MITIGATION OF SALT STRESS IN TOMATO WITH CALCIUM NITRATE

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CERTIFICATE

This is to certify that the thesis entitled **'Mitigation of Salt Stress in Tomato with Calcium Nitrate'** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **Rezowana Nizam**, Registration No. **08-02944** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: December, 2013
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The Author

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ABSTRACT

The pot experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to April 2014.BARI Tomato-5was used as planting material. The two factors experiment was laid out in RCBD with four replications. The factors are: Factor A: Five levels of sodium (Na) salt such as, (i) L_0: control (ii) L_1: 2, (iii) L_2: 4, (iv) L_3: 6 and (v) L_4: 8 dS/m and Factor B: Three concentration of calcium (Ca^{2+}) as mitigating agent of salt stress (i). M_0: Control (ii). M_1: 5 and (iii) M_2: 10 mM Ca^{2+} respectively. The results of this experiment showed that, the salt stress reduced the morphological parameters and yield (kg) of tomato with the increment of salinity. The lowest plant height (81.5 cm), number of branch (18.0), SPAD value (21.3), fruit weight (55.4 g) and yield per plant (1.42 kg) was recorded at $L_4$and highest value was observed at control. The present results also showed that, Ca^{2+}significantly increased the growth contributing characters as well as yield of tomato in both saline and non-saline conditions. For combined effect, tallest plant (94.0 cm), highest number of fruits per plant (50.8), highest weight of individual fruit (76.4 g) and the highest yield per plant (3.88 kg) was produced from L_0M_2; whereas the lowest from L_4M_0. This result suggests that, exogenous Ca^{2+} can effectively mitigate the deleterious effect of salt stress in tomato.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) botanically referred to the family Solanaceae is one of the most important and popular vegetable crop. The centre of origin of the genus *Solanum* is the Andean zone particularly Peru-Ecuador-Bolivian areas

(Salunkhe *et al*., 1987), but cultivated tomato originated in Mexico. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato adds flavor to the foods and it is also rich in medicinal value. It is widely employed in cannery and made into soups, conserves, pickles, ketchup, sauces, juices etc. More than 7% of total vitamin-C of vegetable origin comes from tomato in Bangladesh. It contains 94 g water, 0.5 g minerals, 0.8 g fibre, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate and other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B-1, 0.06 mg vitamin B-2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010).

Tomato ranks top of the list of canned vegetables and next to potato and sweet potato in the world vegetable production (FAO, 2012). The present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia (FAO, 2010). Now Bangladesh is producing a good amount of tomatoes. In Bangladesh it is mainly cultivated as winter vegetable, which occupies an area of 58,854 acres in 2009-10 (BBS, 2010). The total production of tomato was 339 lac tons in China, 137 lac tons in USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egyptin (FAO, 2010). In Bangladesh in the year of 2009-2010 the total production of tomato was 190 thousand metric tons (BBS, 2010). The average tomato production in Bangladesh is 50-90 tons/ha (BARI, 2010). Nowadays, tomatoes are grown round the year. Due to increasing consumption of tomato products, the crop is becoming promising.

In Bangladesh, the yield of tomato not satisfactory in comparison with other tomato growing countries of the World (Aditya *et al*., 1997). The low yield of tomato in Bangladesh however is not an indication of low yielding potentially of this crop but of the fact that the low yield may be attributed to a number of reasons, viz. unavailability of quality seeds of high yielding varieties, land for production based on fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions. The

environmental stresses resulting from drought, temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in crop production (Hernandez *et al.*, 2001; Lawlor and Cornic 2002; Alqudah *et al.*, 2011). Rates of accumulation of Na and/or Cl in the shoot are the critical processes determining genotypic differences in salt tolerance (Kusvuran *et al.*, 2007).

Salinity is a major environmental constraint limiting yield of crop plants in many semi-arid and arid regions. The initial and primary effect of salinity, especially at low to moderate concentrations, is due to osmosis (Munns and Termaat, 1986). Most crops tolerate salinity up to a threshold level, above which yields decrease as salinity increases (Maas, 1986). Plant salt tolerance is generally thought of in terms of the inherent ability of the plant to withstand the effects of high salt concentration in the rhizosphere or in the leaves without significant adverse consequences. Maintenance of growth rate, preserving nutrients, avoiding ion toxicities, and inducing metabolite changes that improve water balance are probably the most common and universal characteristics of salt-tolerant plants. Tomato is one of the world's most important and widespread crops with adverse effects of salinity (Bradbury and Ahmad, 1990; Liang *et al.*, 1996). Salinity reduced tomato yield (Sonnenveld and Welles, 1988), but improved fruit quality traits, such as total soluble solids and colour (Martinez *et al.*, 1987). Large differences are apparent in tolerance of different varieties of tomatoes. A distinctive difference in salt tolerance was obtained with fresh market cultivated tomatoes (Alian *et al.*, 2000).

Calcium is a slowly moving element and it is passively transported by the xylem through the transpiration streams from leaves and fruits. It is reported that tomato fruit surface has no stomata thus cuticular transpiration is the only way of water movement from fruit to atmosphere. It is assumed that translocation of calcium is low in fruits especially in the fruit tip due to low cuticular transpiration in the fruit tip. The cuticle plays an important role in inhibiting transpiration from plant surface (Vogg *et al.*, 2004) which consists of wax, cutin and phenylpropanoids. It was reported that when transpiration demand is high, a higher amount of calcium is absorbed by leaves as compared to fruit (Adams and Ho, 1992). However,

calcium is necessary for cell wall synthesis, enzymatic activity, metabolism and maintaining the integrity of cell wall during rapid expansion of fruit in the early stage of fruit development. Calcium is associated with the middle lamella of cell walls playing a role in support and growth of cell (Wu *et al*., 2002). It is deposited in plant cell wall during cell wall synthesis. It is necessary for the stability of cell membrane and works as a cementing agent in the cell wall as calcium pectate and binds the cells together so that any shortage and/or excess of calcium during rapid cell expansion may cause metabolic disorder during fruit growth. Additionally, application of calcium has been reported to restrict the entry of sodium in plant cell (Hussain *et al*., 2010). So, application of calcium may have some significant effect for the mitigation of salt stress.

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

- To investigate the morpho-physiology, yield contributing charcaters and yield response of tomato to salt stress
- To identify the effect of calcium (Ca^{2+}) on the morpho-physiology, yield contributing charcaters and yield response of tomato
- To examine the role of calcium (Ca^{2+}) on mitigation of salt stress in tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the important vegetable crop in Bangladesh and other countries of the world and it has drawn attention by the researchers for it various way of consumptions. It is adapted to a wide range of climates ranging from tropics to within a few degree of the Artic Circle. However, in spite of its broad adaptation, production is concentrated facing in a diverse biotic factor and abiotic stress conditions. But very few research works available related to growth, yield and development of tomato due to stress especially salt and also the mitigation of salt stress. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the salt stress and also the mitigation of salt stress in vegetable crops as well as tomato, so far been done at home and abroad, have been reviewed in this chapter under the following heads-

2.1 Salt stress on tomato plants

The effects of different levels of salt stress on the oxidative parameters (H_2O_2 and MDA), the total pool sizes of ascorbate, the activities of antioxidant enzymes superoxide dismutase (SOD) and catalase (CAT), as well as the activities and relative transcript levels of the enzymes of ascorbate-glutathione cycle; ascorbate peroxidase (APX), glutathione reductase (GR) and monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR) were studied by Murshed *et al*. (2014) in fruits of tomato. Plants were treated by three concentrations of NaCl (50, 100 and 150 mM) and fruits at different development stages were harvested after 3 and 6 days of stress. The concentrations of ascorbate (AsA) and dehydroascorbate (DHA) generally changed with salt stress treatments. These results suggest that the response of antioxidant systems of tomato fruits to oxidative stress induced by salt stress treatments was different depending on the fruit development stage.

Iseri *et al*. (2014) conducted an investigation with aim to whether sodium chloride seed priming and irrigation at seedling stage enhance response of 5-leaf stage tomato plants (*Lycopersium esculentum* Mill.) to high salt stress. Three experimental groups were as; non-primed seeds, seeds primed with 0.05 M sodium chloride (NaCl), and seeds primed and irrigated with 0.05 M NaCl starting from sowing to salt stress application. Sodium chloride solutions (0.1 M, 0.2 M, 0.4 M, and 0.6 M) were added to cups under pots in every 2 days for 10 days to treatment groups. Control groups were irrigated with distilled water at the same time intervals. Priming reduced mean germination time, and increased final germination percentage together with energy of germination. Increased root and hypocotyl lengths as well as increases in fresh weights supported enhanced seedling vigor. Considering growth and stress parameters such as chlorophyll content, chlorophyll to carotenoid ratios, and lipid peroxidation and electrolyte leakage were less affected in primed plants. Moreover, improvement of the accumulation of osmoregulating defense molecules, such as proline and anthocyanin, and of the inductions of the antioxidative enzyme system points out to higher adaptive response of these plants against deleterious effects of salt.

Tomato plants were subjected to 75 and 150 mM NaCl stress in order to study the effect of salt stress on its antioxidant response and stress indicators by Slathia and Choudhary (2013). Salinity affected all of the considered parameters. Specific activity of superoxide dismutase (SOD) and guaiacol peroxide (GPOX) increases in salt treated plants as compared to control plants. Moreover an increase in lipid peroxidation was observed in tomato plants by an increase in malondialdehyde (MDA) content.

Tropisms represent fascinating examples of how plants respond to environmental signals by adapting their growth and development was investigated by Ampudia *et al*. (2013). Here, a novel tropism is reported, halotropism, allowing plant seedlings to reduce their exposure to salinity by circumventing a saline environment. In response to a salt gradient, Arabidopsis, tomato, and sorghum roots were found to actively prioritize growth away from salinity above following

the gravity axis. Directionality of this response is established by an active redistribution of the plant hormone auxin in the root tip, which is mediated by the PIN-FORMED 2 (PIN_2) auxin efflux carrier. We show that salt-induced phospholipase D activity stimulates clathrin-mediated endocytosis of PIN_2 at the side of the root facing the higher salt concentration. The intracellular relocalization of PIN_2 allows for auxin redistribution and for the directional bending of the root away from the higher salt concentration.

Luo *et al*. (2013) conducted a study with different methods, including seed soaking, root drenching, anthrone colorimetry, and Mo anti-antimony colorimetry, were used to study the effects and the corresponding mechanisms of the *Bacillus megaterium* $CJLC_2$ on the salt-tolerance of tomato. The results showed that $CJLC_2$ could significantly increase the growth of tomato at the absence of NaCl, and the promotion rates of root length, plant height and fresh weight of tomato were 14.33%, 9.20% and 17.75%, respectively. Under the salt stress of NaCl, the increase of NaCl concentration had stronger inhibitory effect on tomato growth. However, $CJLC_2$ could improve the tolerance of tomato to NaCl to a certain extent. The best effect was achieved when the tomato was treated with 100 mmol/L NaCl, in which $CJLC_2$ could increase the root length, plant height and fresh weight by 17.05%, 18.04% and 15.81%, respectively. When the tomato seedlings were treated with 200 mmol/L NaCl, $CJLC_2$ could increase the contents of soluble sugars and soluble proteins of the tomato by 40% and 41%, respectively. When the tomato seedlings were treated with 100 mmol/L NaCl, $CJLC_2$ could improve the contents of P, K, Fe, Cu, Zn, and K+/Na+ ratio in tomato roots by 190%, 12.88%, 6.80%, 34.78%, 10.17%, and 50.72%, respectively, and $CJLC_2$ could also reduce the content of the Na by 25.11%.

The effect of salt stress on physiological response of hydroponically grown tomato fruit was investigated by Hossain and Nonami (2012). Fruit growth rate, water status, cuticle permeability considered for this study. Salt stress was applied by using Ca salt treatment and it plays an important role on all parameters studied in this experiment. Fruit growth rate, predawn water potential, osmotic potential

and cuticle permeability were significantly lower in treated plants than in control plants. This result indicated that turgor was osmotically regulated in fruit under stress condition. Fruit growth rate was found to decline from 12 DAF and eventually ceased when BER externally appeared on fruit surface at the age of 19 DAF in this experiment. The reduction of growth rate coincided with the reduction of water potential in fruit tissue due to salt stress.

Tomato cultivar PKM 1 were subjected to 25, 50, 100, 150 and 200 mM NaCl stress and response of tomato plant to salt stress were determined by Babu *et al.* (2012) to assessing the variability of different biochemical parameters. In this present Study endogenous content of growth hormones IAA and ABA in leaves, proline and mineral (Na+ and K+) content in leaves and mature fruits were estimated. Leaf area and dry matter content of tomato fruits under salt stress were determined to study the effect of salinity on photosynthetic yield. Results showed that leaf area and dry matter content of tomato fruits decreased with application of elevated salt stress, however endogenous content of IAA, ABA and proline was found to be increasing with increase in salt treatment. Application of NaCl caused increase in Na+ content, while K+ content and K+/Na+ ratio decreased with increase in salt stress. Another striking point is that increase in proline and Na+ content was more in leaves than fruits, which suggests that leaves are more sensitive than fruits.

