EFFECT OF SALINITY AND CALCIUM FOLIAR APPLICATION ON GROWTH, YIELD AND FRUIT QUALITY OF TOMATO

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ABSTRACT: *Two pot experiments were carried out at the Experimental Farm of the Faculty of Agriculture in Damanhour, Alexandria University during early summer seasons of 2007 and 2008 in order to study the effect of different levels of NaCl (0, 50 and 100 mM) in nutrient solution and foliar application of Ca-protinate (1%), Ca-Nitro (1%) and Ca-Chelate (0.5%) on vegetative growth, dry matter accumulation, yield, fruit quality and mineral constituents of tomato plants (Lycopersicon esculentum Mill.) cv. Castle Rock.*

Increasing NaCl levels in the nutrient solution from 0 up to 100 Mill mol (mM) significantly decreased vegetative growth, dry weight/plant, fruit yield parameters and calcium content in fruit tissues as well as K, and Ca contents in leaves. On the other hand, treating tomato plants with 100 mM NaCl in the nutrient solution resulted in the highest values of number of fruits infested with blossom-end rot, TSS and titratable acidity, as well as Na and proline contents in the leaves.

Promotive influence in vegetative growth parameters, blossom-end rot (BER) calcium content in fruit tissues and N, and Ca contents in the leaves were due to foliar application of different sources of calcium. The combined interaction between NaCl at a rate of 0 mM in the nutrient solution and different sources of calcium foliar application caused a stimulatory effect on most of the studied characters of tomato plants, meanwhile the same treatments recorded the lowest values of TSS of fruits in the first season and Na and proline contents in leaves in both seasons.

Key Words: *Tomato, salinity, calcium, growth, yield.*

INTRODUCTION

In Egypt, salinity of water and soil became a more pronounced problem in both newly and ancient lands or in North Coast areas. It adversely affects vegetative growth and biomass yield of most horticultural crops. Most of the saline soils are located in the northern middle of Nile Delta as well as its eastern and western sides. This problem is usually counteracting the expansion in land reclamation (Gehad, 2003).

Tomato has been catalogued as moderately to less sensitive to salt stress (Mass and Hoffman, 1977). Its growth withstands salinity up to 2.6 dSm^{-1}, with biomass reduction by 5.3% for each EC unit increase (Hassan *et al.*, 1999 b). Vegetative and root biomass were reduced by (18 and 36%) and (30 and 75%) at 70 and 140 mM NaCl, respectively (Perez-Alfocea *et al.*, 1996). Salinity is known to greatly suppress all growth parameters in terms of plant height, number of leaves and shoots, leaf area, dry matter accumulation and partitioning and relative growth of tomato (Soliman and Doss, 1992; Satti *et al.*, 1994; Hassan *et al.*, 1999 a; Khedr *et al.*, 2005; Tantawy, 2007; Tantawy *et al.*, 2009).

This is due to the specific toxic effect of the accumulated Na and Cl, nutritional imbalances and hyperosmotic effects which lead to turgor decline and dehydration of plant tissues (Yancey *et al.*, 1982; Niu *et al.*, 1995; Liu and Zhu, 1998), inhibition of photosynthesis (Munns and Termat, 1985), diversion and expenditure of carbohydrates and energy pools (Nieman *et al.*, 1988) and accumulation of toxic oxygen free radicals (Hasegawa *et al.*, 2000).

Such yield reduction depends not only on the severity of the given salinity stress, but also to great extent on the variable differences. As the intensity of stress increased flowering, fruit setting and number and size of fruits were mostly decreased in parallel (Satti *et al.*, 1994; Fathy *et al.*, 2005; Tantawy, 2007; Tantawy *et al.*, 2009). In contrast, fruit quality in terms of TSS%, acidity, vitamin C, sugars and DW% mostly tended to be improved (Adams, 1991; Soliman and Doss, 1992; Satti *et al.*, 1994; Fathy *et al.*, 2005; Tantawy *et al.*, 2009).

The incidence of blossom-end rot (BER) in tomato, a physiological disorder caused by calcium deficiency in the distal end of the fruit, is cultivar dependent (Ho *et al.*, 1993) and aggravated by high salinity resulting in poor Ca uptake and distribution to the distal fruit tissue (Ehret and Ho, 1986). Foliar sprays with $CaCl_2$ or soil-applied of Ca NO_3 are often used to provide additional Ca for tomatoes (Geraldson, 1957).

Blossom-end rot incidence was induced by salinity (Adams and Ho, 1992; Ho *et al.*, 1993; Fathy *et al.*, 2005).

