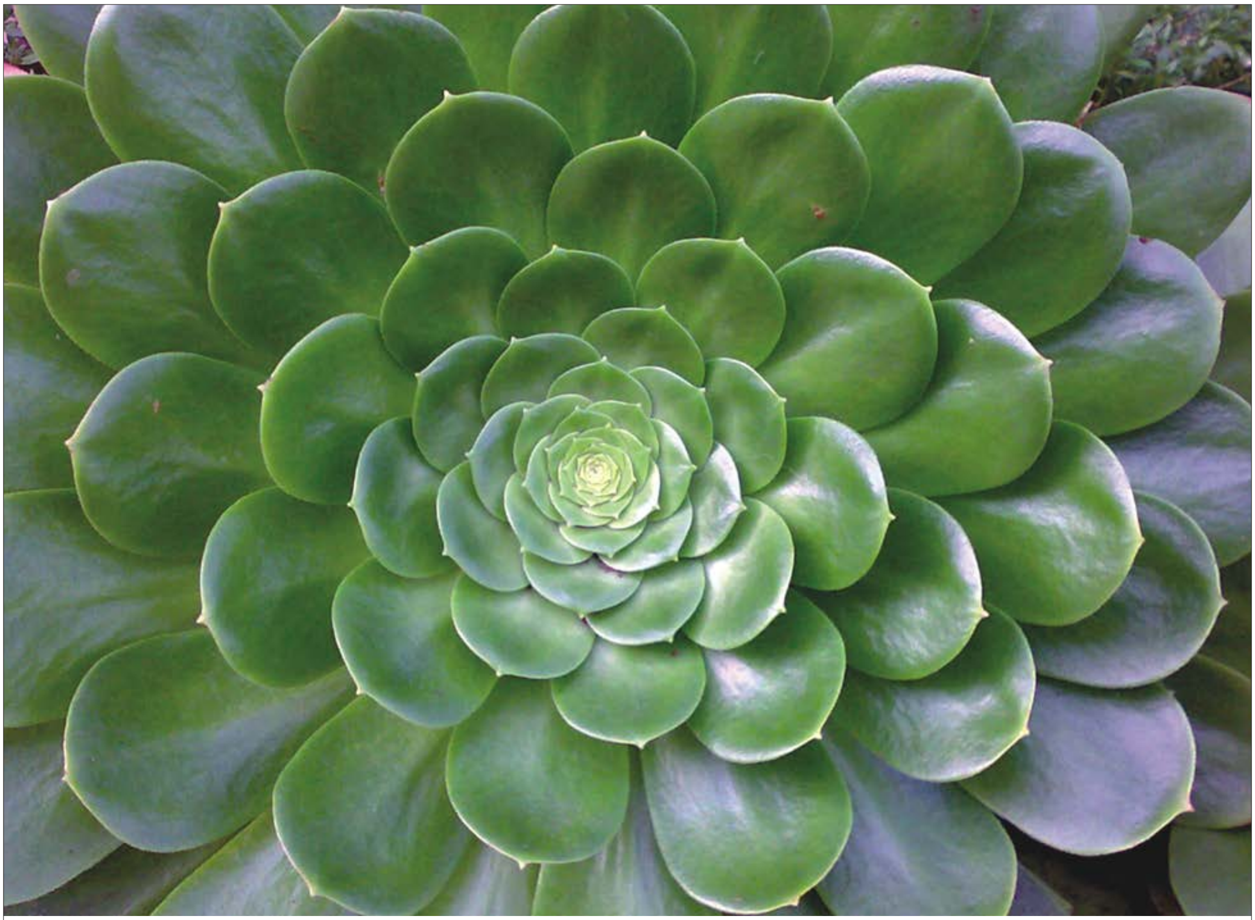

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Response of Tomato Plant Under Salt Stress: Role of Exogenous Calcium

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ABSTRACT

Salt stress is one of the most devastating abiotic stress which severely affects the agricultural productivity in various ways. A study was undertaken to investigate the tolerance and mitigation of salt stress in tomato by exogenous application of calcium (Ca^{2+}). The experimental results showed that salt stress significantly affects morphology, physiology and fruit weight of tomato. Plant height, leaf number and branch number/plant were decreased with increased levels of salinity mostly at 6 and 8 dS m^{-1}. Salinity also adversely affected the shoot dry weight, leaf area, leaf chlorophyll content and also fruit weight/plant mostly at 8 dS m^{-1}. Exogenous application of Ca^{2+} significantly mitigates the adverse effects of salinity on plant biomass production or morphology, physiology and fruit production. The plant height, leaf number/plant, branch number/plant, dry weight of shoot/plant, leaf chlorophyll content, fruit weight/plant were increased with the application of calcium in saline condition compared to without calcium. The fruit weight of tomato is gradually decreased with the increased levels of salinity. In case of treatment combinations, the reduction rate of fruit weight of tomato was decreased with increased levels of Ca^{2+} in response to different saline conditions and the lowest fruit weight was recorded at the highest salinity level (8 dS m^{-1}) along with without Ca^{2+}.