An investigation was conducted by Chen *et al*. (2009) with aimed at a better understanding of the molecular adaptation mechanisms of salt stress was carried out in 7-d-old tomato *Solanum lycopersicum* (L.) Mill cultivars Patio and ‘F144’, using a proteomic approach. Total proteins were extracted from radicles and hypocotyls collected from both non-saline control and salt-stressed seedlings, and separated by two-dimensional gel electrophoresis. Liqud chromatography-electron spray ionization tandem mass spectrometry (LC-ESI-MS/MS) identified 23 salt stress response proteins, classified into six functional categories. The effect of exogenously applied glycinebetaine (GB) on the salt stress-induced inhibition of growth in tomato seedlings of cultivars Patio and ‘F144’ and on the protein profile

was investigated. It was found that GB could alleviate the inhibition of tomato growth induced by salt stress through changing the expression abundance of six proteins in Patio and two proteins in ‘F144’ more than twice compared with salt-stressed seedlings.

Takagi *et al*. (2008) grew well watered and fertilized tomato [*Solanum lycopersicum* (formerly *Lycopersicon esculentum*) L. cv. Momotarou] seedlings for two weeks at two different levels of irrigation-water salinity (0 or 100 mM NaCl) in 3-L pots inside the greenhouse of Hiroshima University, Japan, at atmospheric CO_2 concentrations of either 370 or 1000 ppm, while measuring various plant properties and physiological responses. Results indicated that "salt-stress treatment severely decreased whole-plant biomass," as well as "leaf photosynthesis and transport of carbon assimilates," but that "the impact of stress on these activities was alleviated under elevated CO_2 concentration." This alleviation, as they describe it, "was promoted when sink activity relative to source activity was higher," which they say was "probably owing to improvement of oxidative stress," due "at least partially to the higher constitutive antioxidant enzymes' activities," as well as improved water status "through stomatal closure at high CO_2 concentration." In considering their findings, the seven scientists state that their study "corroborates earlier reports that the interaction between salinity stress and CO_2 concentration result[s] in the alleviative effect of elevated CO_2 on the negative effects of salinity on plant growth," providing yet another indication of the ability of earth's plants to function ever more robustly and to successfully overcome various environmental challenges as the air's CO_2 content continues to climb ever higher.

Kusvuran *et al.* (2007) reported that formerly, most of tomato growth was mainly in soil, while at present cultivation has switched to greenhouse soilless cultures. The principal salinity problem is the accumulation of Na and Cl, as these elements are abundantly present in many irrigation waters and absorbed by most crops. As a result, Na and Cl accumulate in the root environment, and high concentrations can readily be reached in small volumes of growing media as used in the soilless

culture systems. It has been found that salt concentrations (mostly sodium and chloride) in leaves reach toxic levels in sensitive genotypes much faster than in salt-tolerant genotypes. This has been attributed primarily to the ability of roots to exclude the salt from the xylem sap flowing to the shoot.

Leonardi and Martorana (2005) reported that protected cultivations, sowing to the territorial areas in which they are spread, the climatic conditions under which they are carried out and the cultural techniques adopted, represent one of the agrosystems that may be highly subjected to salt stress, whose effects are, more often, yield reduction or a worsening of the product quality. The examined references may be summarized as follows: the application of osmotically active compounds, while not ensuring benefits with reference to proline, would seem to determine in the case of glycinebetaine and at least on the basis of some experiments a better tolerance of the plant to salt stress; experiments regarding the use of ascorbic acid, as antioxidant, even though rather limited in numeric terms, seem to provide fairly encouraging results. It appeared evident how only in a few cases does it prove possible to express a clear judgment with regard to eventual strategies aimed at improving plant salt tolerance.

Thirteen tomato genotypes were subjected to salt treatment under hydroponics and their responses monitored by Agong *et al*. (2004) in a set of 2 experiments with the objective of advancing them as potential salt-tolerant tomato scion and/or rootstocks. Salt applications ranged from 0 to 2% NaCl with the resultant EC values of 1.4 to 37 dS/m, respectively. Genotypes were cultured in the experimental solutions for up to 4 weeks in a triplicated randomized design in the greenhouse. Significant genotypic and/or salt treatment effects were registered on plant height, leaf green meter value and area, dry matter yield, and Na+ and Cl- accumulation in tomato tissues. Salt treatment at 2% NaCl stimulated chlorophyll production per unit leaf area but caused severe depression on dry matter yield and leaf area. These results revealed that some tomato genotypes consistently showed superior biological activity at higher salinity and others exhibited greater shift in the shoot : root ratio based on dry matter biomass production, thus displaying

relatively greater adaptation to salt stress. Two tomato genotypes ('Siozawa' and 'Gambaru Ne-3') displayed superior performance based on these preliminary data.

Mills and Tal (2004) reported that organs or plants grown in vitro do not always exhibit the same responses to salinity as the whole plant of same species grown ex vitro. The response to salinity (100 mM NaCl) of seedlings of the wild tomato species *Lycopersicon pennellii* acc. Atico (Lpa) and of the cultivated tomato *L. esculentum* cv. M82 (Lem), the former is known as salt tolerant and the second as relatively salt sensitive under ex vitro conditions, was compared under in vitro conditions with three different ventilation regimes. It was found that under salinity shoots of the wild species accumulated the same or even more dry biomass than the control (roots somewhat less) under all ventilation levels. Growth of shoots and roots of the cultivated species was inhibited under the same conditions especially under the high ventilation. Ventilation reduced some abnormalities of leaf development related to hyperhydricity and consequently ventilated leaves exhibited a more compounded structure, increased area, increased resistance to water loss and stomata functioning. Ventilation increased K+, Na+ and Cl- accumulation in shoots of both tomato species. This work indicates that differences that characterize whole plants of these species in response to salinity under ex vitro conditions are exhibited also in whole plants grown in vitro under high ventilation. It is suggested that ventilation is needed to evaluate well the response of whole plants to salt stress applied in vitro.

Thirteen tomato (*Lycopersicon esculentum*) cultivars (First, Siozawa, Chwerotonglo, Nyanya, LS-89, Healthy, BFNT-R, Mate, Tueze, Couple T, Joint, gambaru Ne-3 and Kagemusha) were evaluated by Agong *et al*. (2003) subjected to salt treatment under hydroponics and their responses monitored in a set of two experiments with the objective of advancing them as potential salt tolerant tomato scion and/or rootstocks. Salt applications ranged from 0 to 2% NaCl, with the resultant EC values of 1.4 to 37 dS/m. The cultivars were cultured in the experimental solutions for up to four weeks in the greenhouse. Significant genotypic and/or salt treatment effects were registered on plant height, leaf green

meter value and area, dry matter yield, and Na+ and Cl^- accumulation in tomato tissues. Salt treatment at 2% NaCl stimulated chlorophyll production, but caused severe depression on dry matter yield and leaf area. Some tomato cultivars consistently showed superior biological activity at higher salinity and others exhibited greater shift in the shoot:root ratio (from 8:1 to 5:1 for 'First'), based on dry matter biomass production thus displaying relatively greater adaptation to salt stress. Two tomato cultivars (Siozawa and Gambaru Ne-3) displayed superior performance.

The effects of salt stress and adaptation on salicylic acid (SA) content and on antioxidant and lipoxygenase (LOX) enzyme activities were studied by Molina *et al*. (2002) in tomato (*Lycopersicon esculentum* cv. Pera) cells. NaCl-adapted cells were obtained from calluses adapted to 100 mM NaCl by successive subcultures in medium supplemented with 100 mM NaCl. Salt stress treatments consisted of the addition of 100 mM NaCl to cells. Salt stress increased APX and LOX activities as well as lipid peroxidation in unadapted cells and increased Mn-SOD activity in both types of cells.

Tomato (*Lycopersicon esculentum* Mil.) plants from various cultivars growing on half-strength Hoagland solution by Mizrahi (1982) were exposed at anthesis to 3 or 6 grams per liter NaCI. Salinity shortened the time of fruit development by 4 to 15%. Fruits of salt-treated plants were smaller and tasted better than did fruits of control plants. This result was obtained both for ripe fruits tested on the day of picking and for those picked at 100% development and allowed to ripen at room Temperature for 9 days. Percentage of dry weight, total soluble solids, and titratable acidity; content of reducing sugars, Cl, Na+, and various pericarp pigments; and electrical conductivity of the juice were higher in fruits of saline-treated plants than they were in those of control plants, while the pH was lower. Ethylene and CO_2 evolution rates during ripening, as well as the activities of pectin methyl esterase, polymethyl galacturonase, and polygalacturonase; were also higher in fruits of the saline-treated plants.

2.2 Effect of calcium on tomato plant

Through the positive and negative impacts of calcium chloride on the dry weight of shoot and root and growth conditions of plant to reduce the destructive effects of salinity stress reported by Tabatabaeian (2014). By maintaining the proper amount of calcium ions in the soil, toxicity of sodium ions is controlled. In this study the effects of three different nutrient solutions, including the sodium chloride concentration with 0, 30, 60 and 90 mmol, calcium chloride concentrations with 0, 10, 20, 30 mmol and sodium chloride + calcium chloride respectively to the same concentration were reviewed. This test investigated on two cultivated tomato varieties in a hydroponic form and pots containing Coco Peat. In the vegetative growth stage, relative water content of tissue and cytoplasmic membrane stability and leaf chlorophyll concentration after removal of the root and shoot dry weight were measured. Results showed that increase of salinity caused a significant reduction in relative water content of tissues, cytoplasmic membrane stability and chlorophyll concentration in leaves. Dry weight yield of roots and shoots also decreased with increasing the salinity so that all the characters were lowest in 90 mmol of sodium chloride concentration. The results showed that the growth terms of calcium chloride and chloride+calcium chloride solutions were better, as the 10 mmol concentration of calcium chloride has a significant impact on improving the damage caused by the salinity.

Manaa *et al*. (2013) reported that salinity is a major abiotic stress that adversely affects plant growth and productivity when conducting an experiment to find out the effects of salinity and calcium on fruit proteome variations of two tomato genotypes (Cervil and Levovil). Tomato plants were irrigated with a control solution (3 dSm(-1)) or with saline solutions (Na or Ca+Na at 7.6 dSm(-1)). Tomato fruits were harvested at two ripening stages: green (14 days post-anthesis) and red ripe. Total proteins were extracted from pericarp tissue and separated by two-dimensional gel electrophoresis. Among the 600 protein spots reproducibly detected, 53 spots exhibited significant abundance variations between samples and were submitted to mass spectrometry for identification. Most of the identified

proteins were involved in carbon and energy metabolism, salt stress, oxidative stress, and proteins associated with ripening process. Overall, there was a large variation on proteins abundance between the two genotypes that can be correlated to salt treatment or/and fruit ripening stage. The results showed a protective effect of calcium that limited the impact of salinization on metabolism, ripening process, and induced plant salt tolerance.

Nasser and Sholi (2012) conducted an experiment with four levels of salinity (0, 50, 100 and 150 mM NaCl) on seed germination, plants growth (relative fresh and relative dry weight), K^+ and Na^+ content and photosynthetic rate of the four local cultivars (Heb, Ram and J1) and one commercial cultivar (Mar) was studied. Significant difference in G_{50} of Heb cultivar was seen at 50 and 100 mM NaCl when compared with the other four cultivars and the only one achieved 50% germination at 150 NaCl. Salt stress reduced plant growth of all cultivars, but Ram and Mar cultivars were characterized as the most tolerant and sensitive, respectively. No significant difference was seen in K^+/Na^+ ratio among four cultivars tested, but Ram showed the maximum value of 5.72 and 35.09 at 50 and 100 mM NaCl, respectively. Ram also showed better photosynthesis rate (5.1, 3.71) at 50 and 100 mM NaCl, respectively, than the other four cultivars.

Tomato 'Trust' was grown by Hao and Papadopoulos (2004) on rockwool with nutrient solutions containing two levels of calcium (150 and 300 $mg \cdot L^{-1}$) in factorial combination with three levels of magnesium (20, 50, and 80 $mg \cdot L^{-1}$) in Winters, to investigate the effects of calcium and magnesium on growth, biomass partitioning, and fruit production. Plants grown at 20 $mg \cdot L^{-1}$ Mg started to show Mg deficiency symptoms (leaf chlorosis) at 8 weeks after planting. The chlorophyll content of middle and bottom leaves increased with increasing Mg concentration in the nutrient solution. At 300 $mg \cdot L^{-1}$ Ca, total fruit yield and fruit dry matter increased linearly with increasing Mg concentration; marketable fruit yield and total plant biomass showed similar response but to a lower degree. At 150 $mg \cdot L^{-1}$ Ca, total plant biomass, fruit dry matter and yield peaked at 50 $mg \cdot L^{-1}$ Mg. The biomass allocation to fruit increased while allocation to leaves decreased

with increasing Mg concentration. The Mg effects on total and marketable fruit yield were mainly due to its influence on fruit yield in the late growth stage. Incidence of blossom-end rot (BER) at 150 $mg \cdot L^{-1}$ Ca increased linearly with increasing Mg concentration while it was not affected by Mg concentration at 300 $mg \cdot L^{-1}$Ca. For a winter greenhouse tomato crop, the appropriate Ca and Mg concentrations for tomato production appear to be at 300 and 80 $mg \cdot L^{-1}$, respectively.

