JOHP

Journal of Ornamental and Horticultural Plants
Available online on: www.jornamental.com
ISSN (Print): 2251-6433
ISSN (Online): 2251-6441

Effect of Calcium Chloride on Growth and Yield of Tomato under Sodium Chloride Stress

A.Lolaei[1*]
Young Researchers Club, Islamic Azad University, Gorgan Branch, Gorgan, Iran.

Received: 12 March 2012 Accepted: 4 August 2012
*Corresponding author's email: lolaei.abolfazl@gmail.com

Abstract

The effects of salinity and supplied calcium chloride on growth and leaf ions concentration of tomato (*Lycopersicon esculentum* L.) were investigated in Gorgan, Iran. A factorial experiment was conducted based on RCBD with four NaCl levels (0, 50, 100, and 150 mM) and four $CaCl_2$ levels (0, 100, 200 and 300 mg L^{-1}). Data of growth, yield and leaf's Ca, K, and Na content were subjected to analyze of variance. The results showed that fruit yield decreased under salinity stress. Increasing Ca^{2+} concentration in the nutrient solution increased the fruit yield. Leaf Ca^{2+}, K^+, and N content decreased under salinity stress. Tomato in its response to nutrient solution, salinized with sodium chloride and calcium chloride. The results obtained from this experiment show that salinity stress caused a significant reduction in plant growth, leaf number and fruit weight.

Keywords: Fruit number, Ion concentrations, *Lycopersicon esculentum*, Salinity stress.

INTRODUCTION

Soil salinity is one of the major problems in the world for agricultural production (Epstein *et al.,* 1980). Tomato (*Lycopersiconesculentum*) is an important crop in many countriesand have grate economic importance (Marsic and Osvald, 2004). Calcium has been reported to play a significant role in the salinity tolerance and growth of cotton (Zhong and Lauchli, 1993; Cramer, *et al.,* 1987).Calcium ion is not only an essential structural element that strengthens plant cell walls and membranes but also,is a well known secondary messenger in cell signaling processes (White and Broadley, 2003). In the case of Ca deficiency, fruit quality and yield are reduced. Blossom-end rot, a physiological disorder, is associated with low calcium uptake (Adams and Ho, 1993). Calcium is an essential and micro nutrient, which fulfills a fundamental role in plant membrane stability and cell wall-stabilization (Hirschi, 2004). Increasing Ca^{2+} concentration in the nutrient solution, increased leaf areaandfruit fresh weight (Rubio *et al.*, 2009). Many crops including tomato, are susceptible to cell damage because of high salinity (Cuartero and Fernandez, 1999). The effect of salinity on fruit quality has been reported in horticultural crops (Krauss *et al.*, 2006).Chemical attributes of fruit quality horticultural crops such as of pepper have been reduced by salinity treatment (Maggio *et al*., 2004; Colla *et al.*, 2006). Irrigation management is an approach to improve salinity tolerance in crops (Paranychianakis and Chartzoulakis, 2005). This research was done in order to study the role of Ca^{2+} nutrition on the aggregation of salt in tomato.

MATERIALS AND METHODS

This study was conducted using a factorial experimentbased on a randomized complete block design with three replications and 108 plants which were planted in a greenhouse. As four leaves were fully expanded, the plantlets were transferred to the greenhouse. The media was a mixture of perlite and vermiculite (1:1 v/v). Tomatoes were initially irrigated daily for 21 days, but afterthe period of acclimation, were irrigated twice a week with different salinity concentrations. The greenhouse condition was natural sunlight during spring and summer and the temperature was set at 23.8°C on days and 17.8°C atnights. The treatments were imposed after transplanting the plants. The concentration of nutrients in solutions consisted offour NaCl levels (0, 50, 100, and 150 mM) in combination with four Ca concentrations (0, 100, 200 and 300 mg L^{-1}). The changes in Ca:Na ratio, were balanced by varying the levels of Ca and salinity. After fifty days of the treatments initiation, five leaves of each plant were randomly sampled forevaluation of Ca, K, N and Na concentration. To obtain total yieldaverageweightoffruitsperplantwere recorded and thus, yield per plantwas measured. At the end of the experiment, the fresh weight was recorded and the number of leaves per plant wereencountered. Statistical analysis of the results was performed using a one-way analysis of variance (ANOVA). Means comparisons has been carried out using the Tukey test ($P < 0.01$) (SPSS commercial software, SPSS Inc).

