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# The effects of $CaCl_2$ on fruit yield, quality and nutrient contents of tomato under NaCl stress conditions

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## Abstract

In this study, the effects of $CaCl_2$ on fruit yield, quality Ca/Na and K/Na ratios and Na content of tomato leaves under NaCl stress conditions were determined. The doses of 0, 6.8 and 16.8 mM $CaCl_2$ were combined with the doses of 0, 44.4, 70.4 mM NaCl in complete nutrient solution. General, NaCl and $CaCl_2$ decreased fruit yield, NaCl decreased stem amount, whereas it increased at 6.8 mM $CaCl_2$. $CaCl_2$ decreased fruit yield without NaCl, but it increased fruit yield significantly at 44.4 mM dose and caused tolerance to NaCl. The 6.8 mM dose of $CaCl_2$ increased stem amount without NaCl. However, $CaCl_2$ did not cause tolerance at high doses of NaCl in terms of growth. $CaCl_2$ decreased brix of fruit, while NaCl increased it. $CaCl_2$ increased brix without NaCl, but decreased it at 44.4 and 70.4 mM NaCl. $CaCl_2$ and NaCl decreased fruit juice pH significantly. Besides, $CaCl_2$ decreased fruit juice pH at 0 and 44.4 mM of NaCl. The number of fruits which were found to have blossom-end rot (NFBER) did not change without NaCl with the influence of $CaCl_2$. However, $CaCl_2$ applied at high doses of NaCl decreased the NFBER and provided tolerance to NaCl. Increasing dose of NaCl increased significantly the Na content in leaves, but the addition $CaCl_2$ decreased significantly the Na content in leaves. Increasing the dose of $CaCl_2$ applications at 0 and 44.4 mM NaCl levels increased the Ca/Na ratio in tomato leaves. But, the effect of $CaCl_2$ on Ca/Na ratio of leaves was statistically insignificant. The addition of NaCl into the solution nutrient decreased the Ca/Na and K/Na ratios in tomato leaves. The effect of $CaCl_2$ on the K/Na ratio of leaves was not found significant.

**Keywords**: Tomato, NaCl stress, tolerance, $CaCl_2$, yield, quality, Ca/Na, K/Na ratios

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## Introduction

Plants ability to grow and complete their life cycle in settings which contain very high concentrations of various soluble salts is called salt tolerance (Parida and Das, 2005). Salt tolerance is an indicator of resistance to salt stress and varies depending on the plant type, plant environment and the environmental conditions (Gürel and Avcıoğlu, 2001). In order to remove the negative effects of salinity, Tuna et al. (2007) recommended applying Ca and Türkmen et al. (2000) recommended applying K as healer materials in the growth setting.

Ca is an essential element for K/Na and Ca/Na selectivity and helps the prevention of the harmful effects of salinity by regulating ion transport in plants (Renault, 2005). Ca has been reported to be effective in preventing the harmful effects of NaCl in many types of plants (Tuna et al., 2007). Ca has been reported to ease K/Na selectivity and prevent NaCl toxicity by increasing this rate in case of being given to growth environment (Abdel Latef, 2011).

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According to recent studies, low levels of calcium in the root area of tomato is rarely a factor that limits vegetative growth (Del Amor and Marcelis, 2006). However, calcium nutrition of tomato requires a special attention because this nutrient is closely related to the formation of blossom-end rot, which is a physiological disorder. Blossom-end rot occurs as a result of local lack of calcium on the tip of the tomato plant and calcium deficiency in these areas cause disruption in tissue structure (Adams, 2002). Thus, blossom-end rot decreases the quality and saleability of the fruit (Grattan and Grieve, 1999).

Various factors including variety such as calcium, ammonium, potassium, magnesium, salt and salt stress, oxygen efficacy, relative humidity of air and air temperature can increase or decrease the formation of blossom-end rot (Navarro et al., 2005).

Extreme transpiration and temperature levels increase water intake and thus calcium transportation to leaves through xylem increases (Taylor et al., 2004). Still, under such circumstances the transportation of water to fruits decrease due to its rivaly with leaves. Thus, calcium transportation to fruit is limited at the same time. As a result, there occurs an increase in blossom-end rot (Adams, 2002).

Kaya et al. (2002) showed that Ca addition caused a decrease in the membrane permeability caused by saltiness. It has also been reported that Ca contents of plants showed deficiency in high NaCl levels and this deficiency was made up for by adding Ca. The adverse effects of saltiness on plants were prevented by Ca application, Na formed rivalry with Ca ion on the cell wall and thus high levels of Ca in high settings protected the cell membrane from the adverse effects of saltiness (Busch, 1995).

Jaleel et al. (2007) reported that $K^+$, $Ca^{+2}$ and $Mg^{+2}$ caused a decrease in the $Na^+$ of the plant and $NO_3^-$ decreased $Cl^-$ content of the plant. Jaleel et al. (2008) also reported that when NaCl and $CaCl_2$ were applied together, they increased antioxidant enzyme activity and $CaCl_2$ partly fixed the oxidative stress caused by salt.