Supplemental calcium sulphate added to nutrient solution containing salt, significantly improved growth and physiological variables affected by salt stress (e.g. plant growth, fruit yield and membrane permeability) and also increased leaf K, Ca and N in tomato plants (Levent Tuna *et al.*, 2007). Khayyat *et al.*, (2007) found that supplementary Ca improved strawberry fruit weight and number and using $CaSO_4$ was the best source for calcium as compared with $CaCl_2$.

The aim of this work was to enhance tomato fruit yield and its quality by Ca foliar application under different levels of soil salinity.

MATERIALS AND METHDS

Two pot experiments were carried out at the Experimental Farm of the Faculty of Agriculture in Damanhour, Alexandria University during early summer seasons of 2007and 2008 in order to study the effect of different levels of NaCl (0, 50 and 100 mM) in nutrient solution and foliar application of Ca-protinate (1%), Ca-Nitro (1%) and Ca-Chelate (0.5%) on vegetative growth, dry matter accumulation, yield , fruit quality and mineral constituents of tomato plants (*Lycopersicon esculentum* Mill.) grown under plastic tunnels. Tomato plants cv. Castle Rock were transplanted after forty days from seed sowing in plastic containers (40 cm in depth and 50cm in diameter) on 20th Feb. in the two seasons. Each pot had a hole in its bottom which was partially closed with glass wool.

The trials were carried out on virgin soil collected from the southern region of Tahrir Province (Beheira Governorate). The physical and chemical properties of the experimental soil are presented in Table 1.

Table (1): The physical and chemical properties of the used soil (average of the two seasons)

Physical properties		Chemical properties	
Sand (%)	95.3	E.C. (mmhos/cm)	0.14
Silt (%)	3.4	$CaCO_3$ %	7.8
Clay (%)	1.3	Available N (ppm)	2.5
O.M (%)	0.23	Available P (ppm)	5.2
Bulk density g/cm^3	1.6	Available K (ppm)	9.5
F.C. (%)	7.4	Fe (ppm)	1.6
W.P. (%)	3.1	Mn (ppm)	1.2
Texture	Sandy	Zn (ppm)	0.6
pH	7.3	Cu(ppm)	0.4

Plants were irrigated with 100ml of full strength Hoagland solution every two days beginning from transplanting. At 10 days after transplanting, salinity treatments were done using nutrient solutions with 0, 50 and 100 mM NaCl. The electrical conductivities of the nutrient solution were 1.45, 5.45 and 8.85 dsm^{-1}, for 0, 50 and 100 mM NaCl in the nutrient solution respectively.

The experiment included 12 treatments which were the combinations between three salinity levels (0.50 and 100Mm NaCl) and four foliar fertilizer sources of Ca (Ca-protinate 1%, Ca-Nitro 1% and Ca-Chelate 0.5%). The treatments were arranged in a split plot design with four replications. The saline levels were assigned at random in the main plots, while the Ca fertilizer sources treatments were arranged randomly in sub-plot. The sub-plot contained eight containers, 50 cm border space were left between each foliar application treatments to avoid overlapping of calcium foliar application solution. The Ca foliar fertilizer sources and their concentrations are shown in Table 2.

Table (2): Calcium fertilizer sources treatment

Ca sources	Used concentration (recommended)	Nutrient contents
Control	-	Without Ca foliar fertilization
* Ca-protinate	1%	17% Ca and mixed of amino acids
** Ca-nitro	1%	25% CaO, 16%N, 0.5%MgO
***Ca-chelate	0.5%	10% calcium

* Kemto inc., Turkey

**National ammonia & chemical industries – Jordan.

*** El-Naser Co. Egypt.

The aqueous solutions of foliar nutrition were sprayed on tomato plants twice, at 45 and 60 days after transplanting. After 70 days from transplanting, samples of three plants from each treatment were taken and dried at700C till constant weight, grounded and analyzed for total N, P, K, Ca and Na using the methods described by Chapman and Parti (1961). Proline was determined spectrophotometrically following the ninhydrin method described by Bates *et al.* (1973). The fruits were harvested weekly and the overall yields were calculated at the end of harvesting. Fruits infected with blossom-end rot (BER) were recorded and calculated as follows:-

$$BER\% = \frac{\text{No. BER fruits/plant}}{\text{Total No.of fruits/plant}} \times 100$$

Samples of five fruits were taken from each plot at full-ripe maturity stage from the second picking to determine total soluble solids (T.S.S) by Carl Zeis refractometer, while titratable acidity was determined according to A.O.A.C., 1970, calcium percentage was determined Flamephotometrically and dry matter percentage was calculated in tomato fruits. Obtained data were subjected to the analysis of variance according to Snedecor and Cochran (1980). Duncan`s multiple range test was used for the comparison among treatments means (Duncan, 1955).

