protective effect of phosphate, nitrate and citrate ions on different performances of pepper Baladi cv.

Experimental procedure and cultural conditions:

Pepper seedlings (40 day old) were transplanted into plastic pots 25 cm in diameter, filled with clay and sand in 1:1 ratio. Plants were initially irrigated only with tap water during the first month to ensure best establishment. Pots were arranged in factorial experiment (3 x 4) and randomized complete block design. Each treatment contained 10 pots and replicated 3 times.

On 15 April (one month after transplanting) pots were frequently irrigated with salinized water, three weekly successive applications each month up to 12 applications. Each 3 successive salt treatments were followed by one protective ions treatment up to 4 applications. Irrigation with salt and protective ions was amounted to 0.5 L/pant, increased to 1 L/plant with time. In some cases all pots were irrigated with tap water as control plants required.

Salinity treatments:

Salinized water was prepared by 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 give final concentrations of 3000 and 6000 ppm. So treatments were control (0 ppm NaCl, tap water only), 3000 and 6000 ppm NaCl.

The ameliorative ions treatments:

Control (irrigated with tap water), nitrate (HNO_3 form, 0.35 ml/L), phosphate (H_3PO_4 form, 0.35 ml/L) and citrate (citric acid form, 5 g/L). All pots were initially fertilized with 5 g/pot (20-20-20, N, P_2O_5, K_2O) and again during fruiting stage. All the ameliorative ions were applied in irrigation water.

Experimental parameters:

Growth and dry matter:

Ten days after all treatments were completed, nine plants from each treatment (three of each repl.) were carefully taken out with their roots, cut into shoots and roots. Plant height (cm), number of leaves and shoots were recorded. Shoots and roots were dried (75°C / 72 hr), shoot, root, total dry weight / plant (gm) and shoot / root DW ratio were determined. Growth performance in term of % whole plant dry weight relative to that of control (without any treatment), also was calculated (Sacher *et al.*, 1983).

Photosynthetic pigments:

Spectrophotometericaly analysis of fresh fully expananded non-senescenced leaves used for determination of chlorophyll a, b and carotenoids, then chlorophyll a + b was calculated according to method of Nomal (1982).

Ionic and mineral nutrient status:

The dried materials of leaves and roots were used for analysis of major nutrients N, P and K also salt ions Na and Cl. Na and K were analyzed using flame photometer according to Page *et al.* (1982), Cl was extracted with hot water, titrated with $AgNO_3$ solution and determined according to Page *et al.* (1982). N and P were analyzed according to Jackson (1958) and Horneck and Miller (1998), respectively.

Physiological indicator parameters:

Na l / Na r, indicator for Na distribution within plant, it is calculated from Na content of leaves (Na l) relative to Na content of root (Na r). Low ratio contribute to an adaptive protective behavior of retention of Na within root, reduced its translocation into the sensitive shoots (Blom-Zandestra, 2000 and Chartzoulakis and Klapaki, 2000).

K / Na ratio, calculated as ratio of leaves, K and Na content, the higher value associated with salt tolerance and indicated best membrane integrity and higher selectivity (uptake and translocation) of K over Na (De-Pascale *et al.*, 2003).

EC_1 / EC_2, electrolyte leakage index determined based on values of electrical conductivity of leaf tissue sap before stress (EC_1) and after stress (EC_2) according to modified method of Singer *et al.* (1989) Singer *et al.*

(1989). As indicator for membrane integrity, permeability and cell electrolyte status, low value associate with stress tolerant case (Kaya and Higgs, 2003).

Flowering and fruit yield:

Number of flowers and fruits and fruit yield (g) were determined all over the season from 15 plants / treatment (5 plant / repl.), then calculated per plant.

Also, fruit length, diameter (cm) and fruit shape index (length / diameter) were determined. Yield performance (relative yield %), calculated from % of yield of each treatment relative to this of control as an indicator for agronomical performance (yield capacity), which identically express plant sensitivity or less sensitivity case (Beek *et al.*, 1992).

Correlation studies:

Yield per plant was statistically correlated vs. some physiological and ionic indicators / traits to be identified the most useful ones associated with salinity adaptation. All data were statistically analysis based on ANOVA. Different between means were statistically measured using Duncan Multiple Range test.

RESULTS AND DISCUSSION

Growth and dry matter partitioning:

Effect of salinity:

Data in Table 1 showed that growth of pepper plant in term of plant height, number of leaves and shoots, dry matter accumulation in shoots, roots and the whole plant was significantly reduced in proportion to the intensity of salinity stress in two seasons. Shoot / root ratio significantly decreased with 3000 ppm NaCl, tended to increase with 6000 ppm NaCl at both seasons.

Table 1: Effect of salinity on growth and dry matter of sweet pepper during two seasons.

NaCl (ppm)	Plant height (cm)	No. Of eaves	No. of shoots	DW of shoots (g/plant)	DW of roots (g/plant)	DW of total (g/plant)	Relative TDW (%)	Shoot / root ratio
				2001				
0	62.2a	134.2a	15.2a	107.2a	15.5a	123.0a	100	6.9a
3000	58.6b	100.4b	10.4b	78.2b	12.3b	90.5b	73.6	5.8b
6000	52.0c	79.1c	7.8c	65.5c	9.7c	75.2c	61.1	6.7ab
				2002				
0	63.6a	139.6a	15.6a	112.2a	15.5a	127.7a	100	7.3a
3000	59.9b	104.4b	10.9b	80.2b	12.8b	93.0b	72.8	6.2c
6000	53.4c	81.9c	8.2c	69.2c	10.4c	79.6c	62.3	6.6b

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

Non-stressed control plants had the highest values compared with those received moderate (3000 ppm NaCl) and high (6000 ppm NaCl) salinities. Also, it was obvious that shoot growth was more affected due to salinities than root growth.

The whole plant growth performance in term of % total dry weight of the stressed plants relative to that of control was reduced by 26.8 and 38.3% (mean of two seasons) at moderate and higher salinities, respectively.