One of the primary approaches used to decrease the effects of salt on plant growth nutrient addition and especially Ca addition has been reported to play an important role in removing the bad effect of salt on plant growth in glucofits (Yan et al. 1992). Calcium prevents K transportation and K/Na rate from decreasing by stabilizing plants exposed to Na. Significant interaction has been reported between Na and K on plant growth (Rengel, 1992).

In case of sufficient Ca in subtrate setting, K/Na selectivity has been stated to be affected in favor of K by improving K intake (Grattan and Grieve, 1999).

$Ca^{+2}$ ion is another basic element for growth and development. Salt stress affects $Ca^{+2}$ intake negatively, like $K^+$. $Na^+$ translocates with $Ca^{+2}$ in the cell membrane and helps the $Na^+/Ca^{+2}$ ion rate in the apoplast part of the membrane to increase. This causes a disruption in the physiological and functional structure of the membrane and $Ca^{+2}$ balance of the cell is affected. High $Na^+$ concentration frees $Ca^{+2}$ which are bound in the inner membrane structure of the cell and causes internal $Ca^{+2}$ stores to get empty and thus causes an increase in the free $Ca^{+2}$ in the cell (Yokoi et al., 2002).

Grattan and Grieve, (1999) stated that it was necessary to increase the $Ca^{+2}$ levels of plants in order to protect plants from NaCl toxicity. In addition, the authors emphasized the importance of having $Ca^{+2}$ ion concentration at optimum level in order to increase a plant's resistance to salt and stated that $Ca^{+2}$ had a protective effect on plant roots to help the plant to grow well.

In a study which was conducted by making an experiment of pots under climate room conditions to present the effects of salty seedling growing conditions on seedling development, the combinations of 0, 25, 50 and 100 mmol $L^{-1}$ NaCl and 0, 100, 200 and 400 mg $kg^{-1}$ $Ca^{+2}$ doses were applied on seedling growing. In the experiment, the effects of salt and calcium doses on the rate and period of blooming, real leaf apperance period, hypocotyl length, cotyledon length and width, offshoot and root length, offshoot and root weight and offshoot and root dry matter rate were examined. According to the results of the research, increasing doses of salt application had significant but negative effects in measurements and obervations, while increasing doses of calcium had positive but generally insignificant effects (Türkmen et al., 2002).

The purpose of this study is to find out the effects of $CaCl_2$ added to nutrient solutions on the yield, stem+leaf dry matter amount, fruit quality, ratios Ca/Na, K/Na and Na content of leaves tomato under increasing NaCl stress conditions.

## Material and Methods

In the experiment, as a growth media, turf and perlite were mixed with a rate of 1:1 and the prepared mixture was used. 770 g absolute dry growth mixture was put in pots of 3 litres which had a diameter of 1.65 cm and which were 19 cm deep. Holes were made at the bottoms of the pots for a good drainage. The experiment was conducted with a 3x3 factorial experimental design by applying 0-44.4 and 70.4 mM doses of NaCl and 0-6.8 and 16.8 mM doses of $CaCl_2.2H_2O$ in the nutrient solution.

For tomato, the macro element content of the nutrient solution was prepared according to Montesano and Van Iersel (2007) while micro element content was prepared according to the micro element values specified by Hoagland and Arnon (1950) for nutrient solution. Macro and micro nutrient element contents of the nutrient solution are as follows: 11.1 mM $NO_3^-$; 0.87 mM $H_2PO_4^-$; 6.37 mM $K^+$; 2.8 mM $Ca^{+2}$; 1.71 mM $Mg^{+2}$; 1.71 mM $SO_4^{-2}$; 2.5 mg $L^{-1}$ Fe; 0.5 mg $L^{-1}$ Mn; 0.5 mg $L^{-1}$ B; 0.02 mg $L^{-1}$ Cu; 0.05 mg $L^{-1}$ Zn; 0.01 mg $L^{-1}$ Mo. $Ca(NO_3)_2.4H_2O$, $KH_2PO_4$, $KNO_3$, $MgSO_4.7H_2O$, $MnCl_2.2H_2O$, $H_3BO_3$, $ZnSO_4.7H_2O$, $CuSO_4.5H_2O$, $(NH_4)_6Mo_7O_{27}.4H_2O$, Fe-EDDHA were used to prepare this nutrient solution.

pH and EC values of 9 different nutrient solutions prepared by adding increasing amounts of NaCl and increasing amounts of $CaCl_2$ in the nutrient solution were measured, and the values are given in Table 1.

In the experiment, each nutrient solution was applied with three repetitions. Tybiff Aq tomato seedlings were planted as one plant in each pot on 15.04.2013. After planting, 100 ml nutrient solution was applied to each pot for 35 days until 20.05.2013, and 200 ml nutrient solution was applied until harvest.

In the experiment, the pots were irrigated in a way that a small amount of water would be drained and the setting was continuously kept as a field capacity.