RESULTS AND DISCUSSION

Vegetative Growth Effect of salinity:

Data in Table 3 show that both fresh and dry weight and leaf area of tomato plant were markedly reduced by increasing NaCl level in the nutrient solution. Such results may be due to that biomass production of plants was inhibited by salinity. As suggested by Bernstein (1963) and Cusido *et al.* (1987), suppression of plant growth under saline conditions may be due to osmotic reduction in water availability or to excessive accumulation of Na and Cl in plant tissues.

Nevertheless, similar findings coincided with the harmful effect of salinity on the plant growth performance that previously reported by Perez-Alfocea *et al.* (1996), Hassan *et al.* (1999 a, b), Khedr *et al.* (2005), Tantawy (2007), and Tantawy *et al.* (2009) on tomato.

Effect of calcium foliar application:

Data presented in Table 3 show the effect of Ca foliar application on vegetative growth characters of tomato plants as plant fresh weight, stem and leaves fresh weight, plant leaf area and dry weight. It is clear that Ca foliar application treatments had a promoted effect on all vegetative growth characters as compared with the control and showed significant effect on plant and leaves fresh weight. The superior treatments were Ca-protinate and Ca-nitro with non significant differences between them. Obtained results are in conformity with those of Levent Tuna *et al.* (2007) on tomato.

Table (3): Effect of salinity levels and Ca foliar application on vegetative growth and dry weight of tomato at 70 days from transplanting plants during 2007and 2008 seasons

Treatments	Growth characters / plant									
	2007 Season					2008 Season				
Salinity(mM of NaCl)	Plant fresh wt.(g)	Stem fresh wt.(g)	Leaves fresh wt.(g)	leaf area (cm^2/plant)	Dry weight (g/plant)	Plant fresh wt.(g)	Stem fresh wt.(g)	Leaves fresh wt.(g)	leaf area (cm^2/plant)	Dry weight (g/plant)
0	1504a	295a	930a	1870a	117.8a	1557a	317a	964a	2610a	122.8a
50	1257b	228b	842b	1370b	101.6a	1327b	260b	867b	1420b	105.0ab
100	985c	185c	641c	870c	80.7b	1049	214c	672c	980c	88.5b
F. test	**	*	**	*	*	**	*	**	*	*
Ca foliar application										
Without	1133c	206a	711b	1240a	89.7a	1184c	231a	736c	1260a	92.7a
Ca- protinate 1%	1348a	253a	848a	1450a	109.0a	1400a	283a	882a	1550a	114.7a
Ca- nitro 1%	1300a	263a	848a	1450a	104.7a	1383a	293a	884a	1590a	111.6a
Ca- chelate 0.5%	1212b	222a	809a	1340a	97.0a	1277b	248a	802b	1430a	102.7a
F. test	*	N.S	*	N.S	N.S	*	N.S	*	N.S	N.S

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

N.S = not significant, *, ** significant at 0.05and 0.01levele of probability, respectively.

They also mentioned that the effects of supplemental $CaSO_4$ in maintaining membrane permeability, increasing concentration of Ca, N and K and reducing concentration of Na(because of competition in root zone) in leaves could offer an economical and simple solution to tomato crop production problems caused by high salinity.

Effect of the interaction between salinity and calcium foliar application:

Data in Table 4 indicate the effect of the interaction between salinity levels and calcium foliar application on vegetative growth characters of tomato plants. It is clear that the interaction between salinity levels and calcium foliar application had significant effect on leaves fresh weight and plant leaf area. Meantime, the interaction between 0.0 mM NaCl and all tested concentrations of Ca foliar application were the superior treatments regarding fresh weight and plant leaf area, as it has been mentioned above that higher levels of NaCl inhibited the biomass production of tomato plants.

Yield and Its Components

Effect of salinity:

It is obvious from the data in Table 5 and Fig.1 that fruit yield/ plant and average fruit weight were significantly decreased by increasing level of NaCl in the nutrient solution. Such results may be due to that biomass production of plants was inhibited by salinity as shown in Table 3. Concerning blossom-end rot (BER), the same data in Table 5 reveal that number of fruits infected with BER% was significantly increased by increasing NaCl level in the nutrient solution. The negative effects of salinity on quality are well known and are often related to a low uptake rate of calcium which decreased xylem transport of this element or an unfavorable partitioning of cations in plant tissues. Examples of such effects are blossom-end rot of tomato and pepper (Sonneveld, 1988) Similar findings were reported by Satti *et al.* (1994), Fathy *et al.* (2005), Tantawy (2007) and Tantawy *et al.* (2009) on tomato.