The depressive effect of salinity on growth (plant height, number of leaves and shoots), those which associated with number, elongation and expansion of cells and tissues might be much due to the incomplete osmotic regulation (higher accumulation of Na and Cl vs. lower accumulation of K, P and N (Table 7) followed by turgor declines and expansion growth reduction (Yancey *et al.*, 1982; and De-Pascale *et al.*, 2003).

Salinity induce dry matter accumulation reductions might be much due to the direct salt toxicity and the nutrient imbalances (Table 7) and Niu *et al.* (1995) and Liu and Zhu (1998), ATP pools expenditure and diversion from growth (Pasternak, 1987 and Nieman *et al.*, 1988), inhibition of CO_2 assimilation, depletion of carbohydrates, inhibition of protein synthesis (Greenway and Munns, 1980).

Effect of applying the ameliorative ions:

The results of Table 2 illustrated that applying nitrate, phosphate and citrate ions into salinized substrate was significantly improved all growth characteristics compared with control treatment in two seasons.

Citrate ion had the most ameliorative effect on growth followed by phosphate and nitrate. They increased growth performance of pepper plant by 41.2, 36.0 and 28.2% (mean of two seasons), respectively. Also, it was clear that shoot / root ratios were modified, the highest ratio was of phosphate as an adaptive function to reduce the intake of salts (Dalton *et al.*, 1997; Chartzoulakis and Klapaki, 2000 and De-Pascale *et al.*, 2003).

Table 2: Effect of phosphate, nitrate and citrate on growth and dry matter of sweet pepper during two seasons.

Amelior. Ions	Plant height (cm)	No. of leaves	No. of shoots	DW of shoots (g/plant)	DW of roots (g/plant)	DW of total (g/plant)	Relative TDW (%)	Shoot / root ratio
				2001				
Nitrate	60.5b	106.5c	10.5c	85.1b	13.1b	98.2c	129.8	6.4b
Phosphate	61.0b	111.4b	12.1b	91.4a	12.8b	104.2b	137.8	7.0a
Citrate	63.3a	116.5a	13.1a	92.8a	14.4a	107.2a	141.8	6.2b
Control	45.5c	83.8d	8.8d	65.7c	9.9c	75.6d	100	6.2b
				2002				
Nitrate	62.4b	111.4c	11.1c	87.3c	13.8b	101.1b	126.7	6.3c
Phosphate	62.3b	114.7b	12.3b	93.9b	13.3c	107.2c	134.3	7.0a
Citrate	64.0a	120.7a	13.5a	97.6a	14.6a	112.2a	140.6	6.6b
Control	47.2c	87.5d	9.3d	69.8d	10.0d	79.8d	100	6.8b

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

Such pronounced favourable ameliorative effect of these organic and inorganic supplemented ions, could be due to their avoidable effect against the excessive intake and accumulation of the harmful salt ions Na and Cl and reversibly their enhanceable effect on the uptake and accumulation of the useful ones, N, K and P (Tables 8). In addition, they greatly improve and induce an effective salt protective adaptive case reflected by an integrated, stabilized, non leaky, more K/Na selective membranes with more salt protected membrane links transporter enzymes (Lower EC_1/EC_2 values, higher K/Na values). Along with higher capability to retain Na within roots away from the sensitive shoots (lower Na l / Na r values) (Table 11, Blom-Zandestra, 2000, De-Pascale *et al.*, 2003 and Kaya and Higgs, 2003).

The mitigative effect of citrate organic ions on growth under such stressful condition might be also attributed with its involvement in energy metabolism, alleviated the depletion of carbohydrates and the diversion of ATP pools away from growth activities, it was greatly increased PO_4 uptake and accumulation (Table 8). Citrate as organic solute may exhibit an safe osmo-regulatory function against the adverse osmotic / turgor effects of salinity and cryoprotective function against salt toxic effect of membrane and enzymes via its bio-physical allocation at the surfaces of the sensitive membrane and enzymes, implicated also in cation / anion and charges balance (Hasegawa *et al.*, 2000). Also, its anti-oxidantal effects against salt induce oxidative stress. Findings of Mansour *et al.* (1998) confirmed the present effects and roles of citrate.

The anti-stress effects of phosphate ions, which greatly recovered growth of pepper plants could be due to PO_4 ions hinder the uptake of Cl, encourage the uptake and translocation of useful nutrients P and K, restrict the accumulation of Na (Tables 8 and 11), greatly improved P content and probably, in turn, energy case, which greatly stressed by salinity. Meanwhile, nitrate ions, also competitively hinder the uptake of Cl^-, enhanced the uptake of K^+ (complementary ions), thereby reduced the uptake of Na, increased K/Na selectivity (Tables 8 and 11) accordingly improved growth of pepper under present condition. In similar results of Kafkafi *et al.* (1982); Kent and Lauchli (1985) and Pasternak (1987) (NO_3 and PO_4).

Effect of interaction:

The data presented in Table 3 illustrated that the presence of citrate, phosphate and nitrate ions was greatly improved all growth characters of NaCl-stressed pepper plants either at 3000 or at 6000 ppm, their ameliorative effect was in the same order in two seasons. Also, they pronouncedly improved growth of non-stressed control plants. Absence of such ions resulted in dramatic reduction in all growth characters of salt stressed (3000 and 6000 ppm NaCl).

The results markedly indicated that adding citrate, phosphate and nitrate ions was relatively restored growth of 3000 ppm NaCl plants to values similar normal case and to some extent recovered those of 6000 ppm NaCl.

It was also obvious that plant growth performance (relative dry weight %) reduced by 44.8, and 54.6% (3000 and 6000 ppm NaCl), respectively (Means of two seasons).

Table 3: Effect of interaction on growth and dry matter of sweet pepper during two seasons.