Key words: Calcium, leaf area, *Lycopersicon esculentum,* salt stress, salt tolerant

INTRODUCTION

Salinity is one of the major abiotic stress factors that limit the plant growth as well as fruit yield (Parida and Das, 2005). Salinity disturbs the physiology of plants by changing the metabolism of plants (Garg *et al*., 2002), causing cell injury in transpiring leaves, thus reducing growth of plant (Munns, 2005). Salinity badly reduces leaf area, accumulation of dry matter content and also reduces net rate of CO_2 assimilation (Murillo-Amador *et al*., 2000) as well as fruit production. Separately, plants have developed a well-organized defense mechanism of biochemical and physiological processes to protect themselves from the salinity-induced damages including antioxidant responses, ionic homoeostasis and/or osmoregulation (Hasegawa *et al*., 2000; Parida and Das, 2005).

Calcium (Ca) is a signaling molecule and acts as a second messenger which is increased in the cytosol by activating influx channel both in the plasma membrane and tonoplast and plays a significant role in mediating mechanisms involved in recognition and response to abiotic stresses in plants (Kader and Lindberg, 2010). In addition, Hussain *et al.* (2010) and Lazof and Bernstein (1998) reported that Ca^{2+} restrict the entry of Na^+ into the plant cells under sodium stress. The Ca^{2+} has a pivotal participation in salt stress signaling that controls ion homeostasis pathways (Yokoi *et al.*, 2002). It was confirmed by Ca^{2+}-dependent activation of phosphatase leading to transcription of the ENA1 gene, which encodes the P-type ATPase (Mendoza *et al.*, 1994). These findings suggest that calcium can mitigate the sodium toxicity of plant. Many authors stated that exogenous calcium alleviates stress in *Vigna radiata*, *Glycine max*, *Linum usitatissimum* (Manivannan *et al.,* 2007; Arshi *et al.*, 2010; Khan *et al.*, 2010).

In addition, the gypsum ($CaSO_4.2H_2O$) has been exogenously applied to the saline soil for improving the soil chemical, leading to enhance the crop productivity (Cha-Um *et al.*, 2012). However, the studies investigating the role of calcium in response to salinity induced stress in tomato are largely lacking. With this view of objectives, a study has been carried out to investigate the role of Ca^{2+} in mitigating salt stress-induced response in tomato.

MATERIALS AND METHODS

Experimental site: A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh situated at 23°74'N latitude and 90°35'E longitude at an altitude of 8.6 m above the sea level during the period from October, 2013 to March, 2014. The soil of the experimental site was silt loam in texture (sand 20.84%, silt 57.46% and clay 21.7%) with pH 6.9, organic matter 0.86%, available potassium 25 mg kg^{-1} and available sodium 70 mg kg^{-1}. The climate of this area is subtropical. Detail weather data of the experimental area have been presented in Table 1.

Experimental materials and design: The experiment was placed under venyl house which was made by bamboo with polythene roof and pots were kept on the bamboo made frame of 70 cm height. Seedlings of 30 days of BARI Tomato-5 were used as planting materials in this experiment. Five levels of salinity induced by sodium (Na^+) viz., 0, 2, 4, 6 and 8 d S m^{-1} and three levels of Ca^{2+} in the form of $CaSO_4.0.5H_2O$ viz., 0, 5 and 10 mM were used as treatment variables. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications and comprised of 60 pots. Each pot was 35 cm in diameter and 30 cm in height.

Application of sodium and calcium in soil: Tomato plants were treated with 0, 2, 4, 6 and 8 ds m^{-1} salinity levels which were maintained by adding 0, 12, 27, 48 and 58 g of sodium chloride

Table 1: Weather data of the experimental site during the period from October, 2013 to April, 2014

	Average air temperature (°C)				
Years and month	Maximum	Minimum	Total rainfall (mm)	Average relative humidity (%)	Average sunshine (h)
2013					
October	30.80	14.85	44.64	67.82	7.48
November	28.10	6.88	15.60	58.18	7.85
December	25.36	6.12	0.62	54.30	6.85
2014					
January	25.00	12.00	18.00	46.00	9.00
February	28.00	13.00	31.00	37.00	8.00
March	33.00	16.00	58.00	38.00	7.00
April	35.00	23.00	103.00	42.00	6.00

(NaCl), respectively per pot containing 10 kg soil. These total amounts of salts were applied through irrigation water in three splits at 30, 50 and 70 DAT. As a Na^+ stress mitigation agent, Ca^{2+} was used in the form of $CaSO_4.0.5H_2O$ at 0, 5 and 10 mM concentration with irrigation water at 30, 50 and 70 Days after Transplanting (DAT).