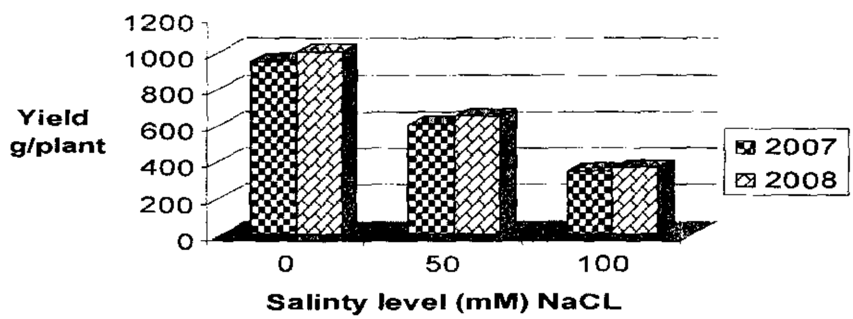

Fig. 1: Effect of salinity on fruit yield of tomato (g/plant) during 2007 and 2008 seasons

Table (4): Effect of the interaction between salinity and Ca foliar application on vegetative growth and dry weight of tomato plant during 2007and 2008 seasons

Treatments		Growth characters / plant									
		2007 Season					2008 Season				
Salinity (mM of NaCl)	Ca foliar application	Plant fresh wt.(g)	Stem fresh wt.(g)	Leaves fresh wt.(g)	leaf area (cm^2/plant)	Dry matter (g/plant)	Plant fresh wt.(g)	Stem fresh wt.(g)	Leaves fresh wt.(g)	leaf area (cm^2/plant)	Dry matter (g/plant)
0 mM	Without	1382a	268a	814c	1720ab	106.2a	1431a	296a	844d	1760bcd	110.1a
	Ca- protinate 1%	1567a	291a	978a	1920a	123.4a	1612a	322a	1012a	2020a	129.0a
	Ca- nitro 1%	1559a	336a	975a	1980a	123.6a	1618a	350a	1008a	2190a	129.6a
	Ca- chelate 0.5%	1508a	283a	952a	1850a	117.9a	1567a	301a	992ab	1960abc	122.4a
50 mM	Without	1122a	186a	734d	1260cde	89.4a	1178a	208a	761e	1240ef	92.8a
	Ca- protinate 1%	1386a	275a	889b	1490bc	113.7a	1436a	306a	923bc	1580cde	114.9a
	Ca- nitro 1%	1304a	254a	891b	1420bcd	105.1a	1392a	296a	918bc	1490cde	108.8a
	Ca- chelate 0.5%	1216a	198a	854bc	1310cde	98.3a	1302a	228a	864cd	1360def	103.3a
100 mM	Without	896a	163a	586f	730e	72.7a	944a	188a	602e	780g	75.2a
	Ca- protinate 1%	1090a	192a	677e	940de	89.8a	1151a	221a	712ef	1060fg	100.1a
	Ca- nitro 1%	1038a	198a	679e	940de	85.5a	1139a	232a	726e	1090fg	96.5a
	Ca- chelate 0.5%	914a	185a	622ef	860e	74.9a	963a	216a	651ef	970g	82.3a
F. test		N.S	N.S	*	*	N.S	N.S	N.S	*	*	N.S

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.
N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Table (5): Effect of salinity and Ca foliar application on fruit yield parameters of tomato plants during 2007 and 2008 seasons

Treatments	Fruit yield parameters / plant							
	2007 Season				2008 Season			
Salinity (mM of NaCl)	Fruit yield g/plant	No. of fruits/ plant	Fruits with BER %	Average fruit wt.(g)	Fruit yield g/plant	No. of fruits/ plant	Fruits with BER %	Average fruit wt.(g)
0	950a	15.3a	3.0c	61.4a	1005a	20.3a	1.6c	49.6a
50	608b	14.0a	8.0b	43.4b	650b	17.3a	6.5b	37.1b
100	350c	10.8a	16.5a	32.3c	367c	12.8a	18.9a	28.8c
F. test	**	N.S	**	*	**	N.S	**	*
Ca foliar application								
Without	573a	13.0a	14.1a	41.1a	607a	16a	13.5a	36.2a
Ca- protinate 1%	653a	13.3a	7.5b	47.5a	697a	17a	7.5b	39.5a
Ca- nitro 1%	677a	13.3a	7.5b	49.5a	717a	17a	7.4b	39.9a
Ca- chelate 0.5%	640a	13.8a	7.5b	44.9a	676a	17a	7.4b	38.4a
F. test	N.S	N.S	*	N.S	N.S	N.S	*	N.S

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Effect of calcium foliar application:

Presented data in Table 5 and Fig.2 show the effect of foliar spray with calcium on yield and its components. It is obvious that, spraying tomato plants grown under saline condition with Ca-protinate, Ca-nitro and Ca-chelate led to non significant differences in fruit yield/plant, number of fruits/plant and average fruit weight.