The last fruit harvest of the tomato plant was made on 17.07.2013 and fresh fruit weights were measured. After the harvest, stem samples were taken and dried at 65 °C, dry matter of stem was measured. The contents of Na and K in the leaf samples were determined by flamephotometer and the Ca content was determined by atomic absorption spectrophotometer according to Kacar (2014). Soluble solids in the fruit (brix) were measured in fruit juice using a refractometer and pH was measured with a glass electrode pH meter. The number of fruits with blossom-end rot per plant was found by counting the rotten fruit in each plant. The data obtained from 3x3 factorial experiment was assessed with variance analysis and LSD test (Yurtsever, 1982).

## Results and Discussion

### The effects of $CaCl_2$ under increasing NaCl doses on the pH, EC and SAR of nutrient solution

The results related to the effect of $CaCl_2$ under increasing NaCl concentrations on the pH, EC and the Na adsorption ratio (SAR) of the nutrient solution are given in Table 1 and 2.

Table 1. The effects of $CaCl_2$ applied in increasing NaCl doses on the pH and EC of the nutrient solution

| $CaCl_2$ (mM) | pH | | | | EC(dS/m) | | | |
|---|---|---|---|---|---|---|---|---|
| | NaCl (mM) | | | | NaCl (mM) | | | |
| | 0 | 44.4 | 70.4 | Ave. | 0 | 44.4 | 70.4 | Ave. |
| 0 | 6.09 | 5.94 | 5.87 | 5.96 | 1.63 | 4.30 | 7.10 | 4.34 |
| 6,8 | 5.65 | 5.72 | 5.65 | 5.67 | 2.22 | 3.87 | 5.43 | 3.84 |
| 16,8 | 5.59 | 5.78 | 5.76 | 5.71 | 2.73 | 4.77 | 6.13 | 4.54 |
| Ort. | 5.44 | 5.81 | 5.76 | - | 2.19**c***| 4.30**b** | 6.22**a** | - |
| $LSD_{0,05}$ NaCl:0.66 | | | | | | | | |

* There is no difference at the level of 0.05 between averages shown with the same letters

The effects of $CaCl_2$ and NaCl doses on the pH of the nutrient solution were found to be insignificant (Table 1). pH values of 9 different nutrient solutions were found to be between 5.59 and 6.09. The effect of $CaCl_2$ on the EC value of the nutrient solution was found to be insignificant. However, EC of the nutrient solution increased with increasing NaCl dose. EC value of the 9 different nutrient solutions prepared by applying 0, 6.8 and 16.8 mM $CaCl_2$ to the nutrient solution at increasing NaCl doses varied between1.63 and 7.10 $dSm^{-1}$. SAR of the nutrient solution varied between 0 and 33.2 (Table 2).

Table 2. The effects of $CaCl_2$ applied in increasing NaCl doses on the Na adsorption ratio (SAR) of the nutrient solution

| $CaCl_2$ (mM) | Na adsorption ratio (SAR) NaCl (mM) | | |
|---|---|---|---|
| | 0 | 44.4 | 70.4 |
| 0.0 | 0.0 | 20.9 | 33.2 |
| 6.8 | 0.0 | 13.2 | 21.0 |
| 16.8 | 0.0 | 9.6 | 15.2 |

## The effect of $CaCl_2$ under increasing NaCl salt stress on the fruit yield of tomato

The effects of $CaCl_2$ under increasing NaCl stress on the fruit yield are given in Table 3.

Table 3. The effect of $CaCl_2$ under increasing NaCl salt stress on the fruit yield, stem+leaf amount of tomato plant

| $CaCl_2$ (mM) | Fruit yield, kg/plant NaCl (mM) | | | | Stem, g/plant NaCl (mM) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 44.4 | 70.4 | Ave. | 0 | 44.4 | 70.4 | Ave. |
| 0.0 | 1.41**a***| 0.86**fgh** | 0.81**gh** | 1.02**a** | 58.11**bc** | 41.77**d** | 27.81**e** | 42.56**b** |
| 6.8 | 1.31**b** | 0.98**de** | 0.77**h** | 1.02**a** | 65.56**a** | 41.50**d** | 30.69**e** | 45.92**a** |
| 16.8 | 1.03**d** | 0.91**ef** | 0.62**ı** | 0.85**b** | 53.43**c** | 29.69**e** | 29.87**e** | 37.66**c** |
| Ort. | 1.25**a** | 0.89**b** | 0.73**c** | | 59.03**a** | 37.65**b** | 29.45**c** | |
| | $LSD_{0.05}CaCl_2$ : 0.052 | | | | $LSD_{0.05}CaCl_2$ : 2.85 | | | |
| | $LSD_{0.05}NaCl$: 0.052 | | | | $LSD_{0.05}NaCl$: 2.85 | | | |
| | $LSD_{0.05}CaCl_2xNaCl$: 0.09 | | | | $LSD_{0.05}CaCl_2xNaCl$: 4.94 | | | |

* There is no difference at the level of 0.05 between averages shown with the same letters.