	Amel. ion	Plant height (cm)	No. of leaves	No. of shootS	DW of shoots (g/plant)	DW of roots (g/plant)	DW of total (g/plant)	Relative TDW (%)	Shoot / root ratio
2001									
0	Nitr.	67.6a	131.7b	14.6c	102.3b	16.1b	118.4c	102.9	6.3bcd
	Phos.	64.6b	130.0b	15.6b	113.9a	14.1cd	128.0b	111.3	8.0a
	Cit.	68.3a	141.3a	16.7a	113.5a	17.5a	131.0a	113.9	6.4bcd
	Cont.	48.3g	134.0b	13.6d	100.5b	14.5c	115.0d	100.0	6.9b
3000	Nitr.	60.6d	107.0d	9.7f	84.7d	13.3e	98.0f	85.2	5.9cd
	Phos.	62.6c	114.3c	12.0e	87.7c	13.5de	101.2e	88.0	6.4bcd
	Cit.	65.0b	114.7c	12.6e	88.6c	14.2c	102.8e	89.4	5.8d
	Cont.	46.0h	65.6g	7.3h	51.81h	8.5i	60.3j	52.4	5.1e
6000	Nitr.	53.3f	81.0f	7.3 h	68.5g	9.8h	78.3i	68.1	6.9b
	Phos.	55.6e	90.0e	8.6 g	72.7f	10.7g	83.4h	72.5	6.6bc
	Cit.	56.6e	93.6e	10.0f	75.8e	11.7f	87.5g	76.1	6.4bcd
	Cont.	42.3i	52.0h	5.3i	45.0i	6.8j	51.8k	45.0	6.6bc
2002									
0	Nitr.	69.0a	137.7b	15.0b	107.5c	16.6b	124.1c	105.7	6.5de
	Phos.	65.6b	138.0b	15.6b	116.6b	14.4c	131.0b	111.6	8.1a
	Cit.	69.6a	147.7a	17.6a	121.1a	17.6a	138.8a	118.2	6.8c
	Cont.	50.3f	135.0c	14.0c	103.9d	13.5d	117.4d	100.0	7.7b
3000	Nitr.	63.3c	113.0e	10.0e	83.3f	13.7d	97.0f	82.6	6.2e
	Phos.	64.0bc	115.3e	12.3d	88.7e	14.3c	103.0e	87.7	6.2e
	Cit.	65.6b	118.3d	13.3c	89.9e	14.2c	104.1e	88.6	6.3e
	Cont.	46.7g	71.0i	8.0h	58.6i	9.3g	68.0j	57.9	6.2e
6000	Nitr.	55.0e	83.6h	8.3gh	71.3h	11.2f	82.5i	70.2	6.3e
	Phos.	57.3d	91.0g	9.0fg	76.6g	11.3f	87.9h	74.8	6.8cd
	Cit.	56.6d	96.0e	9.6ef	81.9f	12.1e	94.0g	80.1	6.8cd
	Cont.	44.5h	76.6j	6.0i	46.7j	7.1h	53.8k	45.8	6.5cde

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

Those were decreased to 11.0 and 21.9% (citrate) , 12.1 and 26.3% (phosphate), 16.1 and 30.8% (nitrate), all relative to non-stressed, received no protective ion-control. Similar results were obtained by Kafkafi *et al.* (1982), Kent and Lauchli (1985); Kaya and Higgs (2003); and Mansour *et al.* (1998).

Photosynthetic pigments:

Effect of salinity:

Salt stressed plants possessed higher chl. a, chl. b, a + b and carotene content, the highest values were of 3000 ppm NaCl followed by 6000 ppm NaCl and the lowest were of the non-stressed ones at both seasons (Table 4). Such results trend was similar with those obtained by Hee Don and Young Jun (2002) and reversely with Kaya and Higgs (2003).

Effect of applying the ameliorative ions:

All the applied ions mostly improved photosynthetic pigments content in a descending order, i.e., citrate > phosphate > nitrate compared with control in two seasons (Table 5).

Citrate and phosphate might be enhanced energy metabolism and compensated the diverted energy, stimulated all energy dependent. Processes included chlorophyll and caroteinoid synthesis (Fathy *et al.*, 2003 and Kaya and Higgs, 2003).

Table 4. Effect of salinity on photosynthetic pigments of sweet pepper during two seasons.

NaCl (ppm)	2001				2002			
	Chl.a (mg/g FW)	Chl.b (mg/g FW)	Chl.a+b (mg/g FW)	Carotenoids (mg/g FW)	Chl.a (mg/g FW)	Chl.b (mg/g FW)	Chl.a+b (mg/g FW)	Carotenoids (mg/g FW)
0	0.463c	0.473b	0.936c	0.124b	0.464c	0.448b	0.912c	0.117b
3000	0.665a	0.491a	1.15a	0.144a	0.642a	0.464a	1.106a	0.137a
6000	0.520b	0.464b	0.983b	0.137a	0.498b	0.458ab	0.953b	0.135a

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

Table 5. Effect of phosphate, nitrate and citrate on photosynthetic pigments of sweet pepper during two seasons.

NaCl (ppm)	2001				2002			
	Chl.a (mg/g FW)	Chl.b (mg/g FW)	Chl. a+b (mg/g FW)	Carotenoids (mg/g FW)	Chl.a (mg/g FW)	Chl.b (mg/g FW)	Chl. a+b (mg/g FW)	Carotenoids (mg/g FW)
Nitrate	0.498c	0.451c	0.949c	0.125b	0.468c	0.419c	0.887c	0.118b
Phosphate	0.574b	0.614a	1.188b	0.163a	0.555b	0.592a	1.140b	0.159a
Citrate	0.775a	0.462b	1.240a	0.171a	0.794a	0.462b	1.25ab	0.165a
Control	0.349d	0.378d	0.727d	0.082c	0.322d	0.353d	0.670d	0.076c

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

Effect of interaction:

Applying citrate, phosphate and nitrate ions at different salinities (0, 3000 and 6000 ppm NaCl highly improved photosynthetic pigment content of their plants compared with those received no ameliorative ions in two seasons. Citrate was of the highest chl. a, chl. a+b and carotenoid followed by phosphate and nitrate. Phosphate was of the highest chl. b compared with others (Table 6).

Ionic and mineral status:

Effect of salinity:

Data presented in Table 7 clearly proved that along with salinity uptake and translocation of useful nutrients N, P and K into shoots were sharply decreased. Whereas, Na and Cl harmful ones were excessively intaked and accumulated. All were intermediately affected with 3000 ppm NaCl and severely with 6000 one.