Leaf area/plant (cm^2): Leaf area was measured by non-destructive method using CL-202 Leaf Area Meter (USA). Mature leaves were measured all the time and were expressed in cm^2.

Leaf chlorophyll content (SPAD value): Leaf chlorophyll content was measured using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). At each evaluation the content was measure 5 times from five leaves at different positions per plant and the average was used for analysis.

Dry weight of leaves and stems/plant (g): After harvesting, all the leaves and stems of plant were collected and sliced into very thin pieces and were put into envelop and placed in oven maintaining at 70°C for 72 h. The samples were then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken in gram.

Chemical analysis of soil sample: Soil samples were analyzed for both physical and chemical properties in the laboratory of the Soil Science department, SAU, Dhaka, Bangladesh. The properties studied included pH, organic matter, available Na and K. The soil was analyzed following standard methods. Particle-size analysis of soil was done by Hydrometer method (Bouyoucos, 1951) and soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5 as described by Jackson (1962). Available Na and K content were measured by flame photometer.

Statistical analysis: Analysis of variance (ANOVA) and Least Significant Difference (LSD) test for the variables at 5% level of probability were conducted using the MSTAT-C Program (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: The plant height varied significantly ($p\leq 0.01$) by different level of salinity stress at different Days After Transplanting (DAT) of tomato (Fig. 1). Salinity significantly reduced the plant height of tomato at different DAT and the reduction was quite incremental with the increase of NaCl concentrations. The natural plant height increased with increasing age but decreased with increasing salinity in tomato. Similar results were also recorded by Mohammad *et al.* (1998) in tomato, Jafari *et al.* (2009) and Nawaz *et al.* (2010) in sorghum, Milne *et al.* (2012) in lettuce and Ewase *et al.* (2013) in coriander. The reduction of plant height may be due to inhibitory behavior of salt stress on cell division and cell expansion (Hernandez *et al.*, 2003).

Different calcium level had significant effect on plant height of tomato at different DAT (Fig. 2). Calcium significantly increased plant height at different growth stages of tomato. From this experiment it was observed that calcium increased the plant height as compared with control where the best result was found from 5 mM concentration of calcium. Manivannan *et al.* (2007) also reported that calcium increased the plant height.

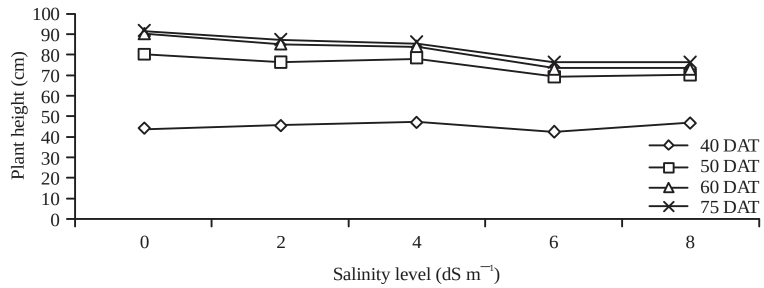

Fig. 1: Effect of salinity levels on plant height of tomato at different DAT (LSD value = 0.4505, 0.5714, 0.645 and 1.421 for 40, 50, 60 and 75 DAT, respectively)

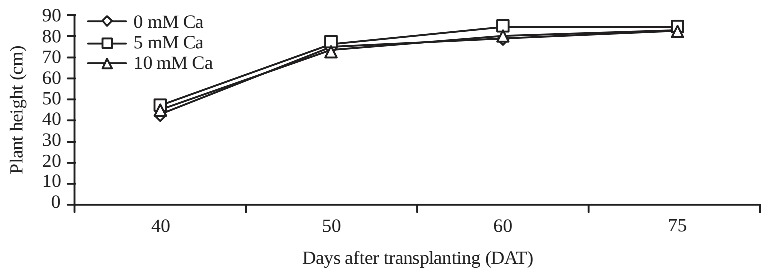

Fig. 2: Effect of calcium levels on plant height of tomato at different DAT (LSD value = 0.349, 0.4426, 0.4997 and 1.101 for 40, 50, 60 and 75 DAT, respectively)

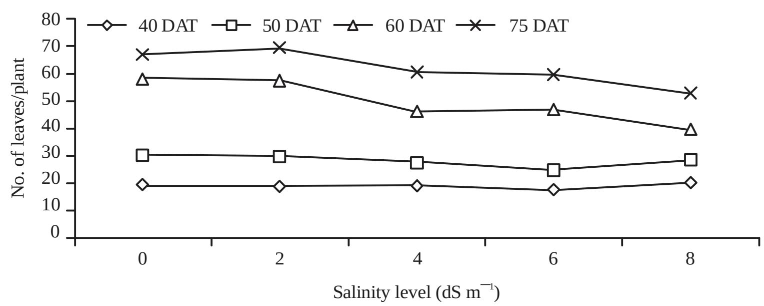

Fig. 3: Effect of salinity levels on leaves number/plant of tomato at different DAT (LSD value = 0.5636, 0.5178, 0.5779 and 6.412 for 40, 50, 60 and 75 DAT, respectively)

Interaction effect between salinity stress and calcium as mitigation agent on plant height was significant at different DAT (Table 2). Increasing the salinity in soil without application of calcium decreased the plant height of tomato at different growth period.