Increasing doses of $CaCl_2$ applied to nutrient solution affected the fruit yield at the 0.01 level (Table 3). While mean fruit yields were 1.02 kg/plant in 0 and 6.8 mM $CaCl_2$ doses, it was 0.85 kg/plant in 16.8 mM $CaCl_2$ dose. Although the effect of 6.8 mM $CaCl_2$ dose on fruit yield was insignificant, 16.8 mM $CaCl_2$ dose decreased the fruit yield significantly. Increasing doses of NaCl applied on nutrient solution significantly decreased the fruit yield at 0.01 level. While fruit yield was (NaCl:0) 1.25 kg/plant in control, it decreased to 0.89 kg/plant in 44.4 mM NaCl dose and to 0.73 kg/plant in 70.4 mM NaCl dose.

Leonardi et al. (2004) examined the quality of tomato based on the NaCl content in nutrient solution and found that the EC of the nutrient solution was increased as 2.7-4.5-6.0-7.5-8.6 $dSm^{-1}$ and NaCl caused a decrease in yield but an increase in the soluble solid and dry matter content of the fruit. The researchers emphasized that salt stress affected yield level of tomato negatively, but had positive effects on blossoming. In addition, it was stated that salty water did not affect the nutrient properties such as carotenoid and antioxidant activity negatively. The effect of NaClx$CaCl_2$ interaction on fruit yield was found to be significant at 0.01 level. In other words, the effect of $CaCl_2$ on fruit yield was found to be dependent on NaCl doses. As the dose of $CaCl_2$ applied to nutrient solution without NaCl (NaCl:0) increased, fruit yield decreased. These decreases were statistically significant and they were found to be higher in high doses of $CaCl_2$. Increasing $CaCl_2$ doses applied to nutrient solution with 44.4 mM NaCl increased the fruit yield significantly and this increase was also found significant at 6.8 mM $CaCl_2$ dose. The fruit yield which was 0.86 kg/plant in control ($CaCl_2$:0) at 44.4 mM NaCl level increased 13.95% at 6.8 mM $CaCl_2$ dose and went up to 0.98 kg/plant and when $CaCl_2$ was applied at this dose, it increased the plant's tolerance to 44.4 mM NaCl.

Tabatabaeian (2014) reported that salinity in tomato decreased stem dry matter amount, the lowest yield was found at the level of 90 mmol/L NaCl and 10 mmol $L^{-1}$ $CaCl_2$ prevented salt damage in tomato. Kaya et al. (2002) stated that $CaCl_2$ application removed the negative effect of salinity on the growth and yield of the strawberry plant and reported that plant water use efficiency increased with Ca and decreased as NaCl increased. $CaCl_2$ applied to nutrient solution at 70.4 mM NaCl decreased the fruit yield. These decreases were found insignificant at 6.8 mM $CaCl_2$ dose, while they were found significant at 16.8 Mm $CaCl_2$ dose. $CaCl_2$ applied to nutrient solution when 70.4 mM NaCl was added did not provide tolerance to NaCl.

## The effect of $CaCl_2$ under increasing NaCl stress on the stem amount of tomato

The results of the effect of $CaCl_2$ under increasing NaCl stress on the stem dry matter amount of tomato plant are given in Table 3. $CaCl_2$ of increasing doses applied to nutrient solution increased stem amount significantly at the level of 0.01 (Table 3). While stem amount was 42.56 g/plant in control ($CaCl_2$:0), it increased to 45.92 g/plant in 6.8 mM $CaCl_2$ dose significantly. On the contrary, 16.8 mM $CaCl_2$ decreased yield to 37.66 g/plant. The effect of NaCl on stem amount was found to be significant at 0.01 level and as NaCl dose increased, stem amount decreased significantly. The effect of NaClx$CaCl_2$ interaction on stem+leaf amount was found to be significant at 0.01 level. In other words, the effect of $CaCl_2$ on stem amount was found to be dependent on NaCl doses.

Increasing doses of $CaCl_2$ applied to nutrient solution without NaCl (NaCl:0) increased the stem dry matter amount significantly at the dose of 6.8 mM but decreased at the dose of 16.8 mM; however, this decrease was found to be insignificant. $CaCl_2$ applied to nutrient solution with 44.4 mM NaCl did not affect the stem dry matter amount at the dose of 6.8 mM, but significantly decreased at the dose of 16.8 mM. $CaCl_2$ applied to nutrient solution with 70.4 mM NaCl increased the stem dry matter amount; however, this increase was found to be insignificant.

## The effect of $CaCl_2$ under increasing NaCl stress on the soluble solid (%) content of fruit (brix)

The results of the effect of $CaCl_2$ under increasing NaCl stress on the brix (%) content in tomato are given in Table 4.