Meanwhile, the same results proved that Cl accumulated more than Na and that both of them were greatly allocated into sensitive shoots more than in less sensitive roots.

Herein, such ionic case could be logically associated with the similar adverse effect of salinity on membrane and its binding transporter enzyme system (H-ATP-ase) (key site of ion regulation, which greatly impaired based on EC_1/EC_2 and K/Na, values (Table 10), more Na selectively over K and more electrolyte leakage case. These results were in agreement with those reported by Richter *et al.* (1999); De-Pascale *et* al. (2003) and Kaya and Higgs (2003).

Table 6. Effect of interaction on photosynthetic pigments of sweet pepper during two seasons.

NaCl ppm	Amel. ion	2001 Chl.a (mg/g FW)	2001 Chl.b (mg/g FW)	2001 Chl. a+b (mg/g FW)	2001 Carotenoids (mg/g FW)	2002 Chl.a (mg/g FW)	2002 Chl.b (mg/g FW)	2002 Chl. a+b (mg/g FW)	2002 Carotenoids (mg/g FW)
0	Nitr.	0.415g	0.446fg	0.861g	0.108e	0.387h	0.428f	0.815f	0.102de
	Phos.	0.504e	0.571c	1.075e	0.145d	0.471f	0.545c	1.016e	0.134c
	Cit.	0.608d	0.501d	1.109d	0.155cd	0.689c	0.484d	1.163c	0.144bc
	Cont.	0.324i	0.375j	0.699j	0.088f	0.309j	0.332j	0.641h	0.087ef
3000	Nitr.	0.616d	0.402ef	1.078e	0.154cd	0.678c	0.306j	0.984e	0.147bc
	Phos.	0.704c	0.671a	1.375b	0.167bc	0.678c	0.651a	1.329b	0.161b
	Cit.	0.980a	0.465e	1.445e	0.169abc	0.981a	0.451e	1.432a	0.162b
	Cont.	0.360h	0.365j	0.725i	0.085f	0.325ij	0.352i	0.677gh	0.076fg
6000	Nitr.	0.464e	0.444g	0.908f	0.112e	0.434g	0.427f	0.861f	0.105d
	Phos.	0.513e	0.600b	1.113d	0.174ab	0.515e	0.580b	1.095d	0.182a
	Cit.	0.738b	0.418h	1.156c	0.187a	0.711b	0.450e	1.160c	0.188a
	Cont.	0.363h	0.393i	0.756h	0.073f	0.330i	0.373h	0.703g	0.064g

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

Effect of applying the ameliorative ions:

All the applied ions (citrate, phosphate and nitrate) were significantly increased N, P and K content of roots and leaves, decreased Na and Cl content compared with those of control, citrate was of the highest K, phosphate was of the highest P, nitrate was of the highest N content at both seasons (Table 8).

From the same data (Table 8), it was observed that citrate followed by nitrate accumulated more K in their leaves and roots than phosphate, all were superior than the control. On the other hand, citrate accumulated less Na in its plant leaves followed by phosphate and nitrate. The later maintained less Na in its plant roots compared with the former ones (first season), but at the second one nitrate and phosphate tended to regulate Na equally, citrate maintained the same trend.

Meanwhile, nitrate reduced Cl accumulation into shoots and roots followed by citrate and at least phosphate at two seasons. The pronounced regulatory effect of the applied phosphate and nitrate ions on ionic and nutritional case under salinities conditions might be directly due to their antagonistic effect vs. Cl ion uptake, they also enhanced the uptake of K^+ as complementary ions, in turn, hindered the uptake and translocation of Na^+ within plant (Kafkafi *et al.*, 1982 and kent and lauchli, 1985).

Table 7. Effect of salinity on ions and mineral nutrients content of leaves and roots of sweet pepper during two seasons.

NaCl	N (%)		P (%)		K (%)		Na (%)		Cl (%)	
(ppm)	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
2001										
0	2.86 a	2.40 a	0.317 a	0.255 a	4.10 a	2.60 a	1.05 c	1.20 c	2.80 c	3.80 c
3000	2.34 b	2.10 b	0.219 b	0.205 b	3.30 b	2.10 b	2.10 b	2.20 b	8.00 b	8.80 b
6000	2.10 c	1.80 c	0.189 c	0.186 c	2.50 c	1.90 c	2.40 a	2.40 a	10.80 a	11.70 a
2002										
0	2.90 a	2.40 c	0.318 a	0.256 a	4.00 a	2.70 a	1.00c	1.20 c	2.50 c	3.50 c
3000	2.40 b	2.20 b	0.222 b	0.215 b	3.30 b	2.10 b	2.00 b	2.10 b	7.50 b	8.40 b
6000	2.20 c	1.90 d	0.189 c	0.199 c	2.50 c	1.90 c	2.30 a	2.30 a	10.20 a	11.10 a

Table 8. Effect of phosphate, nitrate and citrate on ions and mineral nutrients content of leaves and roots of sweet pepper during two seasons.

Ameliorative	N (%)		P (%)		K (%)		Na (%)		Cl (%)	
Ions	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
2001										
Nitrate	2.81 a	2.40 a	0.235 c	0.212 c	3.60 b	2.40 b	1.80 b	1.80 b	5.10 c	5.50 d
Phosphate	2.42 c	2.20 c	0.297 a	0.280 a	3.40 c	2.20 c	1.70 c	1.90 b	5.90 b	6.60 b
Citrate	2.56 b	2.30 b	0.266 b	0.224 b	3.80 a	2.60 a	1.60 d	1.90 b	5.20 c	5.80 c
Control	1.94 d	1.70 d	0.169 d	0.147 d	2.40 d	1.60 d	2.10 a	2.10a	12.60 a	14.50 a
2002										
Nitrate	2.90 a	2.50 a	0.238 c	0.209 b	3.50 b	2.40 b	1.70 b	1.80 b	4.40 d	4.90 d
Phosphate	2.50 c	2.20 c	0.295 a	0.297 a	3.40 c	2.30 c	1.70 b	1.80 b	5.40 b	6.20 b
Citrate	2.60 b	2.30 b	0.257 b	0.225 b	3.80 a	2.60 a	1.60 c	1.80 b	5.10 c	5.50 c
Control	1.90 d	1.70 d	0.181 d	0.162 c	2.50 d	1.70 d	2.10 a	2.00 a	12.0 a	14.1 a

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

On the other hand, phosphate and citrate might be improved energy status, which greatly stressed by salinity (Drew and Lauchlí, 1985; Nieman *et al.*, 1988), thereby improved membrane integrity and selectivity (Table 11) and Kaya and Higgs (2003).