Number of leaves/plant: The leaf number is the very important character for plant growth and development as leaf is the main photosynthetic organ. Salinity adversely affected the production of leaf number/plant in tomato. The results of this experiment showed that different concentration of salt have significant effect on number of leaves/plant of tomato at different DAT (Fig. 3). Number of leaves/plant was decreased with increasing salt stress. Similar observation was also observed

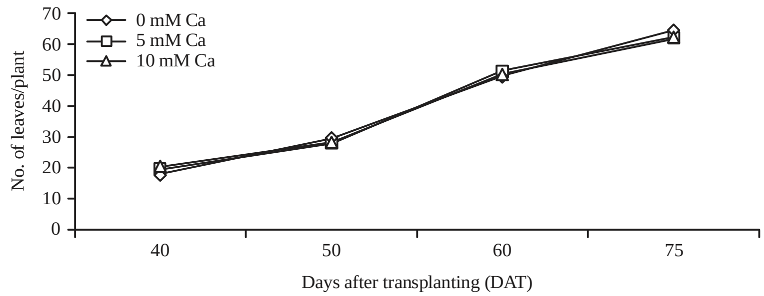

Fig. 4: Effect of calcium levels on leaves number/plant of tomato at different DAT (LSD value = 0.4366, 0.4011, 0.4476 and 12.42 for 40, 50, 60 and 75 DAT, respectively)

Table 2: Interaction effect of salinity and calcium levels on plant height of tomato at different DAT

	Plant height (cm)			
Salinity and calcium level (mM)	40 DAT	50 DAT	60 DAT	75 DAT
0 dS m^{-1}×				
0	38.50^{i}	77.50^{d}	85.50^{d}	88.50^{cd}
5	49.50^{a}	83.00^{a}	97.00^{a}	95.25^{a}
10	45.25^{f}	81.00^{b}	89.25^{b}	91.50^{b}
2 dS m^{-1}×				
0	44.75^{f}	79.25^{c}	85.50^{d}	89.00^{c}
5	48.75^{a-c}	79.50^{c}	85.75^{d}	86.25^{de}
10	43.50^{g}	71.25^{h}	85.00^{d}	87.75^{cd}
4 dS m^{-1}×				
0	47.50^{d}	81.25^{b}	88.00^{c}	90.00^{bc}
5	46.50^{e}	77.25^{d}	83.00^{e}	82.00^{f}
10	49.00^{ab}	75.00^{e}	82.00^{ef}	85.25^{e}
6 dS m^{-1}×				
0	42.25^{h}	68.50^{i}	71.75^{i}	74.25^{h}
5	43.25^{g}	72.75^{g}	81.00^{f}	82.25^{f}
10	42.75^{gh}	68.25^{ij}	69.00	77.00^{g}
8 dS m^{-1}×				
0	44.50^{f}	67.50^{j}	66.75^{k}	75.25^{gh}
5	48.50^{bc}	70.75^{h}	77.75^{g}	77.50^{g}
10	48.00^{cd}	74.00^{f}	76.50^{h}	77.00^{g}
$LSD_{0.05}$	0.7803	0.9897	1.117	2.462
Level of significance	**	**	**	**
CV (%)	1.2	0.92	0.96	2.06

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

by Ewase *et al*. (2013) who reported that number of leaves/plant decreased with the increase of NaCl concentration in coriander. Islam (2004), Jafari *et al*. (2009), Saberi *et al*. (2011) also obtained reduced leaves number/plant under salinity stress.

A significant effect of calcium on the number of leaves/plant of tomato at 40, 50, 60 and 75 DAT was found (Fig. 4). From this study it was found that, the number of leaves/plant was gradually increased with the increase in age with the supplementation of calcium along with salt. Thus these results suggested that the calcium application increased the number of leaves by reducing the effect of salt. This fact was supported by Tzortzakis (2010) in leafy vegetables, Lolaei (2012) in tomato.