Seedlings of tomato (*Lycopersicon esculentum*) cv. L-402 with low calcium efficiency and cv. Jiangshu 1 with high calcium efficiency were cultured in Hoagland solution by Huang *et al* (2003). The amount of calcium supply was decreased from the flowering stage. Reducing Ca application at the flowering stage resulted in a decrease of Ca content in fruits of cv. L-402 but not of cv. Jiangshu 1. Mg contents in fruits of the two cultivars increased, while K contents were not different. Ca contents in proximal parts of the fruit were higher than in distal parts of fruit in both cultivars. Soluble Ca contents in the base of Jiangshu 1 and L-402 increased by 29 and 34%, respectively, while that in the top increased by 19 and 25%, respectively. The contents of Ca-pectate and Ca-phosphate in corresponding tissues of both cultivars decreased. Application of Ca resulted in an increase of Ca-oxalate in the top of fruits of L-402.

The effects of salt stress and adaptation on salicylic acid (SA) content and on antioxidant and lipoxygenase (LOX) enzyme activities were studied by Molina *et al*. (2002) in tomato (*Lycopersicon esculentum* cv. Pera) cells. NaCl-adapted cells were obtained from calluses adapted to 100 mM NaCl by successive subcultures in medium supplemented with 100 mM NaCl. Salt stress increased APX and LOX activities as well as lipid peroxidation in unadapted cells and increased Mn-SOD activity in both types of cells. Application of 200 micro M SA+100 mM NaCl inhibited APX activity in both unadapted and adapted cells, induced the Mn-SOD in adapted cells and increased lipid peroxidation in unadapted cells.

2.3 Use of substances for mitigation of salt stress in tomato plant

Tomato plants were subjected to 75 and 150 mM NaCl stress in order to study the effect of salt stress on its antioxidant response and stress indicators by Slathia and Choudhary (2013). Salinity affected all of the considered parameters. And they reported that various antioxidants like ASA, TPC and GSH also got enhanced under salinity stress showing their role in reducing salt stress.

Tropisms represent fascinating examples of how plants respond to environmental signals by adapting their growth and development was investigated by Ampudia *et al*. (2013) and they reported that salt-induced phospholipase D activity stimulates clathrin-mediated endocytosis of PIN_2 at the side of the root facing the higher salt concentration. The intracellular relocalization of PIN_2 allows for auxin redistribution and for the directional bending of the root away from the higher salt concentration. Their results thus identify a cellular pathway essential for the integration of environmental cues with auxin-regulated root growth that likely plays a key role in plant adaptative responses to salt stress.

Luo *et al*. (2013) conducted a study with different methods, including seed soaking, root drenching, anthrone colorimetry, and Mo anti-antimony colorimetry, were used to study the effects and the corresponding mechanisms of the *Bacillus megaterium* $CJLC_2$ on the salt-tolerance of tomato and reported that when the tomato seedlings were treated with 100 mmol/L NaCl, $CJLC_2$ could reduce the content of the Na by 25.11%. *B. megaterium* $CJLC_2$ could improve the salt tolerance of tomato and promote the growth by enhancing the salt-tolerance related physiological and biochemical characters.

Tomato plants of hybrids Astona andGloria growing on pots by Posada and Rodriguez (2009) with soil were exposed to 20, 40, 60 or 80 mmol NaCl under greenhouse conditions and the electrical conductivity values of treated soil were 2.95, 4.90, 6.56 and 7.70 dS m^{-1}, respectively. NaCl was not added to soil of control plantsand electrical conductivity was 1.42 dS m^{-1}. To soil of some salt-stressed plants, Humitron 60S (23.6% humic acid and 1.1% fulvic acid, from

leonardite) was added1.6 g per plant (40 kg ha^{-1}, proportionally) at transplanting time to reduce the negative effect of salinity on plants. The study was carried out in greenhouse in Tunja, Colombia. Results showed statistical difference between hybrids. Salinity, in general, reduced the values of evaluated growth and yield parameters; however, leonardite ameliorated the negative effects of salinity on plants. The fruits of salt-stressed plants had higher specific leaf area, total soluble solids and titratable acidity in comparison with those of control plants, while total dry matter, yield, and leaf area were reduced. For most evaluated parameters, leonardite had poor effect on alleviation of salt-stress in plants of 20 mmol NaCl treatment, but in soils subjected to 40 to 80 mmol NaCl an increase of yield and dry matter production per plant as well as a reduction of total soluble solids and titratable acidity of fruits was observed. Results showed a possibility to reduce the negative effects of salinity on tomato plants growing under greenhouse conditions by adding leonardite to salinized soils.

Einset *et al*., (2007) reported that exogenous application of compatible solutions has been suggested as an alternative/additional approach to genetic engineering to improve crop productivity under stress conditions. Although the application of exogenous GB to salt-stressed plants was described several decades ago and its function has been relatively well characterized, its effect on protein responsiveness has not yet been completely defined and a detailed understanding of many of its cellular functions has proved elusive. DNA microarray analysis was used to identify genes whose expression was enhanced by the exogenous application of GB to both leaves and roots of *Arabidopsis*. Genes whose expression was enhanced by GB included genes for transcription factors, for membrane trafficking components, for reactive oxygen species (ROS)-scavenging enzymes, and for NADP-dependent ferric reductase that is located on the plasma membrane.

Leonardi and Martorana (2005) reported that protected cultivations, sowing to the territorial areas in which they are spread, the climatic conditions under which they

are carried out and the cultural techniques adopted, represent one of the agrosystems that may be highly subjected to salt stress, whose effects are, more often, yield reduction or a worsening of the product quality. The examined references may be summarized as follows: with regard to plant nutrition, a number of interesting indications for the purposes of attenuating salt stress concern supplementary supplies of potassium and calcium whose effects prove to be rooted in different mechanisms; the treatment with hormones seems to allow a reduction of salt stress effects; however, possible negative effects on plant water status and toxic ions accumulation should be evaluated.

The effects of salt stress and adaptation on salicylic acid (SA) content and on antioxidant and lipoxygenase (LOX) enzyme activities were studied by Molina *et al*. (2002) in tomato (*Lycopersicon esculentum* cv. Pera) cells. Application of 200 micro M SA+100 mM NaCl inhibited APX activity in both unadapted and adapted cells, induced the Mn-SOD in adapted cells and increased lipid peroxidation in unadapted cells. The findings also indicate that adaptation of tomato cells to NaCl results in a higher tolerance to NaCl-induced oxidative stress and suggest a role for SA in this response.

Kishitani *et al*. (1994) reported that accumulation of high concentrations of either inorganic ions or low molecular weight organic solutes. Although they play a crucial role in higher plants grown under saline conditions, their relative contribution varies among species, among cultivars, and even between different compartments within the same plant. There is strong evidence that glycinebetaine (GB) and proline play an adaptive role in mediating osmotic adjustment and protecting the subcellular structures in stressed plants, stabilizing photosynthetic reactions, the structure of extrinsic proteins of the photosystem II (PSII) complex, and ATP synthesis and activation of enzymes.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2013 to April 2014 to study the mitigation of salt stress in tomato by using exogenous calcium (Ca^{2+}) which used as a form of calcium nitrate {$Ca(NO_3).4H_2O$}. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Location of the experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09^{0}N latitude and 90.26^{0}E longitudes. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207 (Anon., 1989).

3.2 Characteristics of soil that used in pot

Experimental site belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and the soil of the pot was medium high in nature with adequate irrigation facilities and remained fallow during the previous season. The soil texture of the experiment was sandy loam. The nutrient status of the farm soil under the experimental pot were collected and analyzed in the Soil Research and Development Institute Dhaka, and result has been presented in Appendix I.

3.3 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and

scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

Seedlings of 30 days of BARI Tomato 5 were used as planting material. The seedlings of tomato were grown at the nursery of Sher-e-Bangla Agricultural University Horticultural Farm. The experiment was conducted in a two side open plastic shade house.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Different levels of NaCl

i L_0: Control
ii. L_1: 2 dS/m
ii. L_2: 4 dS/m
iii. L_3: 6 dS/m
v. L_4: 8 dS/m

Factor B: Different levels of calcium (Ca^{2+})

i. M_0: Control, i.e. no Ca^{2+}
ii. M_1: 5.0 mM Ca^{2+}
iii. M_2: 10.0 mM Ca^{2+}

There were 15 (5 × 3) treatments combination such as L_0M_0, L_0M_1, L_0M_2, L_1M_0, L_1M_1, L_1M_2, L_2M_0, L_2M_1, L_2M_2, L_3M_0, L_3M_1, L_3M_2, L_4M_0, L_4M_1 and L_4M_2.

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. The experiment area was divided into four equal blocks. Each contain by 15 pots where 15 treatments combination were allotted at random. Four plants were placed under each treatment. There were 60 unit pot altogether in the experiment.

3.7 Preparation of the pot

The experimental pots were first filled at 10 December, 2013. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil. The final pot preparation was done on 15 December. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final pot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.8 Application of manure and fertilizers

The sources of N_2, P_2O_5, K_2O as urea, TSP and MP were applied, respectively. The entire amounts of TSP and MP were applied during the final pot preparation. Urea was applied in three equal installments at 15, 30 and 45 days after seedling transplanting. Well-rotten cowdung 20 t/ha also applied during final land preparation. The following amount of manures and fertilizers were used which shown as tabular form recommended by BARI (2005).

Table 1. Fertilizer and manure applied for the experimental field

Manures and Fertilizers	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	20 tons	100	--	--	--
Nitrogen	250 kg	--	33.33	33.33	33.33
P_2O_5 (as TSP)	200 kg	100	--	--	--
K_2O (as MP)	175 kg	100	--	--	--

3.9 Raising of seedlings

Tomato seedlings were raised in one seedbeds of 3 m × 1 m size for BARI Tomato-5. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cow dung was mixed with the soil. 3 g of seeds were sown on each seedbed on 11 November 2013. After sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg ha^{-1}, around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place with 5 to 6

days after sowing. Weeding, mulching and irrigation were done as and when required.

3.10 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental pots in the afternoon of 10 December, 2013. This allowed an accommodation of 1 plant in each pot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the hot sun and removed after seedlings were established. They (transplants) were kept open at night to allow them receiving dew. Each pot allow two seedlings in the pot and one seedling is removed from pot after healthy establishment of seedlings.

3.11 Application of NaCl and Ca^{2+}

As per the treatment the required amount of NaCl was applied in the pot during application of water. The tray was used in the bottom of each pot to collect the water and different nutrient. The Ca^{2+} also applied with irrigation in the pot according treatment combination. NaCl solution and Ca^{2+} applied in the pot soil at 25, 55 and 85 days after transplanting.

3.12 Intercultural operation

After raising seedlings, various intercultural operations such as weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the tomato seedlings.

3.12.1 Weeding

The hand weeding was done as when necessary to keep the pots free from weeds.

3.12.2 Earthing up

Earthing up was done at 20 and 40 days after transplanting on the basement of plant by taking the soil from the boundary side of pots by hand.

3.12.3 Irrigation

Light watering was given by a watering cane in each pot with equal amount as necessary at afternoon.

3.12.4 Pest and disease control

Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Fruit rot disease was observed in the fruits and Diazinon @ 2.0% were applied for controlling fruit rot.

3.13 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they attained slightly red color. Harvesting was started from March, 2014 and was continued up to April, 2014.

3.14 Data collection

Data were collected from plant of each unit pot.

3.14.1 Plant height (cm)

Plant height was measured from plant of each unit pot from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded at 10 days interval starting from 30 days of planting upto 70 days to observe the growth rate of plants.

3.14.2 Number of branches per plant

The total number of branches per plant was counted from plant of each unit pot. Data were recorded was recorded at 10 days interval starting from 30 days of planting upto 70 days.

3.14.3 Number of leaves per plant

The total number of leaves per plant was counted from plant of each unit pot. Data was recorded at 10 days interval starting from 30 days of planting upto 70 days.

3.14.4 SPAD value

SPAD value was determined from plant samples by using an automatic SPAD meter immediately after removal of leaves from plants to avoid rolling and shrinkage. SPAD was recorded at flowering stage and 30 days after flowering.

3.14.5 Leaf area (cm^2)

Leaf area (LA) was determined from plant samples by using an automatic leaf area meter (Model LI-3100, Li-COR, Lincoln, NE, USA) immediately after removal of leaves from plants to avoid rolling and shrinkage. Leaf area was recorded at flowering stage and 30 days after flowering.

3.14.6 Days required for transplanting to 1st flowering

Days required for transplanting to initiation of flowering was counted from the date of transplanting to the initiation of flowering and was recorded.

3.14.7 Number of flower cluster per plant

The number of flower cluster was counted from plant of each unit pot and the numbers of flower clusters produced per plant were recorded.