Table 4. The effect of $CaCl_2$ under increasing NaCl salt stress on brix in the fruit of tomato and the content Na in leaves

| $CaCl_2$ (mM) | Brix in the fruit,% NaCl (mM) | | | | Na content in leaves,% NaCl (mM) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 44.4 | 70.4 | Ave. | 0 | 44.4 | 70.4 | Ave. |
| 0.0 | 4.3e* | 7.8a | 6.3b | 6.1a | 0.21 | 1.01 | 1.05 | 0.76a |
| 6.8 | 5.1d | 5.9bc | 5.0d | 5.3b | 0.14 | 0.59 | 0.80 | 0.51b |
| 16.8 | 5.7bc | 5.6cd | 5.4cd | 5.6b | 0.08 | 0.45 | 0.70 | 0.41b |
| Ort. | 5.0c | 6.4a | 5.6b | | 0.14c | 0.68b | 0.85a | |
| | $LSD_{0.05}CaCl_2$ : 0.36 | | | | $LSD_{0.05}CaCl_2$ : 0.12 | | | |
| | $LSD_{0.05}$NaCl: 0.36 | | | | $LSD_{0.05}$NaCl: 0.12 | | | |
| | $LSD_{0.05}CaCl_2$xNaCl: 0.62 | | | | | | | |

* There is no difference at the level of 0.05 between averages shown with the same letters

The effect of $CaCl_2$ added in nutrient solution on the soluble solid content of the plant was found to be significant at the level of 0.01. As a result of $CaCl_2$ addition to nutrient solution, a decrease was observed in soluble solid content and no difference was found between $CaCl_2$ doses in terms of their effects on soluble solid content. The effect of NaCl on the soluble solid content of the fruit was found to be significant at 0.01 level and NaCl addition was found to increase the soluble solid content of the fruit significantly. This increase was found to be higher at 44.4 mM NaCl dose. Thybo et al. (2006) reported that soluble solid (brix) values of greenhouse tomato were between 4.3-5.0 while Peet et al. (2004) reported that they were between 3.8 and 4.7. Soluble solid (brix) concentration and antioxidant content of the fruit was reported to increase as the level of salt increased.

The effect of NaClx$CaCl_2$ interaction on soluble solid rate was found to be significant at the level of 0.01. In other words, the effect of $CaCl_2$ on soluble solid rate was found to be dependent on NaCl doses. $CaCl_2$ of increasing doses applied to nutrient solution without NaCl (NaCl:0) increased the soluble solid rate significantly, the soluble solid rate which was 4.3% at control ($CaCl_2$:0) increased to 5.1% at 6.8 mM $CaCl_2$ dose and to 5.7% at 16.8 mM $CaCl_2$ dose. As the $CaCl_2$ dose added at levels of 44.4 and 70.4 mM NaCl increased, the soluble solid rate decreased significantly. No difference was found between $CaCl_2$ doses at levels of 44.4 and 70.4 mM NaCl in terms of their effects on the soluble solid rates. However, in tomato grown by applying $CaCl_2$ of 70.4 mM NaCl, the soluble solid rate was found to be lower.

## The effect of $CaCl_2$ under increasing NaCl stress on the fruit juice pH of tomato

The results of the effect of $CaCl_2$ under increasing NaCl salt stress on the fruit juice pH of tomato plant are given in Table 5.

The effect of $CaCl_2$ added in the nutrient solution on the fruit juice pH of tomato plant was found significant at the level of 0.01. As $CaCl_2$ dose increased, fruit pH decreased significantly; however, no difference was found between $CaCl_2$ doses in terms of their effect on fruit pH. The effect of NaCl added in the nutrient solution on fruit pH was found significant at the level of 0.01 and fruit pH was found to decrease significantly as NaCl dose increased.

Table 5. The effect of $CaCl_2$ under increasing NaCl salt stress on fruit juice pH and the number of fruits with blossom-end rot (BER)

| $CaCl_2$ (mM) | Fruit juice pH NaCl (mM) | | | | Fruit number with BER/plant NaCl (mM) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 44.4 | 70.4 | Ave. | 0 | 44.4 | 70.4 | Ave . |
| 0.0 | 4.29a | 4.05b | 3.92ef | 4.08a* | 7.0b | 13.6a | 5.0b | 8.5a |
| 6.8 | 4.04bc | 3.94def | 3.85f | 3.94b | 5.7b | 2.3c | 2.7c | 3.6b |
| 16.8 | 3.93ef | 3.95cde | 4.0bcde | 3.96b | 6.0b | 2.0c | 0.7c | 2.9b |
| Ort. | 4.09a | 3.98b | 3.92c | | 6.2a | 6.0a | 2.8b | |
| | $LSD_{0.05}CaCl_2$ : 0.057<br>$LSD_{0.05}NaCl$: 0.057<br>$LSD_{0.05}CaCl_2xNaCl$: 0.099 | | | | $LSD_{0.05}CaCl_2$ : 1.35<br>$LSD_{0.05}NaCl$: 1.35<br>$LSD_{0.05}CaCl_2xNaCl$: 2.33 | | | |

* There is no difference at the level of 0.05 between averages shown with the same letters

The effect of NaClx$CaCl_2$ interaction on fruit pH was found to be significant at the level of 0.01. In other words, the effect of $CaCl_2$ on fruit pH was found to be dependent on NaCl doses. Increasing doses of $CaCl_2$ without NaCl addition (NaCl:0) decreased fruit juice pH significantly. Similarly, increasing doses of $CaCl_2$ at the level of 44.4 mM NaCl decreased fruit juice pH significantly; however, the difference in the effect of $CaCl_2$ doses at this NaCl level on the fruit juice pH was not found to be significant. 6.8 mM $CaCl_2$ addition at the level of 70.4 mM NaCl decreased fruit juice pH; however, it was not found to be significant. On the other hand, 16.8 mM $CaCl_2$ at the level of 70.4 mM NaCl increased fruit juice pH and this increase was found to be insignificant when compared with the control.