The combined effect of salinity and calcium on the number of leaves/plant was significantly reflected at different stages of tomato (Table 3). At 40 DAT, the highest number of leaves/plant was produced from 8 dS m^{-1} Na with 10 mM Ca combination and the lowest was noticed from 6 dS m^{-1}

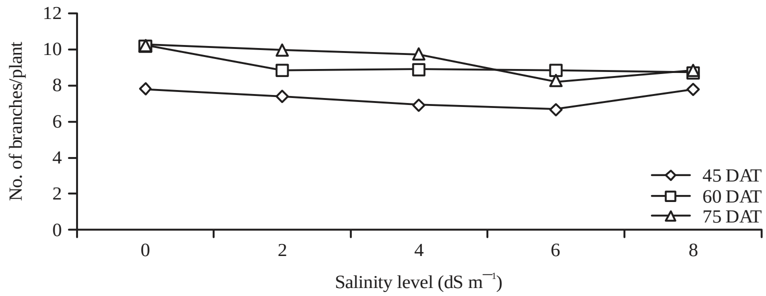

Fig. 5: Effect of salinity levels on branch number/plant of tomato at different DAT (LSD value = 0.436, 0.4769 and 1.138 for 45, 60 and 75 DAT, respectively)

Table 3: Interaction effect of salinity and calcium levels on number of leaves/plant of tomato at different DAT

	No. of leaves/plant			
Salinity and calcium level (mM)	40 DAT	50 DAT	60 DAT	75 DAT
0 dS m^{-1}×				
0	18.75^{ef}	35.00^{a}	57.00^{d}	69.00^{ab}
5	19.25^{de}	27.75^{fg}	58.00^{cd}	65.00^{a-c}
10	21.25^{b}	30.00^{d}	61.75^{b}	69.25^{ab}
2 dS m^{-1}×				
0	19.25^{de}	33.25^{b}	59.00^{c}	70.50^{ab}
5	20.25^{c}	28.75^{e}	63.75^{a}	71.00^{a}
10	18.25^{f}	28.25^{ef}	52.25^{ef}	70.00^{ab}
4 dS m^{-1}×				
0	18.50^{ef}	28.25^{ef}	51.50^{f}	64.00^{a-c}
5	19.25^{de}	30.25^{d}	42.00^{h}	60.25^{a-d}
10	20.00^{cd}	25.25^{i}	47.50^{g}	59.50^{b-d}
6 dS m^{-1}×				
0	16.00^{g}	24.25^{j}	41.75^{h}	64.25^{a-c}
5	18.50^{ef}	24.25^{j}	52.75^{e}	61.75^{a-d}
10	18.75^{ef}	27.00^{gh}	48.25^{g}	55.00^{cd}
8 dS m^{-1}×				
0	18.25^{f}	26.25^{h}	40.25^{i}	52.50^{d}
5	20.25^{c}	29.00^{e}	38.50^{j}	52.25^{d}
10	23.25^{a}	31.25^{c}	42.25^{h}	55.75^{cd}
$LSD_{0.05}$	0.9762	0.8969	1.001	11.11
Level of significance	**	**	**	**
CV (%)	3.54	2.20	1.39	12.42

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

with control (without calcium) treatment. At 50 DAT, the highest leaves number/plant was obtained from no Na and no Ca treatment combination whereas, the lowest number was found from combination of 8 dS m^{-1} Na with no calcium. At 60 and 75 DAT, the highest number of leaves/plant was counted from 2 dS m^{-1} Na with 5 mM Ca combination and the lowest was found from interaction between 8 dS m^{-1} Na with 5 mM Ca.

Number of branches/plant: Number of branches/plant of tomato was significantly affected by the different levels of salinity at 45, 60 and 75 DAT (Fig. 5). Uddin *et al.* (2005) also found that number of branch decreased with the increased salinity in *Brassica* species. Similar observation was also found in rice where tiller number decreased in response to salinity which was reported by Mortazainezhad *et al.* (2006).

A significant effect of calcium was found on the number of branches/plant of tomato at 45, 60 and 75 DAT (Fig. 6). Calcium increased the branch number/plant of tomato as compared with control where the best result was found from concentration of 5 mM calcium.

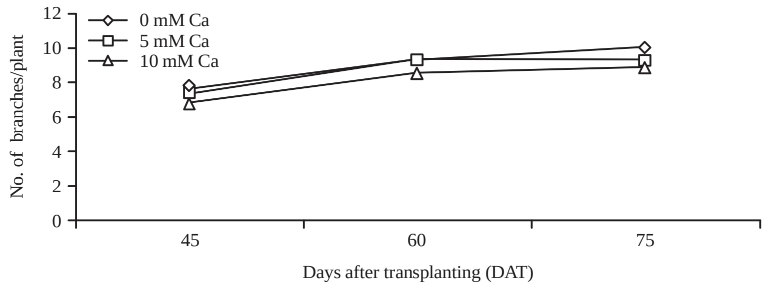

Fig. 6: Effect of calcium levels on branch number/plant of tomato at different DAT (LSD value = 0.3377, 0.3694 and 0.8813 for 45, 60 and 75 DAT, respectively)

Table 4: Interaction effect of salinity and calcium levels on number of branchs/plant of tomato at different DAT