3.14.8 Number of flowers per cluster

The number of flower was counted from plant of each unit pot and number of flower produced per cluster was recorded on the basis of flower cluster per plant.

3.14.9 Number of flowers per plant

The number of flower per plant was counted from plant of each unit pot and the number of flowers per plant was recorded.

1.14.10 Number of fruits per cluster

The number of fruits per cluster was counted from plant of each unit pot and the number of fruits per clusters was recorded.

3.14.11 Number of fruits per plant

The number of fruit per plant was counted from plant of each unit pot and the number of fruits per plant was recorded.

3.14.12 Length of fruit (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 5 selected marketable fruits from each pot and there average was taken and expressed in cm.

3.14.13 Diameter of fruit (cm)

Diameter of fruit was measured at the middle portion of 5 selected marketable fruit from each pot with a slide calipers and there average was taken and expressed in cm.

3.14.14 Dry matter of plant

After harvesting, 150 g plant sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 70^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of plant were computed by simple calculation from the weight recorded by the following formula:

$$\text{Dry matter content of plant (\%)} = \frac{\text{Dry weight of plant}}{\text{Fresh weight of plant}} \times 100$$

3.14.15 Dry matter of fruit

After harvesting, randomly selected 150 g fruit sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of fruit were computed by simple calculation from the weight recorded by the following formula:

$$\text{Dry matter content of fruit (\%)} = \frac{\text{Dry weight of fruit}}{\text{Fresh weight of fruit}} \times 100$$

3.14.16 Weight of individual fruit (g)

Among the total number of fruits during the period from first to final harvest the fruits, except the first and final harvest, was considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit} = \frac{\text{Total weight of fruit (per plant)}}{\text{Total number of fruits (per plant)}}$$

3.14.17 Yield per plant (kg)

Yield of tomato per plant was recorded as the whole fruit per plant harvested in different time and was expressed in kilogram.

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program to find out the significance of the difference for salt stress and calcium nitrate on yield and yield contributing characters of tomato. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the mitigation of salt stress in tomato with calcium nitrate and agro climatic condition of Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameter were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height

Plant height of tomato varied significantly for different levels of salt stress at 30, 40, 50, 60 and 70 days after transplanting (DAT) under the present trial (Appendix III). At 30, 40, 50, 60 and 70 DAT, the tallest plant (15.9 cm, 39.2 cm, 60.5 cm, 79.2 cm and 90.1 cm) was recorded from L_0 (control) which was closely followed (15.1 cm, 37.3 cm, 58.8 cm, 76.8 cm and 85.7 cm) by L_1 (2 dS/m) and then (14.5 cm, 36.3 cm, 57.4 cm, 74.0 cm and 83.7 cm) by L_2 (4 dS/m), whereas the shortest plant (11.9 cm, 32.7 cm, 53.0 cm, 65.8 cm and 75.2 cm) was observed from L_4 (8 dS/m) which was closely follwed (13.5 cm, 35.3 cm, 56.2 cm, 72.0 cm and 81.5 cm) by L_3 (6 dS/m) for same DAT (Figure 1). Data revealed that the salt stress reduced the morphological parameters such as plant height of tomato. Plant salt tolerance is generally thought of in terms of the inherent ability of the plant to withstand the effects of high salt concentration in the rhizosphere. Tomato is one of the world's most important and widespread crops with adverse effects of salinity (Bradbury and Ahmad, 1990; Liang *et al*., 1996). Luo *et al*. (2013) reported that under the salt stress of NaCl, the increase of NaCl concentration had stronger inhibitory effect on tomato growth. Agong *et al*. (2003) found that

significant genotypic and/or salt treatment effects were registered on plant height of tomato plant.

Statistically significant variation was recorded for different levels of calcium nitrate on plant height of tomato at 30, 40, 50, 60 and 70 DAT (Appendix III). Data revealed that at 30, 40, 50, 60 and 70, the tallest plant (14.8 cm, 37.6 cm, 58.9 cm, 75.9 cm and 86.2 cm) was found from M_2 (10.0 mM Ca^{2+}), which was statistically identical (14.3 cm, 36.2 cm, 57.5 cm, 74.0 cm and 83.6 cm) with M_1 (5.0 mM Ca^{2+}), while the shortest plant (13.5 cm, 34.7 cm, 55.2 cm, 70.8 cm and 86.1 cm) was recorded from M_0 (control, no Ca^{2+}) for same DAT (Figure 2). Wu *et al*., 2002 reported that calcium is associated with the middle lamella of cell walls playing a role in support and growth of cell that lead to produced longest plant of tomato.

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on plant height of tomato at 30, 40, 50, 60 and 70 DAT (Appendix III). At 30, 40, 50, 60 and 70 DAT, the tallest plant (16.76 cm, 41.71 cm, 63.1 cm, 84.0 cm and 94.0 cm) was found from L_0M_2 (0 dS/m + 10.0 mM Ca^{2+}) treatment combination, while the shortest (11.7 cm, 32.0 cm, 52.6 cm, 64.0 cm and 74.4 cm) was found from L_4M_0 (control salt + control, Ca^{2+}) treatment combination (Table 2).

4.2 Number of branches per plant

Different levels of salt stress varied significantly in terms of number of branches per plant of tomato for at 30, 40, 50, 60 and 70 days after transplanting (DAT) under the present trial (Appendix IV). At 30, 40, 50, 60 and 70 DAT the maximum number of branches per plant (3.75, 8.57, 14.9, 19.0 and 23.9) was recorded from L_0 which was closely followed (3.57, 7.85, 13.5, 17.2 and 21.5) by L_1 and then (3.23, 7.25, 12.9, 16.6 and 20.4) by L_2. On the other hand, the minimum number (2.77, 6.17, 11.0, 14.6 and 18.1) was recorded from L_4 which was follwed (3.18, 6.98, 11.6, 15.3 and 19.4) by L_3 (Table 3). Agong *et al*. (2003) reported that salt treatment at 2% NaCl stimulated chlorophyll production, but caused severe depression on the production of number of branches.

Table 2. Combined effect of salt stress and calcium (Ca^{2+}) on plant height at different days after transplanting (DAT) of tomato

Treatments	Plant height (cm) at				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
L_0M_0	14.4 cd	35.4 de	55.5 c-f	69.8 c-g	82.8 bc
L_0M_1	16.7 a	40.5 ab	62.9 a	84.0 a	93.6 a
L_0M_2	16.8 a	41.7 a	63.1 a	83.9 a	94.0 a
L_1M_0	13.7 cd	35.2 de	56.4 c-f	72.3 c-f	80.9 b-d
L_1M_1	15.2 bc	36.6 cd	58.1 bc	75.6 b-d	84.5 b
L_1M_2	16.5 ab	40.2 a-c	61.8 ab	82.4 ab	91.9 a
L_2M_0	14.7 c	37.3 b-d	57.8 b-d	76.1 bc	84.8 b
L_2M_1	14.2 cd	36.5 cd	57.3 c-e	74.4 c-e	83.2 bc
L_2M_2	14.5 c	35.1 de	57.1 c-e	71.6 c-f	83.2 bc
L_3M_0	12.9 de	33.4 de	53.5 ef	68.4 d-g	77.0 cd
L_3M_1	13.7 cd	35.6 de	56.5 c-f	71.9 c-f	82.1 bc
L_3M_2	13.9 cd	37.0 b-d	58.5 bc	75.8 b-d	85.4 b
L_4M_0	11.7 e	32.0 e	52.6 f	64.0 g	74.4 d
L_4M_1	11.7 e	32.1 e	52.8 f	67.4 e-g	74.8 d
L_4M_2	12.2 e	33.9 de	53.7 d-f	66.0 fg	76.4 cd
$LSD_{(0.05)}$	1.37	3.47	3.74	6.45	6.43
Level of significance	0.05	0.05	0.05	0.01	0.05
CV(%)	6.77	6.72	4.58	6.15	5.41

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

Table 3. Effect of salt stress and calcium (Ca^{2+}) on number of branches per plant at different days after transplanting (DAT) of tomato

Treatments	Number of branches per plant at				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Salt stress					
L_0	3.75 a	8.57 a	14.9 a	19.0 a	23.9 a
L_1	3.57 b	7.85 b	13.5 b	17.2 b	21.5 b
L_2	3.23 c	7.25 c	12.9 c	16.6 b	20.4 c
L_3	3.18 c	6.98 c	11.6 d	15.3 c	19.4 c
L_4	2.77 d	6.17 d	11.0 e	14.6 d	18.08 d
$LSD_{(0.05)}$	0.16	0.34	0.47	0.58	0.94
Level of significance	0.01	0.01	0.01	0.01	0.01
Calcium (Ca^{2+}) concentration					
M_0	3.04 c	6.99 c	11.8 c	15.4 c	18.8 c
M_1	3.34 b	7.35 b	12.8 b	16.6 b	21.0 b
M_2	3.52 a	7.75 a	13.6 a	17.6 a	22.1 a
$LSD_{(0.05)}$	0.13	0.26	0.36	0.45	0.73
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	6.00	5.57	4.42	4.26	5.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

Number of branches per plant of tomato showed significant differences due to different levels of calcium nitrate at 30, 40, 50, 60 and 70 DAT (Appendix IV). Data revealed that at 30, 40, 50, 60 and 70, the maximum number of branches per plant (3.52, 7.75, 13.6, 17.6 and 22.1) was found from M_2 which was closely followed (3.34, 7.35, 12.8, 16.6 and 21.0) by M_1, whereas the minimum number (3.04, 6.99, 11.8, 15.4 and 18.8) was found from M_0 for same DAT (Table 3).

Different levels of salt stress and calcium nitrate showed significant differences due to their combined effect on number of branches per plant of tomato at 30, 40, 50, 60 and 70 DAT (Appendix IV). At 30, 40, 50, 60 and 70 DAT, the maximum number of branches per plant (4.05, 8.90, 15.6, 20.0 and 25.8) was recorded from L_0M_2 treatment combination and the minimum number (2.35, 5.90, 10.5, 13.8 and 16.3) was found from L_4M_0 treatment combination (Table 4).

4.3 Number of leaves per plant

Statistically significant variation was recorded for number of leaves per plant of tomato due to different levels of salt stress at 30, 40, 50, 60 and 70 DAT under the present trial (Appendix V). At 30, 40, 50, 60 and 70 DAT the maximum number of leaves per plant (8.53, 18.9, 24.7, 29.7 and 31.2) was observed from L_0 which was closely followed (8.03, 17.1, 22.0, 27.8 and 29.9) by L_1 and then (7.38, 16.4, 21.1, 26.9 and 28.9) by L_2, while the minimum number (5.82, 14.3, 17.5, 21.6 and 24.0) was found from L_4 which was follwed (6.27, 15.4, 20.8, 25.0 and 27.4) by L_3 (Figure 3). Adams and Ho, 1992 reported that a higher amount of calcium is absorbed by leaves as compared to fruit.

Different levels of calcium nitrate varied significantly on number of leaves per plant of tomato at 30, 40, 50, 60 and 70 DAT (Appendix V). Data revealed that at 30, 40, 50, 60 and 70, the maximum number of leaves per plant (7.92, 17.7, 23.2, 28.5 and 30.5) was obtained from M_2 which was closely followed (7.33, 16.8, 21.7, 27.0 and 28.8) by M_1, whereas the minimum number (6.37, 14.7, 18.8, 23.1 and 25.4) was found from M_0 for same DAT (Figure 4).

Table 4. Combined effect of salt stress and calcium (Ca^{2+}) on number of branches per plant at different days after transplanting (DAT) of tomato

Treatments	Number of branches per plant at				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
L_0M_0	3.45 cd	8.32 a	13.9 b	17.3 b	21.3 c
L_0M_1	3.75 b	8.50 a	15.3 a	19.6 a	24.8 ab
L_0M_2	4.05 a	8.90 a	15.6 a	20.0 a	25.8 a
L_1M_0	3.35 cd	7.05 bc	12.1 e	15.9 d-f	19.9 c-e
L_1M_1	3.55 bc	7.65 b	13.1 cd	16.7 b-d	20.7 cd
L_1M_2	3.80 ab	8.85 a	15.3 a	19.1 a	23.9 b
L_2M_0	3.20 de	7.05 bc	12.2 de	16.1 c-f	19.5 c-e
L_2M_1	3.15 d-f	7.30 bc	13.0 cd	16.6 b-e	21.0 cd
L_2M_2	3.35 cd	7.40 b	13.5 bc	17.2 bc	20.6 cd
L_3M_0	2.85 f	6.65 cd	10.6 g	14.0 h	17.3 fg
L_3M_1	3.25 c-e	7.00 bc	11.9 e	15.5 e-g	20.0 c-e
L_3M_2	3.45 cd	7.30 bc	12.3 de	16.5 b-f	21.1 cd
L_4M_0	2.35 g	5.90 e	10.5 g	13.8 h	16.3 g
L_4M_1	3.00 ef	6.30 de	10.9 fg	14.5 gh	18.7 ef
L_4M_2	2.95 ef	6.30 de	11.5 ef	15.4 fg	19.3 de
$LSD_{(0.05)}$	0.28	0.59	0.81	1.01	1.62
Level of significance	0.05	0.05	0.01	0.05	0.05
CV(%)	6.00	5.57	4.42	4.26	5.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control
L_1: 2 dS/m
L_2: 4 dS/m
L_3: 6 dS/m
L_4: 8 dS/m

M_0: Control, no Ca^{2+}
M_1: 5.0 mM Ca^{2+}
M_2: 10.0 mM Ca^{2+}

Number of leaves per plant of tomato showed significant differences due to combined effect of different levels of salt stress and calcium nitrate at 30, 40, 50, 60 and 70 DAT (Appendix V). At 30, 40, 50, 60 and 70 DAT, the maximum number of leaves per plant (9.40, 20.7, 27.2, 32.6 and 34.4) was found from L_0M_2 treatment combination and the minimum number (5.15, 12.8, 15.5, 20.6 and 23.1) from L_4M_0 treatment combination (Table 5).