## The effect of $CaCl_2$ under increasing NaCl salt stress on the number of fruits with blossom-end rot (NFBER)

The results of the effect of $CaCl_2$ under increasing NaCl salt stress on the number of fruits with blossom-end rot in tomato plant are given in Table 5. The effects of $CaCl_2$ added in the nutrient solution on the number of fruits with blossom-end rot were found to be significant at the level of 0.01. As $CaCl_2$ dose increased, the number of fruits with blossom-end rot was found to decrease significantly. The difference between $CaCl_2$ doses was not found to be significant in terms of their effects on the number of fruits with blossom-end rot. Similarly, the effects of NaCl on the number of fruits with blossom-end rot were found to be significant at the level of 0.01. The number of fruits with blossom-end rot was found to be lower at 70.4 mM NaCl dose, however, the number of fruits with blossom-end rot were found to be the same with the control at 44.4 mM NaCl dose. It was also reported that salt decreased yield in tomato and caused blossom-end rot and acidity was reported to increase with saltiness in tomato (Cuartero and Fernández-Muñoz, 1999).

The effect of NaClx$CaCl_2$ interaction on the number of fruits with blossom-end rot was found to be significant at the level of 0.01. The effect of $CaCl_2$ on the number of fruits with blossom-end rot was found to be dependent on NaCl doses. The effect of $CaCl_2$ added in the nutrient solution without NaCl addition (NaCl:0) on blossom-end rot was found to be insignificant. However, as the dose of $CaCl_2$ added at the levels of 44.4 and 70.4 mM NaCl increased, the number of fruits with blossom-end rot decreased.

The effect of $CaCl_2$ doses at these NaCl levels on the number of flowers with blossom-end rot was found to be similar or the same. Kacar and Katkat (2010) reported that Ca in the form of pectate had a primary duty on the strengthening of cell walls and plant tissues and Caldwell and Haug (1981) Ca made cell walls stronger by forming a bridge between the carboxyl and phosphate groups of phospolipids.

### The effect of $CaCl_2$ under increasing NaCl salt stress on the Na content and the Ca/Na, K/Na ratios of leaves

The results of the effect of $CaCl_2$ under increasing NaCl salt stress on the content of Na and the ratios of Ca/Na and K/Na of tomato leaves are given in Table 4 and Table 6, respectively. The effect of $CaCl_2$ and NaCl applied to the nutrient solution on the Na content was found statistically significant at 0.01 level. The addition of NaCl to the nutrient solution increased the Na content of leaves. The symptom toxicity in leaves was observed due to higher sodium content (Na content > 0.40%). The addition of $CaCl_2$ to the nutrient solution decreased the Na content of leaves. But this decrease in the Na content of leaves did not prevent the Na toxicity. The effect of NaClx$CaCl_2$ interaction on the Na content of leaves was found insignificant statistically. The $CaCl_2$ addition at the doses of 44.4 and 70.4 mM NaCl decreased the Na content of leaves, but this decrease was found insignificant statistically.

Table 6. The effect of $CaCl_2$ under increasing NaCl salt stress on the ratios Ca/Na and K/Na of tomato leaves

| $CaCl_2$ (mM) | Leaf Ca/Na ratio NaCl (mM) | | | | Leaf K/Na ratio NaCl (mM) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 44.4 | 70.4 | Ave. | 0 | 44.4 | 70.4 | Ave . |
| 0.0 | 28.29c | 3.21f | 2.33f | 11.28c | 4.37 | 0.37 | 0.64 | 1.76 |
| 6.8 | 44.63b | 8.78ef | 6.70ef | 20.04b | 4.95 | 0.78 | 0.88 | 2.20 |
| 16.8 | 91.98a | 15.25de | 7.27ef | 38.17a | 5.72 | 1.17 | 1.16 | 2.68 |
| Ort. | 54.97a | 9.08b | 5.43b | | 5.01a | 0.77b | 0.86b | |
| | $LSD_{0.05}CaCl_2$ : 6.60<br>$LSD_{0.05}NaCl$: 6.60<br>$LSD_{0.05}CaCl_2xNaCl$: 11.43 | | | | $LSD_{0.05}NaCl$: 0.98 | | | |

* There is no difference at the level of 0.05 between averages shown with the same letters