	Number of branches/plant		
Salinity and calcium level (mM)	45 DAT	60 DAT	75 DAT
0 dS m^{-1}×			
0	8.750^{a}	10.25^{ab}	11.00^{a}
5	7.750^{bc}	10.50^{a}	10.75^{ab}
10	7.000^{cd}	9.750^{a-c}	9.250^{b-e}
2 dS m^{-1}×			
0	8.250^{ab}	9.000^{c-f}	10.25^{a-d}
5	8.250^{ab}	9.250^{c-e}	9.000^{cde}
10	5.750^{e}	8.250^{fg}	9.750^{a-d}
4 dS m^{-1}×			
0	7.250^{cd}	9.500^{b-d}	10.00^{a-d}
5	6.750^{d}	9.250^{c-e}	9.750^{a-d}
10	6.750^{d}	8.000^{g}	9.500^{a-e}
6 dS m^{-1}×			
0	6.500^{de}	8.750^{d-g}	8.750^{de}
5	6.750^{d}	9.250^{c-e}	8.250^{de}
10	6.750^{d}	8.500^{e-g}	7.750^{e}
8 dS m^{-1}×			
0	7.750^{bc}	9.000^{c-f}	9.250^{b-e}
5	7.750^{bc}	8.500^{e-g}	8.750^{de}
10	7.750^{bc}	8.500^{e-g}	8.500^{de}
$LSD_{0.05}$	0.7551	0.8259	1.971
Level of significance	**	**	**
CV (%)	7.23	6.37	14.64

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

Number of branches/plant significantly varied due to interaction between different levels of salinity and calcium at different DAT (Table 4). At 45 and 75 DAT, the highest number of branches/plant was obtained from without application of Na and Ca. At 60 DAT, increasing the calcium upto 5 mM without salt stress produced the highest number of branches/plant. Increasing the salinity level from 2-8 dS m^{-1} with 10 mM Ca produced the lowest number of branches/plant at different DAT of tomato.

Leaf chlorophyll content: There was a clear effect of salinity on the leaf chlorophyll content of tomato plant at 50, 70 and 85 DAT (Fig. 7). The chlorophyll content (SPAD reading) in tomato leaves decreased with increasing salinity levels. From the results, it was found that the high levels of salinity (8 dS m^{-1}) induced a significant decrease in the total chlorophyll content as compared to control plants. The total chlorophyll content of the leaves of tomato plant exhibits a little increase when grown at 2 and 4 dS m^{-1}. Chlorophyll content was significantly reduced at 6 dS m^{-1}, these results were also supported by Naher (2014). Salinity reduced the total chlorophyll content in leaves which was also supported by Netondo *et al.* (2004) and Amini and Ehsanpour (2006).

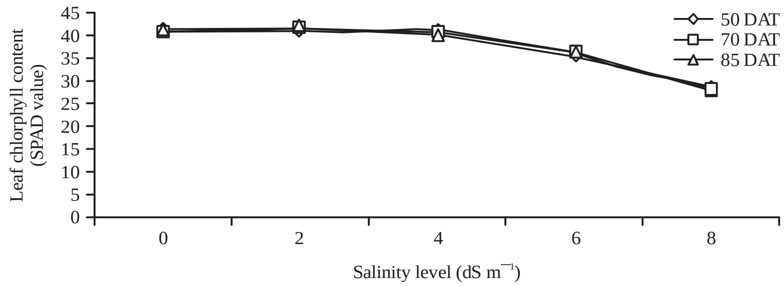

Fig. 7: Effect of salinity levels on leaf chlorophyll content of tomato at different DAT (LSD value = 2.637, 2.131 and 2.371 for 50, 70 and 85 DAT, respectively)

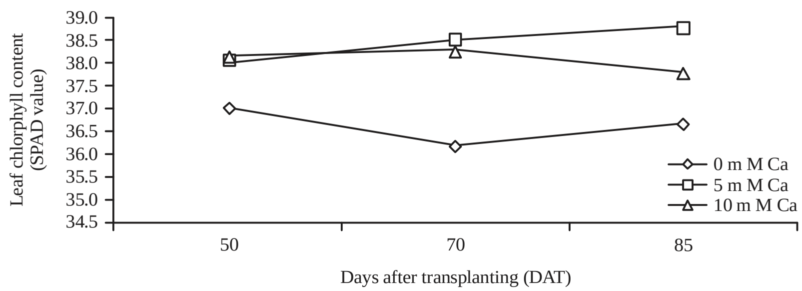

Fig. 8: Effect of calcium levels on leaf chlorophyll content of tomato at different DAT (LSD value = 2.043, 1.651 and 1.836 for 50, 70 and 85 DAT, respectively)

Significant effect of calcium on leaf chlorophyll content of tomato plant was found at 70 and 85 DAT and non-significant effect at 50 DAT (Fig. 8). Calcium increased the leaf chlorophyll content of tomato plant compared to control. This finding was supported by Howladar and Rady (2012). Results suggests that, exogenous Ca^{2+} supply improves the total chlorophyll content in plant which was strongly related to the fruits weight/plant of tomato.