4.4 SPAD values

Significant variation was observed for SPAD values of tomato plant due to different levels of salt stress at flowering stage and 30 days after flowering (Appendix VI). At flowering stage, the highest SPAD values (44.2) was obtained from L_0 which was closely followed (42.2) by L_1, whereas the lowest SPAD values (31.8) was found from L_4 which was follwed (36.4) by L_3. At 30 days after flowering, the highest SPAD values (39.1) was found from L_0 which was closely followed (35.4) by L_1, again the lowest SPAD values (21.3) was recorded from L_4 which was follwed (29.6) by L_3 (Table 6).

SPAD values of tomato at flowering stage and 30 days after flowering varied significantly due to different levels of calcium nitrate (Appendix VI). At flowering stage, the highest SPAD value (40.6) was found from M_2 which was statistically similar (39.2) with M_1, while the lowest SPAD value (37.0) was recorded from M_0. At 30 days after flowering, the highest SPAD value (33.6) was obtained from M_2 which was closely followed (31.8) by M_1, whereas the lowest SPAD value (29.5) was observed from M_0 (Table 6).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences in terms of SPAD values of tomato at flowering stage and 30 days after flowering (Appendix VI). At flowering stage, the highest SPAD value (48.2) was observed from L_0M_2 treatment combination and the lowest SPAD values (31.3) from L_4M_0 treatment combination. At 30 days after flowering, the highest SPAD value (41.1) was found from L_0M_2, while the lowest values (14.6) from L_4M_0 treatment combination (Table 7).

Table 5. Combined effect of salt stress and calcium (Ca^{2+}) on number of leaves per plant at different days after transplanting (DAT) of tomato

Treatments	Number of leaves per plant at				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
L_0M_0	7.40 c-e	16.2 c-e	21.4 d	25.1 fg	26.2 ef
L_0M_1	8.80 b	19.8 ab	25.6 b	31.3 ab	32.9 ab
L_0M_2	9.40 a	20.7 a	27.2 a	32.6 a	34.4 a
L_1M_0	7.15 def	15.8 c-e	19.8 e	25.1 fg	27.6 de
L_1M_1	7.85 c	16.6 cd	21.8 cd	28.2 c-e	30.1 b-d
L_1M_2	9.10 ab	18.9 b	24.4 b	30.2 bc	32.0 a-c
L_2M_0	6.80 f-h	15.5 c-e	19.4 e	23.5 gh	26.5 ef
L_2M_1	7.55 cd	17.0 c	21.7 cd	28.1 c-e	29.9 cd
L_2M_2	7.80 c	16.6 cd	22.3 cd	29.1 cd	30.5 b-d
L_3M_0	5.35 j	13.3 f	18.1 f	21.2 ij	23.7 fg
L_3M_1	6.50 gh	16.0 c-e	21.5 d	26.2 ef	28.1 de
L_3M_2	6.95 e-g	17.1 c	23.0 c	27.7 de	30.3 b-d
L_4M_0	5.15 j	12.8 f	15.5 g	20.6 j	23.1 g
L_4M_1	5.95 i	14.7 e	17.8 f	21.4 h-j	23.3 g
L_4M_2	6.35 hi	15.3 de	19.1 ef	22.8 g-i	25.6 e-g
$LSD_{(0.05)}$	0.50	1.34	1.21	2.10	2.65
Level of significance	0.05	0.01	0.01	0.05	0.05
CV(%)	4.85	5.74	4.01	5.63	6.58

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control
L_1: 2 dS/m
L_2: 4 dS/m
L_3: 6 dS/m
L_4: 8 dS/m

M_0: Control, no Ca^{2+}
M_1: 5.0 mM Ca^{2+}
M_2: 10.0 mM Ca^{2+}

Table 6. Effect of salt stress and calcium (Ca^{2+}) on SPAD value and leaf area of tomato

Treatments	SPAD value at		Leaf area (cm^2) at	
	Flowering stage	30 Days after flowering	Flowering stage	30 Days after flowering
Salt stress				
L_0	44.2 a	39.1 a	202.5 a	188.3 a
L_1	42.2 b	35.4 b	195.2 b	181.9 b
L_2	40.1 c	32.6 c	191.7 b	177.6 b
L_3	36.4 d	29.6 d	183.0 c	170.2 c
L_4	31.8 e	21.3 e	171.3 d	158.8 d
$LSD_{(0.05)}$	1.858	1.998	6.058	5.364
Level of significance	0.01	0.01	0.01	0.01
Calcium (Ca^{2+}) concentration				
M_0	37.0 b	29.5 c	183.5 b	169.7 b
M_1	39.2 a	31.8 b	190.4 a	176.7 a
M_2	40.6 a	33.6 a	192.3 a	179.7 a
$LSD_{(0.05)}$	1.439	1.547	4.693	4.155
Level of significance	0.01	0.01	0.01	0.01
CV(%)	5.79	7.67	3.90	4.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

Table 7. Combined effect of salt stress and calcium (Ca^{2+}) on SPAD value and leaf area of tomato

Treatments	SPAD value		Leaf area (cm^2)	
	Flowering stage	30 Days after flowering	Flowering stage	30 Days after flowering
L_0M_0	40.2 cd	37.0 bc	203.7 bc	186.0 bc
L_0M_1	44.3 b	39.3 ab	190.4 e	181.6 cd
L_0M_2	48.2 a	41.1 a	216.6 a	197.3 a
L_1M_0	38.8 c-e	33.0 d-f	167.0 hi	158.0 gh
L_1M_1	39.9 c-e	37.4 b	213.6 ab	196.0 a
L_1M_2	47.8 a	35.8 b-d	202.7 b-d	191.7 ab
L_2M_0	38.2 de	33.5 c-e	188.6 ef	173.3 d-f
L_2M_1	39.9 c-e	33.4 c-f	194.5 c-e	181.2 cd
L_2M_2	42.4 bc	31.1 e-g	191.8 de	178.2 cd
L_3M_0	36.5 e	29.5 fg	192.0 de	176.0 c-e
L_3M_1	40.1 c-e	30.6 e-g	179.0 fg	166.8 e-g
L_3M_2	32.6 f	28.6 g	178.1 f-h	167.8 e-g
L_4M_0	31.3 f	14.6 i	166.2 i	155.1 h
L_4M_1	32.1 f	18.2 h	171.4 g-i	157.8 gh
L_4M_2	32.0 f	31.1 e-g	175.5 g-i	163.5 f-h
$LSD_{(0.05)}$	3.218	3.460	10.49	9.291
Level of significance	0.01	0.01	0.01	0.01
CV(%)	5.79	7.67	3.90	4.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

4.5 Leaf area

Statistically significant variation was recorded for leaf area due to different levels of salt stress at flowering stage and 30 days after flowering (Appendix VI). At flowering stage, the maximum leaf area (202.5 cm^2) was recorded from L_0 which was closely followed (195.2 and 191.7 cm^2) by L_1, while the minimum leaf area (171.3 cm^2) was found from L_4 which was follwed (183.3 cm^2) by L_3. At 30 days after flowering, the maximum leaf area (188.0 cm^2) was recorded from L_0 which was closely followed (181.9 and 177.6 cm^2) by L_1, while the minimum leaf area (158.8 cm^2) was found from L_4 which was follwed (170.2 cm^2) by L_3 (Table 6). Luo *et al*. (2013) reported that under the salt stress of NaCl, the increase of NaCl concentration had stronger inhibitory effect on tomato growth which leads to decreases leaf area of tomato. Agong *et al*. (2003) found that significant genotypic and/or salt treatment effects were registered on leaf area of tomato.

Different levels of calcium nitrate varied significantly on leaf area of tomato at flowering stage and 30 days after flowering (Appendix VI). At flowering stage, the maximum leaf area (192.3 cm^2) was obtained from M_2 which was statistically similar (190.4 cm^2) with M_1, whereas the minimum leaf area (183.5 cm^2) was found from M_0. At 30 days after flowering, the maximum leaf area (179.7 cm^2) was obtained from M_2 which statistically similar (176.7 cm^2) with M_1, whereas the minimum leaf area (169.7 cm^2) was found from M_0 (Table 6). Hao and Papadopoulos (2004) reported that at 300 $mg \cdot L^{-1}$ Ca, leaf area increased linearly with increasing level.

Leaf area of tomato showed significant differences due to combined effect of different levels of salt stress and calcium nitrate at flowering stage and 30 days after flowering (Appendix VI). At flowering stage, the maximum leaf area (216.6 cm^2) was attained from L_0M_2 treatment combination and the minimum (166.2 cm^2) from L_4M_0 treatment combination. At 30 days after flowering, the maximum leaf area (197.3 cm^2) was attained from L_0M_2 treatment combination and the minimum leaf area (155.1 cm^2) from L_4M_0 treatment combination (Table 7).

4.6 Days from transplanting to 1st flowering

Days from transplanting to 1st flowering of tomato varied significantly due to different levels of salt stress under the present trial (Appendix VII). The minimum days from transplanting to 1st flowering (40.3) was found from L_0 which was statistically similar (41.2) with L_1. On the other hand, the maximum days (46.10) was attained from L_4 which was follwed (43.8 and 42.8) by L_3 and L_2 and they were statistically identical (Table 8). Mizrahi (1982) reported that Salinity shortened the time of fruit development by 4 to 15%. Murshed *et al*. (2014) reported that the response of antioxidant systems of tomato fruits to oxidative stress induced by salt stress treatments was different depending on the fruit development stage.

Significant differences were recorded due to different levels of calcium nitrate showed on days from transplanting to 1st flowering of tomato (Appendix VII). The minimum days from transplanting to 1st flowering (41.5) was recorded from M_2 which was closely followed (42.9) by M_1 and the maximum days (44.1) was found from M_0 (Table 8). Similar findings also reported by Hao and Papadopoulos (2004) earlier from their experiment. Wu *et al*., 2002 reported that calcium is associated with the middle lamella of cell walls playing a role in support and growth of cell that lead to produced earliest floering.

Different levels of salt stress and calcium nitrate varied significantly due to their combined effect in terms of days from transplanting to 1st flowering (Appendix VII). The minimum days from transplanting to 1st flowering (38.8) was observed from L_0M_2 treatment combination, whereas the maximum days (48.3) was found from L_4M_0 treatment combination (Table 9).

Table 8. Effect of salt stress and calcium (Ca^{2+}) on yield contributing characters of tomato

Treatments	Days from transplanting to flowering	Number of flower/cluster	Number of flowers/plant	Number of fruits/cluster
Salt stress				
L_0	40.3 c	7.80 a	67.3 a	5.10 a
L_1	41.2 c	7.55 a	62.0 b	4.93 a
L_2	42.8 b	7.48 a	59.0 b	4.85 a
L_3	43.8 b	6.68 b	48.0 c	4.30 b
L_4	46.1 a	5.78 c	38.4 d	3.88 c
$LSD_{(0.05)}$	1.40	0.38	3.57	0.31
Level of significance	0.01	0.01	0.01	0.01
Calcium (Ca^{2+}) concentration				
M_0	44.1 a	6.53 c	47.0 c	4.18 c
M_1	42.9 b	7.09 b	55.6 b	4.62 b
M_2	41.5 c	7.56 a	62.2 a	5.03 a
$LSD_{(0.05)}$	1.08	0.30	2.76	0.24
Level of significance	0.01	0.01	0.01	0.01
CV(%)	3.96	6.57	7.88	8.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

Table 9. Combined effect of salt stress and calcium (Ca^{2+}) on yield contributing characters of tomato

Treatments	Days from transplanting to flowering	Number of flower/cluster	Number of flowers/plant	Number of fruits/cluster
L_0M_0	40.0 f-h	6.50 f-h	54.0 d-f	4.40 d-f
L_0M_1	41.0 e-h	8.20 ab	71.7 a	5.10 bc
L_0M_2	38.8 h	8.70 a	76.1 a	5.80 a
L_1M_0	43.3 b-e	6.80 d-f	50.9 ef	4.45 d-f
L_1M_1	41.5 e-g	7.50 b-d	61.1 bc	4.95 b-d
L_1M_2	39.8 gh	8.35 a	74.0 a	5.38 ab
L_2M_0	43.5 b-e	7.55 bc	55.1 c-e	4.60 c-f
L_2M_1	43.0 b-e	7.35 c-e	58.8 b-d	4.80 b-e
L_2M_2	42.0 d-g	7.55 bc	63.0 b	5.15 bc
L_3M_0	45.3 bc	6.05 g-i	39.9 gh	4.05 f
L_3M_1	43.5 b-e	6.65 e-g	48.2 f	4.25 ef
L_3M_2	42.5 c-f	7.35 c-e	55.8 c-e	4.60 c-f
L_4M_0	48.3 a	5.75 i	35.1 h	3.40 g
L_4M_1	45.5 b	5.75 i	38.3 gh	4.00 f
L_4M_2	44.5 b-d	5.85 hi	41.8 g	4.25 ef
$LSD_{(0.05)}$	2.42	0.66	6.18	0.54
Level of significance	0.05	0.01	0.01	0.05
CV(%)	3.96	6.57	7.88	8.22

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control
L_1: 2 dS/m
L_2: 4 dS/m
L_3: 6 dS/m
L_4: 8 dS/m

M_0: Control, no Ca^{2+}
M_1: 5.0 mM Ca^{2+}
M_2: 10.0 mM Ca^{2+}

4.7 Number of flower cluster per plant

Different levels of salt stress varied significantly in terms of number of flower cluster per plant of tomato (Appendix VII). Data revealed that the highest number of flower cluster per plant (8.60) was found from L_0 which was closely followed (8.17 and 7.88) by L_1 and L_2 and they were statistically similar, while the lowest number (6.63) was recorded from L_4 which was follwed (7.15) by L_3 (Figure 5). Agong *et al*. (2003) found that significant genotypic and/or salt treatment effects were registered on yield contributing characters of tomato.