RESULTS AND DISCUSSION

Salinity reducedplants growth. Salinity significantly reduced leaf number, leaf fresh weight, leaf Ca and K concentrations and fruit yield in(number and weight of fruit per plant) as compared to the control.

Growth

Total growth, leaf number and leaf fresh weight per plant decreased significantly in 60 mM-NaCl treatment. Addition of Ca,increasedCa concentration in leaves and linearly increased total vegetative biomass and total leaf area per plant. Addition of 60 mMNaCl to nutrient solution significantly reduced leaf number from 29.5 (control) to 19.4 (Table 1). Addition of Ca to saline nutrient solution increased leaf number. However, leaf number increased only when Ca alone was applied to saline nutrient solution rather than NaCl treatment. Addition of NaCl to nutrient solution significantly reduced leaf fresh weight from 113.3g (control) to 59 g in 60 mMNaCl (Table 1). In salt-tolerant cultivars, increasing Ca,can be an effective tool to restore the decreased growth which is caused by high salinity. Ca (with or whithout salinity) increased leaf fresh weight. The reduction in plant growth, calcium and potassium concentrations showed the sensitivity of leaves to salinity stress.

It appears that, salinity affects plant's growth (Borsani *et al*., 2003). Most researchers have focused on the inhibitory role of Cl on plant growth. It is known that high NaCl,induces calcium deficiencies in different plants such as tomato (Navarro *et al.*, 2000). Possible causes of the salinity-induced reduction in CO_2 assimilation include (i) turgor reduction (ii) feedback repression on the Calvin Cycle (iii) Na –induced Kdeficiency and (iv) Na and/or Cl ion toxicity and caused decreased growth plant . Increasing N content,is accompanied by a high Ca uptake. To improve nitrogen efficiency, it is helpful to study the effects of different N rates on dry matter percent and fruit yield via a growth analysis (Scholberg *et al*., 2000).

Yeild

Fruityield was higher by calcium application at 150 mMrather than 50 and 100 mM. Addition of NaCl to nutrient solution, significantly reduced fruit yield in terms of number of fruits per plant from 8.13 (control) to 3.83. Both in presence of Ca or without it, increasing the salinity level in nutrient solution, decreased number of fruits (Table 1). However, fruit number per plant decreased by 5.7 and 3.8respectively, relative to the NaCl treatment. Ca^{2+} treatment had an opposite effect because increasing Ca^{2+} concentration in the nutrient solution increased the fruit production. Addition of NaCl to nutrient solution, significantly decreased fruit yield. Addition ofCa to saline nutrient solution increased fruit weight, relative to the control. However, fruit weight per plant increased by Ca application, relative to the NaCl treatment. Significant differences on fruit weight per plant were observed (Table 1).

High salt concentration in soil, inhibits crop growt and is one of the major problems in agricultural production in arid regions (Malash *et al*., 2008). The most recognizable Ca^{2+} deficiency which affects fruit production is little(Saure, 2001). Increasing of Ca^{2+} concentration in the plant medium under saline condition increased the number of fruits per plant and total yield fruit was affected because the fruit weight was increased (Rubio *et al.*, 2009). In stone-fruit trees, salinity-induced leaf injury has been attributed to reduce total plant yield. (Hoffman *et al.*, 1989).

Ca, Na, N and K concentration in leaf

The data of leaf ion concentration in relation to salinity and Ca levels are presented in Table 2. The application of Ca^{2+} increased concentration of Ca^{2+} and reduced Na+ concentration. Addition of NaCl to nutrient solution, reduced K concentration from 30. 4 (control) to 24.9mg / g dry matter (Table 2). When Ca was added to saline nutrient solution, K concentration decreased from 26.8 to 23.2 mg / g dry matter. The reduction in calcium and potassium concentration showed the sensitivity of such organ to salinity stress. In presentstudy, NaCl stress significantly reduced K and Ca content in plants. Addition of calcium to saline nutrient solution, increased calcium concentration in leaves and reducedCacontent in tomato's leaves.