Concerning BER (%), the same data in Table 5 indicate that number of fruits infected with BER (%) was significantly decreased by foliar spray with calcium as compared with the untreated plants. These findings provide an anatomical basis for the lowest Ca concentration in the distal placental tissue of tomato fruits, the primary site of BER (Adams and Ho, 1992). The obtained results are in harmony with those reported by Levent Tuna *et al,* (2007) on tomato and Khayyat *et al,* (2007) on strawberry.

Effect of the interaction between salinity and calcium foliar application: Presented data in Table 6 indicate that the interaction between salinity levels and calcium foliar application had a significant effect on yield and its components; i.e., fruit yield per plant and average fruit weight. Meantime, the interaction between 0.0 mM NaCl and all tested concentrations of calcium foliar application were the superior treatments regarding fruit yield, number of fruits/plant and average fruit weight. As it has been mentioned above, higher levels of salinity inhibited fruit yield parameters.

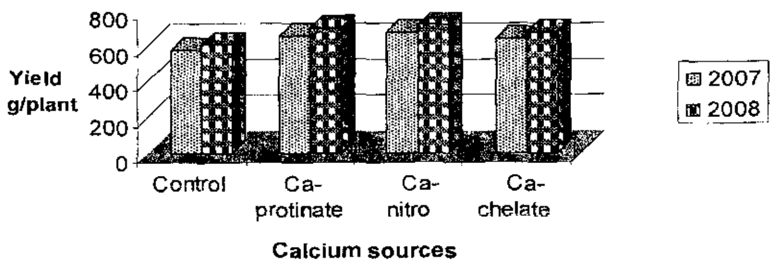

Fig. 2: Effect of Ca sources on fruit yield of tomato (g/plant) during 2007 and 2008 seasons

Table (6): Effect of the interaction between salinity and Ca foliar application on fruit yield parameters of tomato plants during 2007and 2008 seasons

Treatments		Fruit yield parameters / plant							
		2007 Season				2008Season			
Salinity(mM of NaCl)	Ca foliar application	Fruit yield (g/plant)	No. of fruits/ plant	Fruits with BER (%)	Average fruit wt.(g)	Fruit yield (g/plant)	No. of fruits/ plant	Fruits with BER (%)	Average fruit wt.(g)
0 mM	Without	880b	16a	6.7d	55.0ab	930b	19a	2.6e	48.9a
	Ca- protinate 1%	970a	15a	1.7e	64.7a	1030a	21a	1.2e	49.1a
	Ca- nitro 1%	990a	15a	1.7e	66.0a	1050a	21a	1.2e	50.0a
	Ca- chelate 0.5%	960a	16a	1.7e	60.0ab	1010a	20a	1.2e	50.5a
50 mM	Without	550d	14a	10.6cd	39.3cde	590d	17a	8.8cd	34.7bc
	Ca- protinate 1%	620c	14a	7.1d	44.3bcd	670c	17a	5.9de	39.4b
	Ca- nitro 1%	650bc	14a	7.3d	46.4bcd	690c	18a	5.6de	38.3b
	Ca- chelate 0.5%	610c	14a	7.1d	43.6bcd	650c	18a	5.6de	36.1bc
100 mM	Without	290e	10a	25.0a	29.0e	300f	12a	29.2a	25.0d
	Ca- protinate 1%	370e	11a	13.6bc	33.6e	390e	13a	15.4bc	30.0bcd
	Ca- nitro 1%	390e	11a	13.6bc	35.5e	410e	13a	15.4bc	31.5bcd
	Ca- chelate 0.5%	350e	11a	13.6bc	31.2e	370e	13a	15.4bc	28.5cd
F. test		*	N.S	**	*	*	N.S	**	*

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.
N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Fruit quality

Effect of salinity:

Obtained results in Table 7 reveal that TSS and titratable acidity % were significantly increased by increasing the level of NaCl in the nutrient Solution; the highest values of TSS and titratable acidity % were accomplished from the plants which treated with 100mM NaCl in the nutrient solution. As for calcium content, presented data in Table 7 indicate that it was significantly decreased by increasing NaCl level in the nutrient solution.