Different levels of calcium nitrate showed significant differences on number of flower cluster per plant of tomato (Appendix VII). The highest number of flower cluster per plant (8.14) was recorded from M_2 which was closely followed (7.76) by M_1, whereas the lowest number (7.16) was found from M_0 (Figure 6).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on number of flower cluster per plant (Appendix VII). The highest number of flower cluster per plant (8.85) was observed from L_0M_2 treatment combination, while the lowest number (6.10) was attained from L_4M_0 treatment combination (Figure 7).

4.8 Number of flowers per cluster

Different levels of salt stress varied significantly in terms of number of flowers per cluster of tomato (Appendix VII). The highest number of flowers per cluster (7.80) was recorded from L_0 which was statistically similar (7.55 and 7.48) to L_1 and L_2. On the other hand, the lowest number (5.78) was recorded from L_4 which was follwed (6.68) by L_3 (Table 8). Luo *et al*. (2013) reported that salt stress of NaCl, stronger inhibitory effect on tomato growth.

Number of flowers per cluster of tomato showed significant differences for different levels of calcium nitrate (Appendix VII). The highest number of flowers per cluster (7.56) was found from M_2 which was closely followed (7.09) by M_1, while the lowest number (6.53) was recorded from M_0 (Table 8).

Statistically significant variation was recorded for the combined effect of different levels of salt stress and calcium nitrate on number of flowers per cluster (Appendix VII). The highest number of flowers per cluster (8.70) was recorded from L_0M_2 treatment combination, while the lowest number (5.75) was found from L_4M_0 treatment combination (Table 9).

4.9 Number of flowers per plant

Number of flowers per plant of tomato varied significantly due to different levels of salt stress under the present trial (Appendix VII). The highest number of flowers per plant (67.3) was found from L_0 which was closely followed (62.0 and 59.0) by L_1 and L_2 and they were statistically similar, while the lowest number (38.4) was observed from L_4 which was follwed (48.0) by L_3 (Table 8).

Statistically significant variation was recorded for different levels of calcium nitrate on number of flowers per plant of tomato (Appendix VII). The highest number of flowers per plant (62.2) was recorded from M_2 which was closely followed (55.6) by M_1, again the lowest number (47.0) was observed from M_0 (Table 8).

Different levels of salt stress and calcium nitrate showed significant differences on number of flowers per plant due to combined effect (Appendix VII). The highest number of flowers per plant (76.1) was found from L_0M_2 treatment combination and the lowest number (35.1) was observed from L_4M_0 treatment combination (Table 9).

4.10 Number of fruits per cluster

Number of fruits per cluster of tomato varied significantly for different levels of salt stress under the present trial (Appendix VII). The highest number of fruits per cluster (5.10) was recorded from L_0 which was statistically similar (4.93 and 4.85) by L_1 and L_2. On the other hand, the lowest number (3.88) was recorded from L_4 which was follwed (4.30) by L_3 (Table 8).

Different levels of calcium nitrate showed significant differences on number of fruit per cluster of tomato (Appendix VII). The highest number of fruits per cluster (5.03) was found from M_2 which was closely followed (4.62) by M_1, whereas the lowest number (4.18) was found from M_0 (Table 8). Hao and Papadopoulos (2004) reported that at 300 $mg \cdot L^{-1}$ Ca, total fruit number.

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on number of fruits per cluster (Appendix VII). The highest number of fruits per cluster (5.80) was attained from L_0M_2 treatment combination, while the lowest number (3.40) was recorded from L_4M_0 treatment combination (Table 9).

4.11 Number of fruits per plant

Significant variation was recorded in terms of number of fruits per plant of tomato due to different levels of salt stress under the present trial (Appendix VII). The highest number of fruits per plant (44.0) was recorded from L_0 which was closely followed (40.5 and 38.3) by L_1 and L_2 and they were statistically similar, again the lowest number (25.9) was found from L_4 which was follwed (30.9) by L_3 (Figure 8). Agong *et al*. (2003) found that significant genotypic effects were registered on growth parameters.

Number of fruit per plant of tomato showed statistically significant difference due to different levels of calcium nitrate (Appendix VII). The highest number of fruits per plant (41.4) was recorded from M_2 which was closely followed (36.2) by M_1 and the lowest number (30.2) was recorded from M_0 (Figure 9).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on number of fruits per plant (Appendix VII). The highest number of fruits per plant (50.8) was observed from L_0M_2 treatment combination, whereas the lowest number (20.7) was attained from L_4M_0 treatment combination (Figure 10).

4.12 Length of fruit

Length of fruit of tomato varied significantly for different levels of salt stress under the present trial (Appendix VIII). The highest length of fruit (8.96 cm) was recorded from L_0 which was statistically similar (8.46 cm) with L_1 and closely followed (8.04 cm) by L_2. On the other hand, the lowest length (6.06 cm) was recorded from L_4 which was follwed (7.59 cm) by L_3 (Table 10). Hao and Papadopoulos (2004) reported that at 300 $mg \cdot L^{-1}$ Ca, total fruit length increased linearly.

Different levels of calcium nitrate showed significant differences on length of fruit of tomato (Appendix VIII). The highest length of fruit (8.51 cm) was attained from M_2 which was closely followed (7.97 cm) by M_1, whereas the lowest length (6.99 cm) was recorded from M_0 (Table 10).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on length of fruit (Appendix VIII). The highest length of fruit (9.71 cm) was recorded from L_0M_2 treatment combination, again the lowest length (5.21 cm) was observed from L_4M_0 treatment combination (Table 11).

4.13 Diameter of fruit

Different levels of salt stress varied significantly for diameter of fruit of tomato (Appendix VIII). The highest diameter of fruit (5.83 cm) was recorded from L_0 which was statistically similar (5.58 cm) with L_1 and closely followed (5.31 cm) by L_2, while the lowest diameter (4.41 cm) was found from L_4 which was follwed (5.18 cm) by L_3 (Table 10). Posada and Rodriguez (2009) reported that fruits of salt-stressed plants had reduced diameter.

Statistically significant variation was recorded due to different levels of calcium nitrate on diameter of fruit of tomato (Appendix VIII). Data revealed that the highest diameter of fruit (5.61 cm) was recorded from M_2 which was statistically identical (5.37 cm) with M_1, whereas the lowest diameter (4.80 cm) was found from M_0 (Table 10).

Table 10. Effect of salt stress and calcium (Ca^{2+}) on yield contributing characters and yield of tomato

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in fruit (%)	Yield/plant (kg)
Salt stress				
L_0	8.96 a	5.83 a	8.97 a	3.19 a
L_1	8.46 ab	5.58 ab	8.83 a	2.86 b
L_2	8.04 bc	5.31 bc	8.42 b	2.63 b
L_3	7.59 c	5.18 c	8.04 c	2.07 c
L_4	6.06 d	4.41 d	7.32 d	1.42 d
$LSD_{(0.05)}$	0.60	0.37	0.36	0.26
Level of significance	0.01	0.01	0.01	0.01
Calcium (Ca^{2+}) concentration				
M_0	6.99 c	4.80 b	7.88 b	1.93 c
M_1	7.97 b	5.37 a	8.41 a	2.48 b
M_2	8.51 a	5.61 a	8.65 a	2.89 a
$LSD_{(0.05)}$	0.46	0.28	0.28	0.20
Level of significance	0.01	0.01	0.01	0.01
CV(%)	9.27	8.41	5.31	12.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control

L_1: 2 dS/m

L_2: 4 dS/m

L_3: 6 dS/m

L_4: 8 dS/m

M_0: Control, no Ca^{2+}

M_1: 5.0 mM Ca^{2+}

M_2: 10.0 mM Ca^{2+}

Table 11. Combined effect of salt stress and calcium (Ca^{2+}) on yield contributing characters and yield of tomato

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in fruit (%)	Yield/plant (kg)
L_0M_0	7.79 c	5.03 d-g	8.16 cd	2.37 ef
L_0M_1	9.37 ab	5.98 ab	9.18 a	3.33 bc
L_0M_2	9.71 a	6.49 a	9.56 a	3.88 a
L_1M_0	7.51 cd	5.02 d-g	8.10 cd	2.09 fg
L_1M_1	8.33 bc	5.75 bc	9.01 a	2.91 cd
L_1M_2	9.53 a	5.97 ab	9.37 a	3.58 ab
L_2M_0	8.15 c	4.79 e-h	8.02 cd	2.28 ef
L_2M_1	7.94 c	5.42 b-e	8.34 bc	2.72 de
L_2M_2	8.03 c	5.72 b-d	8.90 ab	2.90 cd
L_3M_0	6.27 e	5.01 d-g	8.21 cd	1.71 gh
L_3M_1	7.87 c	5.26 c-f	8.02 cd	2.06 fg
L_3M_2	8.64 a-c	5.26 c-f	7.88 cd	2.44 d-f
L_4M_0	5.21 f	4.14 h	6.92 e	1.20 i
L_4M_1	6.34 e	4.45 gh	7.53 de	1.40 hi
L_4M_2	6.64 de	4.63 f-g	7.52 de	1.67 gh
$LSD_{(0.05)}$	1.04	0.63	0.63	0.45
Level of significance	0.05	0.05	0.05	0.01
CV(%)	9.27	8.41	5.31	12.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

L_0: Control
L_1: 2 dS/m
L_2: 4 dS/m
L_3: 6 dS/m
L_4: 8 dS/m

M_0: Control, no Ca^{2+}
M_1: 5.0 mM Ca^{2+}
M_2: 10.0 mM Ca^{2+}

Diameter of fruit showed significant differences due to combined effect of different levels of salt stress and calcium nitrate (Appendix VIII). The highest diameter of fruit (6.49 cm) was observed from L_0M_2 treatment combination and the lowest diameter (4.14 cm) was recorded from L_4M_0 treatment combination (Table 11).

4.14 Dry matter content in plant

Dry matter content in plant of tomato varied significantly for different levels of salt stress under the present trial (Appendix VIII). The highest dry matter content in plant (12.1%) was found from L_0 which was statistically similar (11.9% and 11.7%) by L_1 and L_2, whereas the lowest (11.0%) was observed from L_4 which was statistically similar (11.2%) with L_3 (Figure 11).

Different levels of calcium nitrate showed significant differences on dry matter content in plant of tomato (Appendix VIII). The highest dry matter content in plant (12.3%) was recorded from M_2 which was closely followed (11.8%) by M_1, while the lowest (10.7%) was found from M_0 (Figure 12).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on dry matter content in plant (Appendix VIII). The highest dry matter content in plant (13.6%) was observed from L_0M_2 treatment combination, while the lowest (10.2%) was recorded from L_4M_0 treatment combination (Figure 13).

4.15 Dry matter content in fruit

Statistically significant variation was observed in terms of dry matter content in fruit of tomato for different levels of salt stress under the present trial (Appendix VIII). The highest dry matter content in fruit (8.97%) was recorded from L_0 which was statistically similar (8.83%) with L_1 and closely folowed (8.42 cm) by L_2, while the lowest (7.32%) was recorded from L_4 which was follwed (8.04%) by L_3 (Table 10). Posada and Rodriguez (2009) reported that fruits of salt-stressed plants had reduced total dry matter.