Effect of interaction:

Data in Table (9) showed that presence of citrate, phosphate and nitrate ions in root media of 3000 ppm NaCl treatment greatly improved N, P and K uptake and translocation into shoots, restored their content similar to the control treatment, also those were partly restored at the strongest salinity 6000 ppm NaCl. Na and Cl accumulation was also greatly avoided at moderate salinity and partly at higher salinity. Such ameliorative ions were most effective in recovering Na value than Cl. Also, K was more restored than N and P.

The same data also proved that in most cases citrate treatment was of the most balanced protective regulatory effect on ionic and nutritional case under salinity stress.

Physiological indicator parameters:

It was of great benefit to included some indispensable physiological parameters as an reliable sensor for salinity / plant interaction, also as a decisive indicator for the protective adaptive effect of the applied ameliorative ions. Those which presented here were (K/Na), (EC_1/EC_2) and (Na l / Na r) ratios.

Effect of salinity:

The results in Table 10 indicated that K/Na value was significantly diminished, reversely EC_1/EC_2 and Na l / Na r values were elevated with salinity in both seasons. This suggested that, as the intensity of salinity stress increased, membranes structure and function were impaire (breakdown, loss their integrity and selectivity) (Low K/Na, high EC_1 / EC_2 value), sharp intake and translocation of Na over K into shoots, with less capability to maintain Na within roots or secreting it into outer media (higher Na l / Na r values), thereby more ion imbalances and toxicity of plant metabolic machinery.

Moreover, the pronounced low P content and the probable energy lack case with salinity, this greatly restricted membrane regulatory transporter system (Drew and Lauchli, 1985; Pasternak, 1987 and Nieman *et al.*, 1988). Such results and interpretation coincided by those reported by Navarro *et al.* (2002) and Kaya and Higgs (2003).

Effect of applying the ameliorative ions:

Supplementing pepper plants growth substrate with citrate, phosphate and nitrate ions were considerably improved K/Na ratio (increased), EC_1/EC_2 and Na l / Na r (were decreased). Control plants were of the worst values (Table 11). The results were in similar trend in two seasons and significantly differed in most cases except those of Na l / Na r at the first season.

Table 9. Effect of interaction on ions and mineral nutrients content of leaves and roots of sweet pepper during two seasons.

NaCl	Amel.	N (%)		P (%)		K (%)		Na (%)		Cl (%)	
ppm	Ion	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots
2001											
0	Nitrate	3.30a	2.60a	0.307c	0.260c	4.10b	2.70b	1.07hi	1.20f	2.50h	1.70i
	Phos.	2.70c	2.30cd	0.375a	0.301a	4.00bc	2.50c	1.02ij	1.30f	3.10g	4.21gh
	Citrate	2.90b	2.40bc	0.350b	0.254c	4.50a	2.90a	1.00j	1.20f	2.40h	3.70h
	Control	2.50d	2.30de	0.236e	0.203d	3.70d	2.44cd	1.10h	1.20f	3.30g	4.50g
3000	Nitrate	2.70c	2.40ab	0.208fg	0.198d	3.60d	2.40d	1.14e	2.10e	5.00f	4.20gh
	Phos.	2.40ef	2.30de	0.274d	0.280b	3.40e	2.18f	2.00f	2.10e	6.10e	5.66f
	Citrate	2.50de	2.30de	0.237e	0.214d	3.90c	2.62b	1.80g	2.20d	5.40f	6.60e
	Control	1.80h	1.60h	0.158h	0.127f	2.20h	1.50h	2.40b	2.40b	15.60b	18.70b
6000	Nitrate	2.40def	2.20fg	0.191g	0.175e	3.00c	2.10fg	2.30c	2.30c	7.70d	9.50c
	Phos.	2.20g	1.90g	0.241e	0.257c	2.80g	2.00g	2.20d	2.30c	8.70c	9.80c
	Citrate	2.30fg	2.00f	0.211f	0.203d	3.00f	2.30e	2.10e	2.29cd	7.80d	7.20d
	Control	1.40i	1.30i	0.113i	0.110g	1.50i	1.10i	2.90a	2.75a	19.10a	20.30a
2002											
0	Nitrate	3.50a	2.60a	0.306c	0.242c	4.00b	2.70b	0.983gh	1.1g	2.06 r	2.50r
	Phos.	2.70c	2.40c	0.373a	0.311a	3.90b	2.60c	1.00gh	1.2fg	2.61j	3.90i
	Citrate	2.90b	2.40c	0.333b	0.253c	4.30a	2.90a	0.966h	1.2fg	2.42 j	3.20j
	Control	2.50d	2.30de	0.258e	0.216d	3.60c	2.50d	1.06g	1.23de	3.0 i	4.50h
3000	Nitrate	2.70c	2.50b	0.216fg	0.206d	3.60c	2.40e	2.03d	2.0 de	4.1 h	4.10i
	Phos.	2.40e	2.30de	0.277d	0.289b	3.40d	2.20g	1.91e	2.0 e	5.8 f	5.50g
	Citrate	2.50d	2.40d	0.229f	0.217d	3.90b	2.60c	1.78f	2.1 d	5.2 g	6.30f
	Control	1.80f	1.60h	0.163i	0.145f	2.10h	1.50i	2.38b	2.4 b	14.8 b	17.00b
6000	Nitrate	2.50d	2.20e	0.190h	0.177e	2.90f	2.20g	2.25c	2.3 c	7.1 e	8.20d
	Phos.	2.30e	1.90g	0.234f	0.290b	2.70g	2.10h	2.30c	2.2 c	7.9 c	9.00c
	Citrate	2.40e	2.10f	0.209g	0.203d	3.00e	2.30f	2.10d	2.2 c	7.5 d	7.10e
	Control	1.50g	1.30i	0.121j	0.125g	1.50i	1.10j	2.80a	2.7 a	13.1 a	20.0a

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 the physiological indicator parameters of sweet pepper during two seasons.