The negative effects of salinity on fruit quality are well-known and are often related to a low uptake of calcium, decreasing translocation of this element through xylem or an unfavorable partitioning of cations in plant tissues (Sonneveld 1988).The obtained results are in harmony with those reported by Adams (1991), Soliman and Doss (1992),Satti *et al.* (1994), Fathy *et al.* (2005) and Tantawy *et al.* (2009).

Effect of calcium foliar application:

The effect of calcium foliar application on TSS, titratable acidity, dry matter and calcium % in both seasons of study are presented in Table 7. It can be seen from such data that spraying tomato plants with Ca-protinate, Ca-nitro and Ca-chelate led to significant effect on fruit Ca % as compared with the control with non significant differences between the three sources of calcium, but it did not reflect any significant effect on TSS, titratable acidity and dry matter %. These results contradicted with those reported by Levent Tuna *et al.* (2007).

Effect of the interaction between salinity and calcium foliar application:

Presented data in Table 8 indicate that the interaction between NaCl levels in the nutrient solution and calcium foliar application had significant effect on TSS in the first season and calcium % in both seasons of study. The interaction between NaCl at a rate of 0.0 mM and different sources of calcium gave the highest values of fruit calcium content%, while the interaction between NaCl at a rate of 100 mM and Ca-chelate at 0.5% recorded the highest values of TSS. Proline and Leaf Mineral Concentration.

Table (7): Effect of salinity and Ca foliar application on fruit quality characteristics of tomato plants during 2007and 2008 seasons

Treatments	Fruit quality							
	2007 Season				2008 Season			
Salinity (mM of NaCl)	T.S.S (%)	Titratable acidity (%)	Dry matter (%)	Calcium (%)	T.S.S (%)	Titratable acidity (%)	Dry matter (%)	Calcium (%)
0	6.4a	0.67c	5.18a	0.24a	5.8b	0.60c	5.12a	0.21a
50	7.6a	0.76b	5.32a	0.15b	7.1a	0.66b	5.25a	0.17b
100	8.1a	0.84a	5.36a	0.12b	7.8a	0.76a	5.32a	0.11c
F. test	N.S	*	N.S	*	*	*	N.S	*
Ca foliar application								
Without	7.0a	0.75a	5.3a	0.13b	6.7a	0.66a	5.18a	0.12b
Ca- protinate 1%	7.3a	0.73a	5.2a	0.18a	6.9a	0.65a	5.22a	0.19a
Ca- nitro 1%	7.5a	0.77a	5.3a	0.19a	7.0a	0.68a	5.26a	0.19a
Ca- chelate 0.5%	7.5a	0.76a	5.3a	0.17a	6.9a	0.69a	5.27a	0.18a
F. test	N.S	N.S	N.S	*	N.S	N.S	N.S	*

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.
N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Table (8): Effect of the interaction between salinity and Ca foliar application on fruit quality characteristics of tomato plants during 2007and 2008seasons

Treatments		Fruit quality							
		2006 Season				2007 Season			
Salinity (mM of NaCl)	Ca foliar application	T.S.S (%)	Titratable acidity (%)	Dry matter (%)	Calcium (%)	T.S.S (%)	Titratable acidity (%)	Dry matter (%)	Calcium (%)
0 mM	Without	5.6c	0.61a	5.18a	0.18ab	5.4a	0.56a	5.09a	0.17b
	Ca- protinate 1%	6.2c	0.64a	5.20a	0.26a	5.8a	0.58a	5.12a	0.26a
	Ca- nitro 1%	6.8bc	0.72a	5.16a	0.27a	6.0a	0.62a	5.14a	0.26a
	Ca- chelate 0.5%	6.8bc	0.71a	5.18a	0.24a	5.8a	0.62a	5.14a	0.26a
50 mM	Without	7.2b	0.72a	5.24a	0.13bc	6.8a	0.64a	5.16a	0.12c
	Ca- protinate 1%	7.6ab	0.76a	5.21a	0.16ab	7.2a	0.66a	5.22a	0.19b
	Ca- nitro 1%	7.8a	0.78a	5.23a	0.16ab	7.2a	0.65a	5.31a	0.18b
	Ca- chelate 0.5%	7.8a	0.74a	5.26a	0.15bc	7.2a	0.67a	5.32a	0.17b
100 mM	Without	8.2a	0.92a	5.33a	0.09d	7.8a	0.78a	5.30a	0.08d
	Ca- protinate 1%	8.0a	0.78a	5.32a	0.12c	7.8a	0.72a	5.32a	0.12c
	Ca- nitro 1%	8.0a	0.82a	5.41a	0.13bc	7.8a	0.76a	5.33a	0.12c
	Ca- chelate 0.5%	8.0a	0.82a	5.39a	0.12c	7.6a	0.79a	5.34a	0.11cd
F. test		*	N.S	N.S	*	N.S	N.S	N.S	*

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Effect of salinity:

Presented data in Table 9 show that NaCl levels in the nutrient solution had significant effect on K, Ca and Na % in tomato plant leaves. Tomato plants treated with 0.0 mM NaCl in the nutrient solution gave the highest values of K and Ca%, but it had the lowest values of Na% and proline content. Otherwise, NaCl at 100 mM gave the highest values of Na % and proline content.