Dry matter content in fruit of tomato showed significant differences due to different levels of calcium nitrate (Appendix VIII). The highest dry matter content in fruit (8.65%) was found from M_2 which was statistically identical (8.41%) with M_1 and the lowest (7.88%) was recorded from M_0 (Table 10). Hao and Papadopoulos (2004) reported that at 300 $mg \cdot L^{-1}$ Ca, total fruit yield and fruit dry matter increased linearly.

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on dry matter content in fruit (Appendix VIII). The highest dry matter content in fruit (9.56%) was recorded from L_0M_2 treatment combination, whereas the lowest (6.92%) was found from L_4M_0 treatment combination (Table 11).

4.16 Weight of individual fruit

Weight of individual fruit of tomato varied significantly due to effects of different levels of salt stress under the present trial (Appendix VIII). The highest weight of individual fruit (72.0 g) was found from L_0 which was statistically similar (69.8 g and 68.7 g) by L_1 and L_2. On the other hand, the lowest (55.1 g) was observed from L_4 which was follwed (66.8 g) by L_3 (Figure 14).

Statistically significant variation was recorded for different levels of calcium nitrate on weight of individual fruit of tomato (Appendix VIII). The highest weight of individual fruit (68.7 g) was recorded from M_2 which was statistically identical (67.2 g) with M_1, whereas the lowest weight (63.5 g) was attained from M_0 (Figure 15).

Combined effect of different levels of salt stress and calcium nitrate showed significant differences on weight of individual fruit (Appendix VIII). The highest weight of individual fruit (76.4 g) was observed from L_0M_2 treatment combination, again the lowest (52.5 g) was recorded from L_4M_0 treatment combination (Figure 16).

4.17 Yield per plant

Different levels of salt stress varied significantly in terms of yield per plant of tomato under the present trial (Appendix VIII). The highest yield per plant (3.19 kg) was recorded from L_0 which was closely followed (2.86 kg and 2.63 kg) by L_1 and L_2 respectively, which was statistically similar, while the lowest yield (1.42 kg) was found from L_4 which was follwed (2.07 kg) by L_3 (Table 10). Most crops tolerate salinity up to a threshold level, above which yields decrease as salinity increases (Maas, 1986). Tomato yield were subjected to 75 and 150 mM NaCl stress in order to study the effect of salt stress on its antioxidant response and stress indicators by Slathia and Choudhary (2013).

Different levels of calcium nitrate showed significant differences on yield per plant of tomato (Appendix VIII). The highest yield per plant (2.89 kg) was recorded from M_2 which was closely followed (2.48 kg) by M_1, whereas the lowest yield (1.93 kg) was observed from M_0 (Table 10). Hao and Papadopoulos (2004) reported that at 300 $mg \cdot L^{-1}$ Ca, total fruit yield increased linearly.

Yield per plant varied significantly due to the combined effect of different levels of salt stress and calcium nitrate (Appendix VIII). The highest yield per plant (3.88 kg) was recorded from L_0M_2 treatment combination and the lowest yield (1.20 kg) was observed from L_4M_0 treatment combination (Table 11).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from October 2013 to April 2014 to study the mitigation of salt stress in tomato with calcium nitrate. Seedlings of 30 days of BARI Tomato-5 were used as test crop. The experiment consisted of two factors: Factor A: NaCl salt concentration (five levels) as L_0: Control, L_1: 2 dS/m, L_2: 4 dS/m, L_3: 6 dS/m and L_4: 8 dS/m; Factor B: Calcium nitrate (three levels) as M_0: Control i.e. no calcium, M_1: 5.0 mM Ca^{2+} and M_2: 10.0 mM Ca^{2+}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Data on different growth and yield parameter were recorded and statistically significant variation was found for different level of salt stress and calcium nitrate and their combined effect.

At 30, 40, 50, 60 and 70 DAT the tallest plant (15.9 cm, 39.2 cm, 60.5 cm, 79.2 cm and 90.1 cm) was recorded from L_0, whereas the shortest plant (11.9 cm, 32.7 cm, 53.0 cm, 65.8 cm and 75.2 cm) from L_4. At 30, 40, 50, 60 and 70 DAT the maximum number of branches per plant (3.75, 8.57, 14.9, 19.0 and 23.9) was recorded from L_0 and the minimum number (2.77, 6.17, 11.0, 14.6 and 18.1) from L_4. At 30, 40, 50, 60 and 70 DAT the maximum number of leaves per plant (8.53, 18.9, 24.7, 29.7 and 31.2) was observed from L_0, while the minimum number (5.82, 14.3, 17.5, 21.6 and 24.0) from L_4. At flowering stage, the highest SPAD values (44.2) was obtained from L_0, whereas the lowest (31.8) from L_4. At 30 days after flowering, the highest SPAD values (39.1) was found from L_0, again the lowest (21.3) from L_4. At flowering stage, the maximum leaf area (202.5 cm^2) was recorded from L_0, while the minimum leaf area (171.3 cm^2) from L_4. At 30 days after flowering, the maximum leaf area (188.3 cm^2) was recorded from L_0, while the minimum leaf area (158.8 cm^2) from L_4. The minimum days from transplanting to 1st flowering (40.3) was found from L_0 and the maximum days (46.1) from L_4. The highest number of flower cluster per plant (8.60) was found from L_0, while the

lowest number (6.63) from L_4. The highest number of flowers per cluster (7.80) was recorded from L_0 and the lowest number (5.78) from L_4. The highest number of flowers per plant (67.3) was found from L_0, while the lowest number (38.4) from L_4. The highest number of fruits per cluster (5.10) was recorded from L_0 and the lowest number (3.88) from L_4. The highest number of fruits per plant (44.0) was recorded from L_0, again the lowest number (25.9) from L_4. The highest length of fruit (8.96 cm) was recorded from L_0 and the lowest length (6.06 cm) from L_4. The highest diameter of fruit (5.83 cm) was recorded from L_0, while the lowest diameter (4.41 cm) from L_4. The highest dry matter content in plant (12.1%) was found from L_0, whereas the lowest (11.0%) from L_4. The highest dry matter content in fruit (8.97%) was recorded from L_0, while the lowest (7.32%) from L_4. The highest weight of individual fruit (72.0 g) was found from L_0 and the lowest (55.1 g) from L_4. The highest yield per plant (3.19 kg) was recorded from L_0, while the lowest yield (1.42 kg) from L_4.

At 30, 40, 50, 60 and 70, the tallest plant (14.8 cm, 37.6 cm, 58.9 cm, 75.9 cm and 86.2 cm) was found from M_2, while the shortest plant (13.5 cm, 34.7 cm, 55.2 cm, 70.8 cm and 86.1 cm) from M_0. At 30, 40, 50, 60 and 70, the maximum number of branches per plant (3.52, 7.75, 13.6, 17.6 and 22.1) was found from M_2, whereas the minimum number (3.04, 6.99, 11.8, 15.4 and 18.8) from M_0. At 30, 40, 50, 60 and 70, the maximum number of leaves per plant (7.92, 17.7, 23.2, 28.5 and 30.5) was obtained from M_2, whereas the minimum number (6.37, 14.7, 18.8, 23.1 and 25.4) from M_0. At flowering stage, the highest SPAD value (40.6) was found from M_2 while the lowest SPAD value (37.0) from M_0. At 30 days after flowering, the highest SPAD value (33.6) was obtained from M_2, whereas the lowest SPAD value (29.5) from M_0. At flowering stage, the maximum leaf area (192.3 cm^2) was obtained from M_2, whereas the minimum leaf area (183.5 cm^2) from M_0. At 30 days after flowering, the maximum leaf area (179.7 cm^2) was obtained from M_2, whereas the minimum leaf area (169.7 cm^2) from M_0. The minimum days from transplanting to 1st flowering (41.5) were recorded from M_2 and the maximum days (44.1) from M_0. The highest number of flower cluster per plant (8.14) was recorded from M_2,

whereas the lowest number (7.16) from M_0. The highest number of flowers per cluster (7.56) was found from M_2, while the lowest number (6.53) from M_0. The highest number of flowers per plant (62.2) was recorded from M_2, again the lowest number (47.0) from M_0. The highest number of fruits per cluster (5.03) was found from M_2, whereas the lowest number (4.18) from M_0. The highest number of fruits per plant (41.4) was recorded from M_2 and the lowest number (30.2) from M_0. The highest length of fruit (8.51 cm) was attained from M_2, whereas the lowest length (6.99 cm) from M_0. The highest diameter of fruit (5.61 cm) was recorded from M_2, whereas the lowest diameter (4.80 cm) from M_0. The highest dry matter content in plant (12.3%) was recorded from M_2, while the lowest (10.7%) from M_0. The highest dry matter content in fruit (8.65%) was found from M_2 and the lowest (7.88%) from M_0. The highest weight of individual fruit (68.7 g) was recorded from M_2, whereas the lowest weight (63.5 g) from M_0. The highest yield per plant (2.89 kg) was recorded from M_2, whereas the lowest yield (1.93 kg) from M_0.

At 30, 40, 50, 60 and 70 DAT, the tallest plant (16.8 cm, 41.7 cm, 63.1 cm, 84.0 cm and 94.0 cm) was found from L_0M_2, while the shortest (11.7 cm, 32.0 cm, 52.6 cm, 64.0 cm and 74.4 cm) from L_4M_0. At 30, 40, 50, 60 and 70 DAT, the maximum number of branches per plant (4.05, 8.90, 15.6, 20.0 and 25.8) was recorded from L_0M_2 and the minimum number (2.35, 5.90, 10.5, 13.8 and 16.3) from L_4M_0 treatment combination. At 30, 40, 50, 60 and 70 DAT, the maximum number of leaves per plant (9.40, 20.7, 27.2, 32.6 and 34.4) was attained from L_0M_2 and the minimum number (5.15, 12.8, 15.5, 20.6 and 23.1) from L_4M_0. At flowering stage, the highest SPAD value (48.2) was observed from L_0M_2 and the lowest (31.3) from L_4M_0. At 30 days after flowering, the highest SPAD value (41.1) was found from L_0M_2, while the lowest (14.6) from L_4M_0 treatment combination. At flowering stage, the maximum leaf area (216.6 cm^2) was attained from L_0M_2 and the minimum (166.2 cm^2) from L_4M_0 treatment combination. At 30 days after flowering, the maximum leaf area (197.3 cm^2) was attained from L_0M_2 and the minimum leaf area (155.1 cm^2) from L_4M_0 treatment combination. The minimum days from transplanting to 1^{st} flowering (38.8) was observed from L_0M_2, whereas

the maximum days (48.3) from L_4M_0 treatment combination. The highest number of flower cluster per plant (8.85) was observed from L_0M_2, while the lowest number (6.10) from L_4M_0. The highest number of flowers per cluster (8.70) was recorded from L_0M_2, while the lowest number (5.75) from L_4M_0. The highest number of flowers per plant (76.1) was found from L_0M_2 and the lowest number (35.1) from L_4M_0. The highest number of fruits per cluster (5.80) was attained from L_0M_2, while the lowest number (3.40) from L_4M_0. The highest number of fruits per plant (50.8) was observed from L_0M_2, whereas the lowest number (20.7) from L_4M_0. The highest length of fruit (9.71 cm) was recorded from L_0M_2, again the lowest length (5.21 cm) from L_4M_0. The highest diameter of fruit (6.49 cm) was observed from L_0M_2 and the lowest diameter (4.14 cm) from L_4M_0. The highest dry matter content in plant (13.6%) was observed from L_0M_2, while the lowest (10.2%) from L_4M_0. The highest dry matter content in fruit (9.56%) was recorded from L_0M_2, whereas the lowest (6.92%) from L_4M_0. The highest weight of individual fruit (76.4 g) was observed from L_0M_2, again the lowest (52.5 g) from L_4M_0. The highest yield per plant (3.88 kg) was recorded from L_0M_2 and the lowest yield (1.20 kg) from L_4M_0.

Above finding revealed that the combination of L_0M_2 was more suitable in consideration of yield contributing characters and yield and application of calcium nitrate reduced salt stress condition in some extent.

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Another experiment may be carried out with various levels of salt stress.
2. Others level of calcium nitrate and another stress reducing substances also may be used for further study.
3. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

REFERENCES

Adams, P. and Ho, L. C. 1992. The susceptibility of modern tomato cultivars to blossom-end rot in relation to salinity. *J. Hort. Sci*., **67**: 827-839.

Aditya, T. L., Rahman, L., Alam M. S. and Ghoseh, A. K. 1997. Correlation and path co-efficient analysis in tomato. *Bangladesh J. Agril. Sci*., **26**(1): 119-122.

Agong, S. G., Kingetsu, M., Yoshida, Y., Yazawa, S. and Masuda, M. 2003. Response of tomato genotypes to induced salt stress. *African Crop Sci. J*., **11**(2): 133-142.

Agong, S. G., Yoshida, Y., Yazawa, S. and Masuda, M. 2004. Tomato response to salt stress. *Acta Hort*., **637**: 93-97

Alian, A., Altman, A. and Heuer, B. 2000. Genotypic difference in salinity and water stress tolerance of fresh market tomato cultivars. *Plant Sci*., **152**: 59-65.