On the other hand, addition of Ca to nutrient solutions containing NaCl, increased Ca concentration. When Ca was added, Ca concentration increased from 1.5 of (control) to 2.03mg/gdry matterin 150 Mm Ca^{2+} treatment. Na^{+} concentration in leaves increased in the high NaCl treatment, but it was reduced by calcium application. The highest Naconcentration in leaves, was observed in plants which was treatedby 60 Mm Na. Addition of NaCl to nutrient solution,decreasedCa and K content in leaves. When Ca was added, Na concentration decreased from 0.41 to 0.09 mg/ g dry matter. Salinity application, markedly increased Na^{+} and Cl^{-} concentration. Significant differences in nitrogen concentration in leaves between salt-treated and control plants were found after treatments. N reduction is accompanied by a high NaCl uptake from 28.8 to 23.3 mg / gdry matter.

Caincreased N concentration markedly (Table 2). It was reported that high NaCl concentration induced Ca^{2+} deficiencies in a broad range of crops such as tomato (Lopez and Satti, 1996). It was reported that, plants which are exposed to NaCl, inevitably absorb a large amount of Na, which-subsequently had reduction in K content (Hasegawa *et al.,* 2000). One of the primary plant responses to salinity is the decrease in K+ concentration in plant leaves (Gorham, 1993; Khatun and Flowers, 1995).Calcium has been shown to ameliorate the adverse effects of salinity on plants (Ehret *et al*., 1990). A reduction in K concentration and K/Na ratio in saline condition was reported by Rush and Epstein (1978). The reduction of N is accompanied by a high NaCl uptake .

ACKNOWLEDGEMENTS

The authors would like to thank The Department of SoilScience, Gorgan University, and The Horticulture Institute of Gorgan for their supports.

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Tables

Table 1. Effects of NaCl and $CaCl^2$ on leaf number and leaf fresh weight, number of fruit and fruit weight ratios of tomato

treatment	Leaf number	Leaf fresh weight (g)	Number of fruit	Fruit weight (g)
Ca =0/salinity=0	29.5 c	113.3 c	8.13 d	48.9 c
Ca =0/salinity=30	23.7 e	80.3 e	5.73 e	41.6 d
Ca =0/salinity=60	19.4 f	59 e	3.83 f	34.06 e
Ca =50/salinity=0	32.6 b	124 b	10.43 c	50.5 c
Ca =50/salinity=30	27.8 d	90 d	8.2 d	42.3 d
Ca =50/Salinity=60	21.3 e	79.6 e	8.1 d	37.56
Ca =100/salinity=0	34.6 a	128.6 b	12.4 b	54.6 b
Ca =100/salinity=30	29.06 c	88 d	9.5 cd	48.1 c
Ca =100/Salinity=60	26.46 d	82.66 d	9.13 cd	43.56
Ca =150/salinity=0	30.83 c	136 a	13.4 a	58.9 a
Ca =150/salinity=30	30.53 c	91.6 d	10.9 c	51.7 c
Ca =150/Salinity=60	30.16 c	85.6 d	10.5 c	49.3 c

Within each column, same letter indicates no significant difference among treatments ($p \leq 0.01$).

Table 2. Effects of NaCl and CaCl2 on Ca, Na, K and N concentrations in leaf of tomato

treatment	Ca %	Na%	K%	N%
Ca =0/Salinity=0	1.53 d	0.05 e	30.46 a	28.2 b
Ca =0/Salinity=30	1.35 e	0.24 b	28.43 b	25.1 c
Ca =0/Salinity=60	1.20 f	0.41 a	24.93 d	23 e
Ca =50/Salinity=0	1.80 c	5 c10.	28.4 b	29 ab
Ca =50/Salinity=30	1.39 e	0.21 b	26.83 c	26.5 c
Ca =50/Salinity=60	1.32 e	0.34 ab	25.56 c	24.3 d
Ca =100/Salinity=0	1.94 b	0.1 d	30.5 a	30.2 a
Ca =100/Salinity=30	1.44 d	0.18 c	28.23 b	28 b
Ca =100/Salinity=60	1.38 e	0.22 b	26 c	25 c
Ca =150/Salinity=0	2.1 a	0.09 d	27.43 bc	30.3 a
Ca =150/Salinity=30	1.51 d	0.14 c	24.73 d	27.6 b
Ca =150/Salinity=60	1.44 d	0.16 c	23.26 d	25.1 c

Within each column, same letter indicates no significant difference among treatments ($p \leq 0.01$).