Changes in proline levels in plants have been correlated with their ability to tolerate or adapt to saline conditions (Chowdhury *et al.,* 1993). The obtained results are in harmony with those reported by Ehret and Ho (1986).

Effect of calcium foliar application:

The effect of calcium foliar application on proline and leaf mineral concentration, i.e., N, P, K, Ca and Na in both seasons of study are presented in Table 9. It can be seen from such data that spraying tomato plants with different sources of calcium caused significant effect on Na and Ca % with non significant differences between the three sources of calcium, but it did not record any significant effect on N, P, K % and proline concentration. Similar results were obtained by Levent Tuna *et al.* (2007) on tomato.

Effect of the interaction between salinity and calcium foliar application:

The results listed in Table 10 clearly show that the interaction between NaCl levels in the nutrient solution and calcium foliar application had significant effect on Ca, Na and proline content in tomato leaves, the interaction between NaCl at 0.0 mM and different sources of calcium gave the highest values of Ca percentage, while the same results of Na and proline contents were recorded by the interaction between NaCl at 100 mM and different sources of calcium foliar application. On the other hand, the interaction treatments did not reflect any significant effect on N, P and K percentage in both seasons of study.

RECOMMENDATION

From the previous results of this investigation, it could be recommend that application of calcium as Ca-protinate or Ca-nitro at a rate of 1% for tomato plants grown under saline conditions were the superior treatments for enhancing growth, fruit yield and quality as compared with the other treatments.

Table (9): Effect of salinity and Ca foliar application on Proline and leaf mineral concentration of tomato plants during 2007and 2008 seasons

Treatments	Proline and leaf mineral concentration											
	2007 Season						2008 Season					
Salinity mM of NaCl	N%	P%	K%	Ca%	Na%	Proline ($mol\ g^{-1}$)	N%	P%	K%	Ca%	Na%	Proline ($mol\ g^{-1}$)
0	5.1a	0.22a	1.71a	2.52a	0.12c	0.53c	4.6a	0.22a	1.80a	2.62a	0.12c	0.50c
50	4.7a	0.21a	1.70a	1.62b	0.53b	2.35b	4.5a	0.20a	1.75a	1.59b	0.54b	2.28b
100	4.2a	0.20a	1.56b	1.03c	1.88a	4.90a	4.2a	0.21a	1.56b	1.02c	1.86a	4.95a
F. test	N.S	N.S	*	*	*	**	N.S	N.S	*	*	*	**
Ca foliar application												
Without	4.1b	0.19a	1.62a	1.46b	0.84a	2.57a	4.0b	0.20a	1.68a	1.47b	0.90a	2.57a
Ca- protinate 1%	5.0a	0.21a	1.66a	1.82a	0.86a	2.57a	4.7a	0.23a	1.70a	1.85a	0.82a	2.57a
Ca- nitro 1%	5.1a	0.22a	1.66a	1.83a	0.83a	2.62a	4.7a	0.23a	1.73a	1.84a	0.82a	2.58a
Ca- chelate 0.5%	4.3b	0.21a	1.69a	1.77a	0.83a	2.57a	4.3b	0.21a	1.69a	1.83a	0.82a	2.58a
F. test	*	N.S	N.S	*	N.S	N.S	*	N.S	N.S	*	N.S	N.S

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

Table (10): Effect of the interaction between salinity and Ca foliar application on proline and leaf mineral concentration of tomato plants during 2007and 2008 seasons.