The interaction effect between salinity and calcium levels on leaf chlorophyll content of tomato plant was significant at 50, 70 and 85 DAT (Table 5). The highest leaf chlorophyll content was observed from interaction between 2 dS m^{-1} Na with 5 mM Ca and the lowest reading was observed from 8 dS m^{-1} Na with 5 mM Ca treatment combination.

Leaf area/plant: Leaf area/plant was significantly influenced by different salinity levels (Table 6). Leaf area decreased with increasing concentration of salinity in tomato. Similar result was also reported by Sixto *et al.* (2005), Munns and Tester (2008) and Saberi *et al.* (2011). According to Hernandez *et al.* (2003) salt stress inhibited the cell division and cell expansion, consequently leaf expansion and as a result leaf area is reduced.

Different levels of calcium exerted significant effect on leaf area/plant of tomato (Table 6). Increasing the calcium level upto 10 mM Ca decreased the leaf area/plant compared to control.

The combined effect of salt and calcium was a significant effect on the leaf area/plant (Table 7). The leaf area was found higher with 10 mM Ca concentration with 0, 2 and 4 dS m^{-1} Na treated plant. Increased salinity levels such as 6 and 8 dS m^{-1} treated plants showed higher leaf area in 5 mM concentration of calcium.

Table 5: Interaction effect of salinity and calcium levels (mM) on leaf chlorophyll content of tomato at different DAT

Salinity and calcium level (mM)	Leaf chlorophyll content (SPAD value) 50 DAT	70 DAT	85 DAT
0 dS m^{-1} ×			
0	43.05^{a}	41.17^{ab}	41.57^{ab}
5	42.63^{a}	41.75^{ab}	43.17^{ab}
10	39.83^{a}	40.25^{ab}	39.80^{b}
2 dS m^{-1}×			
0	40.80^{a}	40.47^{ab}	41.22^{ab}
5	41.58^{a}	43.47^{a}	44.17^{a}
10	41.70^{a}	41.58^{ab}	41.33^{ab}
4 dS m^{-1}×			
0	41.78^{a}	41.70^{ab}	40.67^{ab}
5	41.30^{a}	41.05^{ab}	40.58^{ab}
10	40.25^{a}	39.78^{b}	39.80^{b}
6 dS m^{-1}×			
0	28.83^{bc}	28.10^{c}	28.92^{cd}
5	39.85^{a}	40.22^{ab}	40.63^{ab}
10	39.45^{a}	41.03^{ab}	40.10^{ab}
8 dS m^{-1}×			
0	30.77^{b}	29.65^{c}	31.08^{c}
5	25.02^{c}	26.15^{c}	25.40^{d}
10	29.58^{bc}	28.90^{c}	27.95^{cd}
$LSD_{0.05}$	4.567	3.691	4.106
Level of significance	**	**	**
CV (%)	8.48	6.86	7.62

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

Table 6: Effect of salinity and calcium levels on leaf area/plant, leaf dry weight/plant, stem dry weight/plant and fruit weight/plant of tomato

Treatments	Leaf area/plant (cm^2)	Leaf dry weight/plant (g)	Stem dry weight/plant (g)	Fruit weight/plant (kg)
0 (dS m^{-1} Na)	178.1^{a}	24.090^{a}	16.4000^{a}	0.8275^{a}
2 (dS m^{-1} Na)	176.9^{a}	20.450^{b}	15.7000^{b}	0.6033^{b}
4 (dS m^{-1} Na)	163.8^{b}	19.580^{b}	11.6200^{c}	0.5200^{c}
6 (dS m^{-1} Na)	152.5^{c}	15.180^{c}	9.0830^{d}	0.4700^{d}
8 (dS m^{-1} Na)	148.2^{d}	10.990^{d}	7.2170^{e}	0.3542^{e}
$LSD_{0.05}$	2.924	2.079	0.2644	0.02605
Level of significance	**	**	**	**
0 (mM Ca)	169.9^{a}	17.48^{b}	11.5100^{c}	0.5210^{b}
5 (mM Ca)	162.2^{b}	16.91^{b}	12.1100^{b}	0.6175^{a}
10 (mM Ca)	159.6^{c}	19.79^{a}	12.3900^{a}	0.5265^{b}
$LSD_{0.05}$	2.265	1.61	0.2048	0.02018
Level of significance	**	**	**	**
CV (%)	2.17	13.97	2.67	5.19

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

Dry weight of leaves and stems/plant: NaCl induced changes in dry matter production in different parts of tomato plant. There was significant effect on leaves and stems dry weight with the different levels of salinity (Table 6). It was found that, leaves and stems dry weight decreased with the increasing salinity level. The present results were in line with those of Akhtar and Hussain (2009), who reported decline in dry weights of shoots under high salinity stress. Decreased leaves dry weight does not seem to be due to a reduction in leaves number (Cruz and Cuatreno, 1990) but due to a reduction in leaf area which can be reduced proportionately more than the stems dry weight (Van Ieperen, 1996).