The effect of NaCl, $CaCl_2$ and $NaClxCaCl_2$ interaction on the Ca/Na and K/Na ratios of leaves were found significant statistically at 0.01 level. Increasing dose of NaCl decreased significantly the Ca/Na ratio of leaves. Increasing dose of $CaCl_2$ increased significantly the Ca/Na ratio of leaves. The effect of $CaCl_2$ on the Ca/Na ratio varied depend on the NaCl dose. Increasing dose of $CaCl_2$ at the levels of 0 and 44.4 mM NaCl increased the Ca/Na ratio significantly. But the effect of $CaCl_2$ on the Ca/Na ratio of leaves at the dose of 70.4 mM NaCl was not found significant. The effect of NaCl on the K/Na ratio of leaves was found significant statistically at 0.01 level. As the dose of NaCl increased, the K/Na ratio of leaves decreased significantly. The effect of $CaCl_2$ and $NaClxCaCl_2$ interaction on K/Na ratio of leaves was found insignificant. In order to decrease the uptake of sodium by plant at the growing media with higher salt, the elevation of calcium in growing media is important method for providing the tolerance of plant against salt. In general, it is determinated that the ratios of Ca/Na and K/Na of the plant which has tolerance to salt stress is higher. Especially, it is suggested that the ratios of Ca/Na, K/Na and sodium concentration of leaves and tissue is determinated for assess the degree of plant's tolerance against salt (Marschner, 1995; Daşgan et al., 2002). Yetişir and Uygur (2009) reported that the ratios of Ca/Na and K/Na in watermelon and zucchini genotype decreased with the application of salt. The researchers reported that the plants which have higher both dry matter and Ca/Na, K/Na ratios are resistant to the salt.

## Conclusion

In general, NaCl and $CaCl_2$ decreased fruit yield, NaCl decreased stem amount whereas $CaCl_2$ increased it at 6.8 mM. $CaCl_2$ decreased fruit yield without NaCl, but it increased fruit yield significantly at 44.4 mM dose and caused tolerance to NaCl. However, $CaCl_2$ did not cause tolerance at high doses of NaCl in terms of growth. Calcium chloride used together with sodium chloride reduces more than without sodium chloride the fruit yield and stem dry matter. $CaCl_2$ decreased brix of fruit, while NaCl increased it. $CaCl_2$ increased brix without NaCl, but decreased it at 44.4 and 70.4 mM NaCl. $CaCl_2$ and NaCl decreased fruit juice pH significantly. $CaCl_2$ applied at high doses of NaCl decreased the NFBER and provided tolerance to NaCl. Increasing dose of $CaCl_2$ increased significantly the Ca/Na ratio of leaves. The effect of $CaCl_2$ on the Ca/Na raito varied depend on the dose of NaCl. Increasing dose of $CaCl_2$ at the levels 0 and 44.4 mM NaCl increased the ratio Ca/Na significantly. But the effect of $CaCl_2$ on the ratio Ca/Na of leaves at the dose of 70.4 mM NaCl was not found significant. As the dose of NaCl increased, the K/Na ratio of leaves decreased significantly. The effect of $CaCl_2$ and $NaClxCaCl_2$ interaction on K/Na ratio of leaves was found insignificant.

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## References

Abdel Latef, A.A.H., 2011. Ameliorative effect of calcium chloride on growth, antioxidant enzymes, protein patterns and some metabolic activities of canola (*Brassica napus* L.) under seawater stress. *Journal of Plant Nutrition* 34(9): 1303-1320.

Adams, P., 2002. Nutritional control in hydroponics, In: D. Savvas, H. C. Passam (Eds). Hydroponic Production of Vegetables and Ornamentals. Embryo Publications, Athens, pp: 211-261.

Busch, D.S., 1995. Calcium regulation in plant cell and his role in signalling. *Annual Review of Plant Physiology and Plant Molecular Biology* 46: 95-102.

*Caldwell, C. R., Haug, A., 1981. Temperature dependence of the barley root plasma membrane-bound $Ca^{+2}$ and $Mg^{+2}$ dependent ATPase.* Physiologia Plantarum *53(2): 117-124*.

Cuartero, J., Fernández-Muñoz, R., 1999. Tomato and salinity. *Scientia Horticulturae* 78(1-4): 83-125.

Daşgan, H.Y,, Aktaş, H., Abak, K., Cakmak, I., 2002. Determination of screening techniques to salinity tolerance in tomatoes and investigation of genotype responses. *Plant Science* 163 (4): 695-703.

Del Amor, F.M., Marcelis, L.F.M., 2006. Differential effect of transpiration and Ca supply on growth and Ca concentration of tomato plants. *Scientia Horticulturae* 111(1): 17-23.

Grattan, S. V., Grieve, C. M., 1999. Mineral nutrient acquisition and response by plants grown in saline environments, In: Handbook of Plant and Crop Stress. M. Pessarakli (Ed). Marcel Dekker Inc., New York, USA. pp: 203-229.

Gürel, A., Avcıoğlu, R., 2001. Bitkilerde Strese Dayanıklılık Fizyolojisi. In: Bitki Biyoteknolojisi II, Genetik Mühendisliği ve Uygulamaları. S. Özcan, E. Gürel, M. Babaoğlu (Eds.). Selçuk Üniversitesi Vakfı Yayınları, Konya, Turkey. pp: 308-313. [in Turkish]

Hoagland, D.R., Arnon, D.I., 1950. The water-culture method for growing plants without soil. The Circular 347. California Agricultural Experiment Station, College of Agriculture, University of California, Berkeley, USA. 31 p.