Salinity mM of NaCl	Ca foliar application	2007 Season N%	P%	K%	Ca%	Na%	Proline (mol g^{-1})	2008 Season N%	P%	K%	Ca%	Na%	Proline (mol g^{-1})
0 mM	Without	4.2a	0.20a	1.72a	2.02b	0.13c	0.56c	4.0a	0.21a	1.81a	2.12b	0.14c	0.48c
	Ca- protinate 1%	5.6a	0.22a	1.73a	2.78a	0.11c	0.50c	4.9a	0.23a	1.78a	2.86a	0.12c	0.50c
	Ca- nitro 1%	5.8a	0.23a	1.65a	2.69a	0.11c	0.54c	4.9a	0.23a	1.79a	2.79a	0.11c	0.52c
	Ca- chelate 0.5%	4.7a	0.21a	1.70a	2.58a	0.12c	0.52c	4.5a	0.22a	1.80a	2.75a	0.11c	0.51c
50 mM	Without	4.1a	0.20a	1.61a	1.34cd	0.52b	2.28b	4.0a	0.20a	1.70a	1.28cde	0.58b	2.26b
	Ca- protinate 1%	5.2a	0.21a	1.70a	1.66bc	0.54b	2.30b	4.8a	0.20a	1.74a	1.68bc	0.52b	2.28b
	Ca- nitro 1%	5.1a	0.21a	1.72a	1.68bc	0.52b	2.41b	4.8a	0.20a	1.78a	1.70bc	0.52b	2.29b
	Ca- chelate 0.5%	4.2a	0.21a	1.78a	1.70bc	0.52b	2.41b	4.4a	0.20a	1.76a	1.70bc	0.52b	2.29b
100 mM	Without	4.0a	0.18a	1.52a	1.02d	1.88a	4.88a	4.1a	0.19a	1.52a	1.02e	1.98a	4.96a
	Ca- protinate 1%	4.4a	0.20a	1.56a	1.02d	1.92a	4.92a	4.3a	0.22a	1.58a	1.00e	1.82a	4.94a
	Ca- nitro 1%	4.5a	0.21a	1.58a	1.02d	1.86a	4.92a	4.4a	0.22a	1.62a	1.04e	1.82a	4.94a
	Ca- chelate 0.5%	4.0a	0.21a	1.58a	1.04d	1.86a	4.88a	4.1a	0.22a	1.52a	1.03e	1.82a	4.94a
F. test		N.S	N.S	N.S	*	*	*	N.S	N.S	N.S	*	*	*

Values having the same alphabetical letter (s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

N.S= not significant, *, ** significant at 0.05 and 0.01 level of probability, respectively.

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تأثير الملوحة و الرش الورقى بالكالسيوم على النمو والمحصول وجودة الثمار فى الطماطم

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الملخص العربي:

أجريت هذه الدراسة خلال الموسم الصيفى المبكر لعامى ٢٠٠٧ و ٢٠٠٨ فى المزرعة البحثية بكلية الزراعة بدمنهور، جامعة الإسكندرية، وذلك لدراسة تأثير المعاملة بتركيزات مختلفة من الملوحة فى المحلول المغذى وهى صفر، ٥٠، ١٠٠ مللى مول من كلوريد الصوديوم و الرش الورقى بثلاثة مصادر مختلفة للكالسيوم وهى بروتينات كالسيوم و نيترو كالسيوم بتركيز ١% و الكالسيوم المخلبى بتركيز ٠,٥ % والتفاعل بينهم على النمو الخضرى و الوزن الجاف والمحصول وجودة الثمار بالإضافة إلى المحتوى من العناصرفى أوراق نباتات الطماطم صنف كاسيل روك.

أدت الزيادة فى مستوى كلوريد الصوديوم فى المحلول المغذى من صفر إلى ١٠٠ مللى مول إلى انخفاضا معنويا فى صفات النمو الخضرى، مساحة الورقة، الوزن الجاف للنبات، صفات المحصول الثمرى، محتوى الثمار من الكالسيوم وكذلك محتوى الأوراق من البوتاسيوم والكالسيوم. وعلى الجانب الآخر، سجلت معاملة نباتات الطماطم بكلوريد الصوديوم بتركيز ١٠٠ مللى مول فى المحلول المغذى أعلى القيم بالنسبة لعدد الثمار المصابة بعفن الطرف الزهرى، المواد الصلبة الذائبة الكلية و الحموضة الكلية فى الثمار وكذلك محتوى الأوراق من الصوديوم والبرولين.

سجلت المعاملات الثلاثة للتغذية الورقية بالكالسيوم تأثيرا معنويا منشطا بالنسبة لصفات النمو الخضرى، نسبة الثمار المصابة بعفن الطرف الزهرى وكذلك محتوى الأوراق من الكالسيوم والصوديوم.

سجلت معاملات التفاعل بين كلوريد الصوديوم بتركيز ١٠٠ مللى مول فى المحلول المغذى والمصادر المختلفة للتغذية الورقية بالكالسيوم تأثيرا معنويا منشطا على معظم الصفات المدروسة لنباتات الطماطم. بينما سجلت نفس المعاملات أقل القيم بالنسبة للمواد الصلبة الذائبة الكلية فى الثمار فى الموسم الأول ومحتوى الأوراق من الصوديوم والبرولين فى كلا الموسمين.