NaCl (ppm)	2001			2002		
	K / Na	EC_1 / EC_2	Na l / Na r	K / Na	EC_1 / EC_2	Na l / Na r
0	3.90a	0.59c	0.845a	3.80a	0.55c	0.837c
3000	1.60b	0.83b	0.942a	1.60b	0.78b	0.923b
6000	1.20c	0.99a	0.993a	1.10c	0.98a	1.00a

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

Table 11. Effect of phosphate, nitrate and citrate on the physiological indicator parameters of sweet pepper during two seasons.

Ameliorative ions	2001			2002		
	K / Na	EC_1 / EC_2	Na l / Na r	K / Na	EC_1 / EC_2	Na l / Na r
Nitrate	2.20b	0.77b	0.980a	2.40b	0.69b	0.941ab
Phosphate	2.40b	0.69c	0.896a	2.30c	0.66b	0.919b
Citrate	2.60a	0.59d	0.853a	2.70a	0.56c	0.863c
Control	1.60c	1.60a	0.980a	1.60d	1.13a	0.958a

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

These results might be associated with the compensated effect of phosphate *and citrate ions on energy case*, thereby better membrane integrity and selectivity added to their (nitrate & phosphate) direct regulatory effect (antagonistic, synergistic) of salt and nutrient uptake and translocation. On the other hand, citrate, within plant tissue may protect membranes and their binding transporter enzymes (surface physical function), or evoked osmoprotective role against salinity.

Those were in agreement with results found by Kent and Lauchli (1985); Mansour *et al.* (1988) and Kaya and Higgs, 2003).

Effect of interaction:

Presence of the *ameliorative* ions in the salinized substrate was greatly improved K/Na selectively, protected membranes against salt adverse effects (lowering EC_1/EC_2), restricted translocation of Na into shoots, maintained more Na within roots (lowering Na l / Na r). They fully restored such values to be similar the normal ones of control plants at moderate salinity and to large extent at higher salinity, K/Na ratio, also was relatively recovered in two seasons (able 12).

Flowering and fruit yield:

Effect of salinity:

In proportion to salinity, number of flowers and fruits, fruit yield of plant were significantly reduced in two seasons. Fruit yield was reduced by 12.2 and 29.2% (mean of two seasons) at 3000 and 6000 ppm NaCl, respectively (Table 13).

Fruit length was significantly decreased with salinity, fruit diameter was only decreased at high salinity. Whereas, fruit shape index was not affected at moderate salinity, tended to increase at high salinity in two seasons

Table 12. Effect of interaction on the physiological indicator parameters of sweet pepper during two seasons.

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	Nitr.	3.80b	0.62ef	0.89b	4.10b	0.54gh	0.863ef
	Phos.	3.90b	0.60f	0.78b	3.90c	0.57fg	0.830fg
	Cit.	4.40a	0.50g	0.81a	4.50a	0.49h	0.796g
	Cont.	3.40c	0.64ef	0.89ab	3.40d	0.60h	0.860ef
3000	Nitr.	1.70e	0.78d	1.00b	1.70f	0.72d	0.976bc
	Phos.	1.70e	0.64ef	0.94b	1.70f	0.62ef	0.903de
	Cit.	2.17d	0.59f	0.80b	2.20e	0.55g	0.843fg
	Cont.	0.89g	1.30b	0.98b	0.91i	1.26b	0.970bc
6000	Nitr.	1.20f	0.92c	1.00b	1.30h	0.81c	0.983bc
	Phos.	1.60ef	0.83d	0.95b	1.20h	0.79c	1.02ab
	Cit.	1.40ef	0.68e	0.94b	1.40g	0.65e	0.950cd
	Cont.	0.50h	1.50a	1.00b	0.54j	1.53a	1.04a

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

Table 13. Effect of salinity on flowering, fruit yield and quality of sweet pepper during two seasons.

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	53.40a	23.70a	537.7a	100.0	7.30a	3.10a	2.40a
3000	45.70b	20.20b	465.4b	86.55	6.50a	3.20a	b
6000	36.80c	16.80c	376.6c	70.03	6.10a	2.20a	2.10a
							2.90a
2002							
0	54.50a	25.10a	550.3a	100.0	7.00a	3.30a	2.10b
3000	49.00b	21.10b	490.4b	89.11	6.50b	3.10a	2.00b
6000	38.10c	17.30c	394.0c	71.62	5.90c	2.30b	2.50a

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

Such results were in accordance with those reported by Chartzoulakis and Klapaki (2000) and De-Pascale *et al.* (2003).
Accordingly, sweet pepper, Egyptian Balady cv. could considered as relatively less to moderately-salt sensitive at 3000 ppm NaCl and moderately at 6000 ppm NaCl. This was in harmony with its growth responses, shoot / root adaptive modification (Table 1) and somewhat with ionic and physiological adaptive case (K/Na, EC_1/EC_2 and Na l / Na r) (Tables 7 and 10), those confirmed by correlation values . Table 16 and by all the previously discussed and reviewed.

Effect of applying the ameliorative ions:

Apparently, supplementing pepper plants with citrate, phosphate and nitrate ions were effectively improved number of flowers and fruits and fruit yield per plant as well as fruit length, diameter and shape index compared with control in two seasons. Their beneficial effect was arranged as citrate > phosphate > nitrate, in the same order they were increased fruit yield performance (relative yield %) by 56.8, 43.0 and 35.7%, respectively (Table 14).

Table 14. Effect of phosphate, nitrate and citrate ions on flowering, fruit yield and quality of sweet pepper during two seasons.