A significant effect of calcium on dry matter production of leaves and stems of tomato has been presented in Table 6. Calcium increased the dry weight of leaves and stems of tomato plant. Manivannan *et al.* (2007) reported that, calcium had the ameliorative effect on salt stress and increased the total dry weight of plant through increasing the vegetative growth of plant.

Table 7: Interaction effect of salinity and calcium levels on leaf area, leaf and stem dry weight, fruit weight/plant of tomato

Salinity and calcium level (mM)	Leaf area/plant (cm^2)	Leaf dry weight/plant (g)	Stem dry weight/plant (g)	Fruit weight/plant (kg)
0 dS m^{-1} ×				
0	187.2^{ab}	24.77^{ab}	16.48^{b}	0.8575^{a}
5	157.4^{gh}	22.23^{abc}	17.02^{a}	0.9000^{a}
10	189.7^{a}	25.27^{a}	15.70^{c}	0.7250^{b}
2 dS m^{-1} ×				
0	178.9^{c}	21.92^{a}-^{c}	15.50^{cd}	0.5025^{d}
5	169.4^{d}	20.33^{cd}	16.38^{b}	0.6500^{c}
10	182.4^{bc}	19.10^{cde}	15.23^{d}	0.6575^{c}
4 dS m^{-1} ×				
0	160.6^{fg}	20.40^{cd}	12.38^{f}	0.4675^{de}
5	163.2^{ef}	16.98^{de}	9.450^{h}	0.6200^{c}
10	167.5^{de}	21.35^{bc}	13.02^{e}	0.4725^{de}
6 dS m^{-1} ×				
0	156.4^{gh}	11.70^{f}	6.825^{j}	0.4625^{de}
5	168.0^{de}	16.38^{e}	10.88^{g}	0.4850^{d}
10	133.2i	17.48^{de}	9.550^{h}	0.4625^{de}
8 dS m^{-1} ×				
0	166.2^{de}	8.575^{f}	6.375^{j}	0.3150^{f}
5	153.1^{h}	8.650^{f}	6.825^{j}	0.4325^{e}
10	125.2^{j}	15.75^{e}	8.450^{i}	0.3150^{f}
$LSD_{0.05}$	5.065	3.601	0.458	0.04513
Level of significance	**	**	**	**
CV (%)	2.17%	13.97%	2.67%	5.19%

**Significant at $p \leq 0.01$, Different lowercase letters beside the mean value indicate significant at $p \leq 0.01$

In interaction effect of salinity and calcium on leaves and stems dry weight exhibited a significant effect (Table 7). Without application of salt with 10 mM and 5 mM Ca produced the highest amount of leaves and stems dry weight, respectively where both the lowest leaves and stems dry weight was accumulated in 8 dS m^{-1} Na with 0 mM Ca treatment combination.

Fruit weight/plant: Fruit weight/plant varied significantly due to different levels of salinity (Table 6). Fruit weight/plant decreased with increased salinity levels. It might be due to high saline soil decreased the number of fruits/plant. Similar observation was also reported by Lolaei (2012).

Statistically significant variation was recorded for different levels of calcium in terms of fruit weight/plant (Table 6). Fruit weight increased with the supply of calcium and highest result was recorded from 5 mM of Ca^{2+} and the lowest was obtained from control treatment which was statistically similar with 10 mM Ca. This result suggests that calcium reduced the toxic effect of salinity and increased the fruit weight in tomato which agrees with the result of Lolaei (2012).

Interaction effect of salinity and calcium levels showed significant differences for fruit weight/plant of tomato (Table 7). The maximum fruit weight/plant was recorded from combination of 0 dS m^{-1} Na and 5 mM Ca which was statistically at par with 0 dS m^{-1} Na with 0 mM Ca whereas the lowest weight was accounted from both 8 dS m^{-1} Na with 0 mM Ca and 8 dS m^{-1} Na with 10 mM Ca.

CONCLUSION

Considering the above mentioned results, it may be concluded that, the fruit weight of tomato gradually decreased by the increase of salinity levels and this reduction rate was decreased by exogenous supply of calcium. Among the calcium levels, 5 mM showed the highest result in growth, physiology and fruit production as compared to 10 mM. Therefore, this experiment suggests that Ca^{2+} can effectively mitigate the deleterious effect of Na^+ stress in tomato cultivation. Calcium can be recommended for farmers to use in their fields for alleviating salt stress.

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