Alqudah, A. M., Samarah, N. H, Mullen, R. E. 2011. Drought stress effect on crop pollination, seed set, yield and quality. *E. Lichtfouse, In*: alternative farming systems, biotechnology, drought stress and ecological fertilisation, sustainable agriculture reviews 6.

Ampudia, G., Julkowska, C. S., Darwish, M. M., Gandullo, E., Korver, J., Brunoud, R. A., Haring, G., Munnik, M. A., Vernoux, T. and Testerink, C. 2013. Halotropism is a response of plant roots to avoid a saline environment. *Current Biol*., **23**(20): 2044-2050.

Anonymous. 1989. Annual Report 1987-88. Bangladesh Agricultural Research Council. p. 45.

Babu, M. A., Singh, D. and Gothandam, M. 2012. The effect of salinity on growth, hormones and mineral elements in leaf and fruit of tomato cultivar PKM1. *J. Animal & Plant Sci*., **22**(1): 159-164.

BARI. 2010. Krishi Projukti Hatboi, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. p. 304.

BBS. 2010. Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, Dhaka. p. 163.

Bose, T. K. and Som, M. G. 1990. Vegetable crops in India. Naya Prakash, Calcutta-Six, India. p. 687-691.

Bradbury, M. and Ahmad, R. 1990. The effect of silicon on the growth of *Prosopis juliflora* growing in saline soil. *Plant Soil*. **125**: 71-78.

Chen,S., Gollop, N. and Heuer, B. 2009. Proteomic analysis of salt-stressed tomato (*Solanum lycopersicum*) seedlings: effect of genotype and exogenous application of glycinebetaine. *J. Expt. Bot*., **60**(7): 2005-2019.

Einset, J., Nielsen, E., Connolly, E. L., Bones, A., Sparstad, T., Winge, P. and Zhu, J. K. 2007. Membrane-trafficking RabA4c involved in the effect of glycine betaine on recovery from chilling stress in Arabidopsis. *Physio. Plant.*, **130**: 511-518.

FAO. 2010. Production Year Book. Food and Agricultural Organizations of the United Nations. Rome, Italy. 68**: 113-115.**

FAO. 2012. Production Year Book. Food and Agricultural Organizations of the United Nations. Rome, Italy. 70**: 78-83.**

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Hao, X. and Papadopoulos, A. P. 2004. Effects of Calcium and Magnesium on Plant Growth, Biomass Partitioning, and Fruit Yield of Winter Greenhouse Tomato. *Hort. Sci*., **39**(3): 512-515.

Hernandez, J. A., Ferrer, M. A., Jimenez, A., Barcelo, A. R., Sevilla, F. 2001. Antioxidant system and production in the apoplast of *Pisum sativum* L. leaves: its relation with NaCl-induced necrotic lesions in minor veins. *Plant Physiol*., **127**: 817-831.

Hossain M. M. and Nonami, H. 2012. Effect of salt stress on physiological response of tomato fruit grown in hydroponic culture system. *Hort Sci*., **39**(1): 26-32.

Huang, C. X., Zhou, J. M., Fan, X. H., Wang, H. Y., Duan, Z. Q. 2003. Effect of a decrease in Ca application on Ca type and content in fruit of tomato cultivars with different calcium efficiency during fluorescence. *Plant Physiol. Comm*., **39**(1): 128-130.

Hussain, K., Nisar, M. F., Majeed, A., Nawaz, K., Bhatti, K. H., Afghan, S., Shahazad, A., Zia-ul-Hassnian, S. 2010. What molecular mechanism is adapted by plants during salt stress tolerance? *African J. Biotech*., **9**: 416-422.

Iseri, O,D., Sahin, F.I. and Haberal, M. 2014. Sodium chloride priming improves salinity response of tomato at seedling stage. *J. Plant Nutri*., **37**(3): 374-392.

Kishitani, S., Watanabe, K., Yasuda, S., Arakawa, K. and Takabe, T. 1994. Accumulation of glycinebetaine during cold acclimation and freezing tolerance in leaves of winter and spring barley. *Plant, Cell Env*., **17**: 89-95.

Kusvuran, S., Yasar, F., Ellialtioglu, S. and Abak, K. 2007. Utilizing some of screening methods in order to determine tolerance of salt stress in the melon (*Cucumis melo* L.). *Res. J. Agric. Biol. Sci*., **3**: 40-45.

Kusvuran, S., Yasar, F., Ellialtioglu, S., Abak, K. 2007. Utilizing some of screening methods in order to determine tolerance of salt stress in the melon (*Cucumis melo* L.) *Res. J. Agric. and Biol. Sci*., **3**: 40-45.

Lawlor, D. W. and Cornic, G. 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant Cell Env.*, **25**: 275-294.

Leonardi, C. and Martorana, M. 2005. Osmotic stress and tomato under protected cultivation: functional response and management strategies. *Italus Hortus*. **12**(1): 43-56.

Liang, Y. C., Shen, Q. R., Shen, Z. G. and Ma, T. S. 1996. Effects of silicon on salinity tolerance of two barley cultivars. *J. Plant Nutr*., **19**: 173-183.

Luo, H., Wu, H. J., Xie, Y. L. and Gao, X. W. 2013. Effects of Bacillus megaterium CJLC2 on the growth and the salt-tolerance related physiological and biochemical characters of tomato under salt stress. *Acta Phyto. Sinica*. **40**(5): 431-436

Maas, E. V. 1986. Salt tolerance of plants. *Appied Agril. Res*., **1**: 12-26.

Manaa, A., Faurobert, M., Valot, B., Bouchet, J. P., Grasselly, D., Causse, M. and Ahmed, H. B. 2013. Effect of salinity and calcium on tomato fruit proteome. *Plant Nutri*., **17**(6): 338-52

Martinez, V., Cerda, A. and Fernandez, F. G. (1987). Salt tolerance of four tomato hybrids. *Plant & Soil*. **97**: 233-242.

Mills, D. and Tal, M. 2004. The effect of ventilation on in vitro response of seedlings of the cultivated tomato and its wild salt-tolerant relative Lycopersicon pennellii to salt stress. *Plant Cell Tissue Organ Culture*. **78**(3): 209-216

Mizrahi, Y. 1982. Effect of Salinity on Tomato fruit ripening. *Plant Physiol*., **69**: 966-970.

Molina, A., Bueno, P., Marin, M. C., Rodriguez-Rosales, M. P., Belver, A, Venema, K. and Donaire, J. P. 2002. Involvement of endogenous salicylic acid content, lipoxygenase and antioxidant enzyme activities in the response of tomato cell suspension cultures to NaCl. *New Phytologist*. **156**(3): 409-415.

Munns, R. and Termaat, A. 1986. Whole plant responses to salinity. *Australian J. Plant Physio*., **13**: 143-160.

Murshed, R., Lopez_Lauri, F. and Sallanon, H. 2014. Effect of salt stress on tomato fruit antioxidant systems depends on fruit development stage. *Physiol. Mol. Biol. Plants*. **20**(1): 15-29.

Nasser J. Y. and Sholi, C. 2012. Effect of Salt Stress on Seed Germination, Plant Growth, Photosynthesis and Ion Accumulation of four Tomato Cultivars. *American J. Plant Physio.*, **7**: 269-275.

Posada, F. C. and Rodriguez, C. A. 2009. Reducing Negative Effects of Salinity in Tomato (*Solanum lycopersicum* L.) Plants by Adding Leonardite to Soil. *Acta Hort*., **821**: 113-139.

Salunkhe, F. C., Marui, K. and Nakano, Y. 1987. Origin of the genus *Lycopersicon*. Workshop papers Agricultural Economics and Social Sciences Programme. BARC, Dhaka, No. 1. p. 4.

Slathia, S. and Choudhary, S. P. 2013. The effect of salinity stress on stress indicators and antioxidant system response on *Solanum lycopersicum* L. plants. *Annals Forst*., **21**(1): 77-84.

Sonneveld, C. and Welles, G. H. W. 1988. Yield and quality of rockwool-grown tomatoes as affected by variations in EC-value and climatic conditions. *Plant and Soil*. **111**: 37-42.

Tabatabaeian, J. 2014. Effect of Calcium Nutrition on Reducing the Effects of Salinity on Tomato Plant. *American J. Plant Nutri. Ferti. Tech.*, **4**: 11-17.

Takagi, M., El-Shemy, H.A., Sasaki, S., Toyama, S., Kanai, S., Saneoka, H. and Fujita, K. 2008. Elevated CO_2 concentration alleviates salinity stress in tomato plant. *Acta Agric. Soil Plant Sci*., **10**: 1080.

UNDP. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development. Report 2: Agro-ecological Regions of Bangladesh, FAO, Rome. p. 212, 577.

Vogg G., Fisher S., Leide J., Emmanuel E., Jetter R., Levy A. A., Riederer M. 2004. Tomato fruit cuticular waxes and their effects on transpiration barrier properties: functional characterization of a mutant deficient in a very-long-chain fatty acid β-ketoacyl-CoA synthase. *J. Expt. Botany*, **55**: 1401-1410.

Wu Z., Liang F., Hong B., Young J. C., Sussman M. R., Harper J. F., Sze, H. 2002. An endoplasmic reticulumbond Ca^{2+}/Mn^{2+} pump, ECA1, supports plant growth and confers tolerance to Mn^{2+} stress. *Plant Physiology*, **130**: 128-137.

APPENDICES

Appendix I. Soil characteristics of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from October 2013 to April 2014

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
October, 2013	26.5	19.4	81	22	6.9

November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	31.4	19.6	54	11	8.2
April, 2014	34.4	23.1	64	119	8.2

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Analysis of variance of the data on plant height of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Replication	3	0.550	0.241	0.595	0.780	2.889
Salt stress (A)	4	29.619**	70.814**	95.914**	315.688**	364.428**
Calcium nitrate (B)	2	8.358**	42.384**	68.058**	133.417**	188.020**
Interaction (A×B)	8	2.096*	12.892*	16.374*	81.571**	44.305*
Error	42	0.922	5.902	6.863	20.451	20.326

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of branches per plant of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom					
		Number of branches per plant at				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Replication	3	0.024	0.087	0.358	1.004	0.552
Salt stress (A)	4	1.728**	9.883**	29.779**	34.742**	58.613**
Calcium nitrate (B)	2	1.176**	2.854**	16.254**	24.653**	55.224**
Interaction (A×B)	8	0.082*	0.405*	1.009**	1.233*	3.094*
Error	42	0.039	0.169	0.318	0.496	1.294

** Significant at 0.01 level of probability;

Appendix V. Analysis of variance of the data on number of leaves per plant of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom	Mean square				
		Number of leaves per plant at				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT

Replication	3	0.079	1.832	0.219	0.772	3.165
Salt stress (A)	4	15.871**	36.449**	81.675**	112.748**	92.274**
Calcium nitrate (B)	2	12.241**	46.459**	98.131**	154.518**	136.472**
Interaction (A×B)	8	0.294*	2.560**	1.847*	5.430*	7.677*
Error	42	0.122	0.885	0.723	2.172	3.455

** Significant at 0.01 level of probability;

Appendix VI. Analysis of variance of the data on SPAD values and leaf area of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom	Mean square			
		SPAD value		Leaf area (cm^2)	
		Flowering stage	30 Days after flowering	Flowering stage	30 Days after flowering
Replication	3	0.796	2.427	21.931	29.325
Salt stress (A)	4	292.731**	548.068**	1736.096**	1548.693**
Calcium nitrate (B)	2	66.130**	82.294**	429.314**	529.262**
Interaction (A×B)	8	42.019**	66.981**	791.400**	427.416**
Error	42	5.086	5.880	54.074	42.392

** Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on yield contributing characters of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom	Mean square					
		Days from transplanting to 1st flowering	Flower cluster/plant (No.)	Flower/cluster (No.)	Flowers/plant (No.)	Fruits/cluster (No.)	Fru
Replication	3	2.417	0.100	0.328	44.526	0.050	
Salt stress (A)	4	62.558**	7.502**	8.216**	1622.026**	3.063**	**
Calcium nitrate (B)	2	32.617**	4.883**	5.318**	1154.961**	3.656**	**
Interaction (A×B)	8	8.721*	1.122*	1.043**	72.826**	1.136*	
Error	42	2.869	0.141	0.215	18.738	0.144	

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters and yield of tomato as influenced by different levels of salt stress and calcium nitrate

Source of variation	Degrees of freedom	Mean square					
		Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in plant (%)	Dry matter content in fruit (%)	Weight of individual fruit (g)	Yield/plant (kg)
Replication	3	0.209	0.113	0.298	0.095	3.687	0.047
Salt stress (A)	4	14.644**	3.505**	2.727**	5.264**	523.328**	5.851**
Calcium nitrate (B)	2	11.965**	3.518**	13.616**	3.066**	143.266**	4.679**
Interaction (A×B)	8	1.142*	1.226*	1.610*	0.527*	60.689**	0.262*
Error	42	0.526	0.196	0.642	0.195	18.007	0.098

** Significant at 0.01 level of probability; * Significant at 0.05 level of probability