Ameliorative ions	No. of flowers / plant	No. of fruits / plant	Fruit yield / plant (g)	Relative yield (%)	Fruit length (cm)	Fruit diameter (cm)	Fruit shape index
2001							
Nitrate	45.80c	20.50c	462.6c	136.5	6.40 b	2.50c	2.60a
Phosphate	48.10b	21.50b	503.1b	148.4	6.30b	3.20a	2.10a
Citrate	50.10a	23.10a	534.8a	157.7	7.80a	3.10ab	2.50a
Control	37.20d	15.80d	339.0d	100.0	6.20b	2.60bc	2.50a
2002							
Nitrate	47.10c	21.30c	484.5c	135.11	6.60b	2.70b	2.40a
Phosphate	49.00b	23.10b	522.5b	145.70	6.20b	3.20a	1.90b
Citrate	51.10a	24.10a	559.4a	155.95	7.40a	3.20a	2.30a
Control	39.00d	16.10d	358.6d	100.0	5.60c	2.60b	2.20a

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

Effect of interaction:

Adding the ameliorative ions into salt stressed and non-stressed plants were significantly improved their flowering, fruiting, fruit yield and quality at the two seasons.. Fruit yield at 3000 ppm NaCl increased by 11.9 and 6.8% due to citrate and phosphate ions application, respectively and only reduced by 1.6% in case of nitrate and greatly reduced by 40.1% in the absence of such ions. At higher salinity (6000 ppm NaCl) in the absence of the protective ions, yield severely reduced by 52.2%, such reduction recovered to be only decreased by 9.6, 19.7 and 22.8% due to applying of citrate, phosphate and nitrate, respectively (mean of two seasons) (Table 15).

Correlation studies:

Data presented in Table (16) indicated that fruit yield of pepper plant was positively correlated with N, P, K content, K/Na ratio as well as chlorophyll a, (a+b) and carotenoids content. On the other hand, it negatively correlated with Na and Cl content, EC_1 / EC_2 and Na l / Na r values in two seasons.

It also was positively and weakly correlated with chlorophyll b and shoot / root ratio, in two seasons. Such relations greatly confirmed the previous discussion and interpretation of the effect of salinities and protective ions on pepper plant yielding capacities.

Meanwhile, proved the essentiality of ionic and nutritional case and the physiological performance measured by EC_1/EC_2, K/Na and Na l / Na r parameters as an indicator for the case of sensitivity or tolerability under salinity.

Table 15: Effect of interaction on flowering, fruit yield and quality of sweet pepper during two seasons.

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	Nitr.	53.30c	23.60b	510.0d	101.53	5.70cd	2.40de	2.40abc
	Phos.	55.00b	25.00a	561.7b	111.82	6.10cd	3.20abcd	2.10bc
	Cit.	56.30a	25.60a	577.0a	114.87	9.50a	3.40abc	2.70abc
	Cont.	49.00e	20.60cd	502.3de	100.0	8.10b	3.60ab	2.20bc
3000	Nitr.	47.60f	20.60cd	495.7e	98.68	6.60bc	2.80bcde	2.40abc
	Phos.	49.00e	21.70c	533.3c	106.17	6.20cd	3.80a	1.60c
	Cit.	50.60d	23.30b	552.7b	110.03	7.80b	3.30abcd	2.40abc
	Cont.	35.60j	15.30f	280.0i	55.74	5.50cd	2.9abcde	1.80bc
6000	Nitr.	36.60i	17.30e	382.3h	76.10	6.80bc	2.20ef	3.00ab
	Phos.	40.30h	18.00e	414.3g	82.46	6.60bc	2.50cde	2.60abc
	Cit.	43.30g	20.30d	475.0f	94.56	6.00cd	2.50de	2.50abc
	Cont.	27.00k	11.60g	234.7j	46.72	5.10d	1.40f	3.50a
2002								
0	Nitr.	53.60c	24.60c	540.0c	106.44	6.00cd	2.80c	2.20bcde
	Phos.	55.60b	26.60b	585.0b	108.33	6.20bc	3.50ab	1.80de
	Cit.	57.60a	28.30a	605.0a	103.41	8.00a	3.60a	2.2bcde
	Cont.	51.00de	20.60f	507.3de	100.0	7.90a	3.50ab	2.70bcd
3000	Nitr.	49.30e	21.60e	516.7d	101.85	6.80bc	2.90bc	2.30bc
	Phos.	50.00de	23.00d	545.0c	107.43	6.10bc	3.50ab	1.70e
	Cit.	51.30d	24.00c	576.0b	113.54	7.80a	3.50ab	2.2bcde
	Cont.	37.60h	15.60c	324.0h	63.86	5.20d	2.70c	1.90cde
6000	Nitr.	38.30h	17.60h	397.0g	78.25	7.00b	2.40c	2.80a
	Phos.	41.30g	19.60g	397.0f	78.25	6.20bc	2.70c	3.30bcd
	Cit.	44.30f	20.00fg	437.7f	86.28	6.50bc	2.60c	2.40ab
	Cont.	28.30i	12.00j	244.7i	48.23	3.80e	1.50d	2.50ab

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

Table 16. Correlation coefficients on fruit yield / plant (g) vs. some physiological and chemical traits during two seasons.

Traits	Fruit yield / plant (g)	
	2001	2002
Chlorophyll a	0.541	0.587
Chlorophyll b	0.470	0.433
Chlorophyll a + b	0.611	0.622
Carotenoids	0.623	0.584
N (%)	0.803	0.787
P (%)	0.835	0.846
K (%)	0.946	0.959
Na (%)	-0.798	-0.797
Cl (%)	-0.936	-0.923
K / Na	0.753	0.702
EC_1 / EC_2	-0.965	-0.946
Na l / Na r	-0.760	-0.763
Shoot / root ratio	0.237	0.296

Additionally, it was observed that the most strong correlations were of fruit yield vs P, K and Cl^- content as well as EC_1 / EC_2 value of two seasons. This lead to be suggested that under this work condition, ultimately membrane integrity and permeability measured by EC_1/EC_2, energy case reflected by P content, K content as the most useful counteracting cation and Cl harmful salt ion, were involved in plant / salinities responses and as basic indicators for salt sensitivity or tolerability. Also, Na content, K/Na and Na l / Na r ratios were involved and considered as important indicators.