Jaleel, C.A., Gopi, R., Manivannan, P., Panneerselvam, R., 2007. Antioxidative potentials as a protective mechanism in *Catharanthus roseus* (L.) G. Don. plants under salinity stress. *Turkish Journal of Botany* 31: 245–251.

Jaleel, C.A., Kishorekumar, A., Manivannan, P., Sankar, B., Gomathinayagam, M., Panneerselvam, R., 2008. Salt stress mitigation by calcium chloride in *Phyllanthus amarus*. *Acta Botanica Croatica* 67(1): 53–62.

Kacar, B., Katkat, V. A., 2010. Bitki Besleme. Nobel Yayınları No. 849, Ankara, Turkey. 678 p. [in Turkish]

Kacar, B., 2014. Bitki, Toprak ve Gübre Analizleri 2. Kolay Uygulanabilir Bitki Analizleri. Nobel Yayınları No. 910, Ankara, Turkey. 407 p. [in Turkish]

Kaya, C., Kirnak, H., Higgs, D., Saltali, K., 2002. Supplementary calcium enhances plant growth and fruit yield in strawberry cultivars grown at high (NaCl) salinity. *Scientia Horticulturae* 93(1): 65-74.

Leonardi, C., Martorana, M., Giuffirda, F., Fogliano, V., Pernice, R., 2004. Tomato fruit quality in relation to the content of sodium chloride in the nutrient solution. *Acta Horticulturae (ISHS)* 659: 769-774.

Marschner, H., 1995. Mineral nutrition of higher plants. 2nd Edition. Academic Press, London, UK. pp. 657-680.

Montesano, F., van Iersel, M.W., 2007. Calcium can prevent toxic effects of $Na^+$ on tomato leaf photosynthesis but does not restore growth. *Journal of the American Society for Horticultural Science* 132(3): 310–318.

Navarro, J.M., Flores, P., Carvajal, M., Martinez, V., 2005. Changes in quality and yield of tomato fruit with ammonium, bicarbonate and calcium fertilisation under saline conditions. *The Journal of Horticultural Science and Biotechnology* 80(3): 351-357.

Parida, A.K., Das, A.B., 2005. Salt tolerance and salinity effect on plant: a review. *Ecotoxicology and Environmental Safety* 60(3): 324-349.

Peet, M.M., Harlow, C.D., Larrea, E.S., 2004. Fruit quality and yield in five small-fruited greenhouse tomato cultivars under high fertilization regime. *Acta Horticulturae* 659, 811-818.

Renault, S., 2005. Response of red-oiser dogwood (*Cornus stolonifera*) seedlings to sodium sulphate salinity: effects of supplemental calcium. *Physiologia Plantarum* 123(1): 75-81.

Rengel, Z., 1992. The role of calcium in salt toxicity. *Plant Cell and Environment* 15(6): 625-632.

Tabatabaeian, J., 2014. Effect of calcium nutrition on reducing the effects of salinity on tomato plant. *American Journal of Plant Nutrition and Fertilization Technology* 4, 11-17.

Taylor, M. D., Locascio, S. J., Alligood, M. R., 2004. Blossom-end rot incidence of tomato as affected by irrigation quantity, calcium source, and reduced potassium. *HortScience* 39(5): 1110-1115.

Thybo, A. K., Edelenbos, M., Christensen, L. P., Sorensen, J. N., Thorup-Kristensen, K., 2006. Effect of growing systems on sensory quality and chemical composition of tomatoes. *LWT - Food Science and Technology* 39(8): 835-843.

Tuna, A. L., Kaya, C., Ashraf, M., Altunlu, H., Yokas, I., Yağmur, B., 2007. The effects of calcium sulphate on growth, membrane stability and nutrient uptake of tomato plants grown under salt stress. *Environmental and Experimental Botany* 59(2): 173-178.

Türkmen, Ö., Şensoy, S., Erdal, İ., 2000. Effect of potassium on emergence and seedling growth of cucumber grown in salty conditions. *Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Tarım Bilimleri Dergisi* 10(1): 113-117.

Türkmen, Ö., Şensoy, S., Erdal, İ., Kabay, T., 2002. Kalsiyum uygulamalarının tuzlu fide yetiştirme ortamlarında domateste çıkış ve fide gelişimi üzerine etkileri. *Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Tarım Bilimleri Dergisi* 12(2): 53-57. [in Turkish]

Yan, F., Schubert, S., Mengel, K., 1992. Effect of low root medium pH on net proton release, root respiration and root growth of corn (*Zea mays* L.) and broad bean (*Vicia faba* L.). *Plant Physiology* 99(2): 415-421.

Yetişir, H., Uygur, V., 2009. Plant growth and mineral element concentration of different gourd species and watermelon under salinity stress. *Turkish Journal of Agriculture and Forestry* 33: 65-77.

Yokoi, S., Bressan, R. A., Hasegawa, P. M., 2002. Salt stress tolerance of plants. JIRCAS Working Report. 25-33. Available at [Access date : 15.05.2016]: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.528.5895&rep=rep1&type=pdf

Yurtsever, N., 1982. Tarla Deneme Tekniği. Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü Yayınları, Yayın No: 91, Ankara, 121p. [in Turkish]