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التأثيرات المخففة لإضافة أيونات الفوسفات والنترات والسترات على أداء محصول الفلفل تحت ظروف إجهاد الملوحة

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أجريت تجارب ملوحة على نباتات الفلفل البلدى بمزرعة البرامون بمحافظة الدقهلية عامى ٢٠٠١ ، ٢٠٠٢ (العروة الصيفية) لدراسة تأثير مستويات مختلفة من الملوحة فى صورة كلوريد صوديوم (صفر ، ٣٠٠٠ ، ٦٠٠٠ جزء فى المليون) بمياه الرى والتأثيرات المخففة والمضادة للملوحة بإضافة أيونات الفوسفات (فى صورة حمض فوسفوريك بمعدل ٠,٣٥ مل/لتر) ، أيونات النترات (فى صورة حمض نيتريك بمعدل ٠,٣٥ مل/لتر) وأيونات السترات (فى صورة حمض ستريك ، ٥ جم/لتر) بمياه الرى وتأثير التفاعل بينها على الأداء الأيونى والفسيولوجى والمحصولى للنباتات المذكورة بهدف تحسين النمو والإنتاجية وتفسير ذلك على أساس السلوك الأيونى والفسيولوجى تحت ظروف الإجهاد ٠

وتلخصت أهم النتائج فى الآتى:-

أولا: تأثيرات الملوحة: حدث نقص معنوى مع زيادة شدة الإجهاد الملحى فى إرتفاع النبات وعدد الأوراق والفروع وتراكم المادة الجافة بالفروع والجذور والمادة الجافة الكلية ونسبة وزن الفروع / الجذور وعدد الأزهار والثمار ومحصول وجودة الثمار فى موسمى التجربة ٠ وكان النقص فى تراكم المادة الجافة الكلية بمقدار (٢٦,٨ ، ٣٨,٣٢%) وفى محصول الثمار / نبات بمقدار (١٢,٢ ، ٢٩,٢%) متوسط الموسمين بالنسبة للمقارنة عند الملوحة المتوسطة والعالية (٣٠٠٠ ، ٦٠٠٠ جزء فى المليون كلوريد صوديوم) على التوالى ٠

ثانيا: تأثير الأيونات المضادة للملوحة: أدت إضافة أيونات السترات > الفوسفات > النترات فى مياه الرى إلى حدوث تحسن معنوى كبير فى كل الصفات المذكورة وزاد تراكم المادة الجافة الكلية بمقدار ٤١,٢ ، ٣٦,٠ ، ٢٨,٠% وفى محصول الثمار بمقدار ٥٦,٨ ، ٤٣,٠ ، ٣٥,٧% على التوالى بالنسبة للمقارنة نتيجة لتحسين الأداء الأيونى والفسيولوجى ونقص إمتصاص وإنتقال وتراكم الأيونات الملحية الضارة (صوديوم وكلوريد) إلى الأوراق ٠

تأثير التفاعل: أدت إضافة أيونات السترات > الفوسفات , النترات إلى وسط النمو المعامل ملحيا إلى حدوث تحسن معنوى كبير فى كل صفات النمو وتراكم المادة الجافة والصفات المحصولية عند الملوحة المتوسطة وبدرجة مناسبة عند الملوحة العالية نتيجة لحدوث تأثيرات مماثلة على الأداء الأيونى والفسيولوجى وصبغات البناء الضوئى وكان النقص فى المادة الجافة الكلية بمقدار ٤٤,٨ ، ٥٤,٦% بتأثير الملوحة المتوسطة والعالية إنخفض ليصبح فقط (١١ ، ٢١,٩%) ، (١٢,١ ، ٢٦,٣%) ، (١٦,١ ، ٣٠,٨%) فى وجود السترات والفوسفات والنترات على التوالى ، كذلك كان النقص فى محصول الثمار بمقدار (٤٠,١ ، ٥٢,٢%) مع الملوحة المتوسطة والعالية على التوالى وحدثت زيادة فى المحصول عند إضافة السترات والفوسفات بمقدار ١١,٩ ، ٦,٨% مع الملوحة المتوسطة ٠ وإنخفض النقص عند الملوحة العالية ليصبح ٩,٦ ، ١٩,٧% على التوالى ، وأدت إضافة النترات إلى تقليل نقص المحصول بتأثير الملوحة المتوسطة ليصبح ١,٦% وعند الملوحة العالية ليصبح فقط ٢٢,٨%٠

الإرتباط الإحصائي: كان هناك إرتباط إحصائي موجب بين المحصول ومحتوى الأوراق من النتروجين والفوسفور والبوتاسيوم والكلوروفيل وقيم بوتاسيوم / صوديوم ونسبة وزن فروع / جذور وإرتباط سالب مع محتوى الأوراق من الصوديوم والكلوريد وقيم EC_1/EC_2 ، Na r / Na l وإعتبر محتوى الأوراق من البوتاسيوم والفسفور والكلوريد وقيم EC_1/EC_2 أهم القياسات والدلائل لتحديد التحمل أو الحساسية للملوحة ٠

فى النهاية نوصى بإضافة السترات (حمض الستريك بمعدل ٥ جم / لتر أو الفوسفات (حمض الفوسفوريك بمعدل ٠,٣٥ مل/لتر) فى مياه الرى (٣ إضافات شهرية إبتداء من الشهر الثانى بعد الشتل) تحت ظروف ملوحة مماثلة لتخفيف التأثيرات الضارة للملوحة وتحسين النمو ومحصول وجودة الثمار لنباتات الفلفل وإعتبار الفلفل البلدى نبات قليل الحساسية نسبيا عند الملوحة المتوسطة ومعتدل الحساسية للملوحة العالية ويمكن إستخدامه فى برامج التربية للملوحة ٠