MITIGATION OF SALT STRESS IN TOMATO USING CALCIUM AND SALICYLIC ACID

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MITIGATION OF SALT STRESS IN TOMATO USING CALCIUM AND SALICYLIC ACID

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CERTIFICATE

This is to certify that the thesis entitled, ***MITIGATION OF SALT STRESS USING CALCIUM AND SALICYLIC ACID*** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural university, Dhaka, in partial fulfillment of the requirement for the degree of* ***MASTER OF SCIENCE IN HORTICULTURE*** *embodies the results of a piece of bona fide research work carried out by* ***HUMAIRA BINTE MUSTAFIZ,*** *bearing Registration No.* ***18-09217*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.*

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

Dated: DECEMBER, 2020

Place: Dhaka, Bangladesh

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Dedicated

To

My Beloved Parents

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ABSTRACT

One of the major constraints to crop production is salt stress, which has an impact growth, yield and quality. An experiment was conducted to study the effect of calcium (Ca^{+2}) and salicylic acid (SA) as mitigating agent against salt stress in tomato plant during the period from November 2018 to March 2019. The experiment consisted of two factors: Factor A (salinity level): S_0 = control, S_1 = 4 dSm^{-1}, S_2 = 8 dSm^{-1} and S_3 = 12 dSm^{-1} and Factor B (mitigating agents): T_0 = control (no Ca^{+2} or SA application), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm salicylic acid (SA) and T_4 = 250 ppm salicylic acid (SA). Plant height, chlorophyll content, number of flowers, fruits and yield per plant, as well as various quality parameters such as total soluble soild, lycopene, vitamin C, pH and titratable acidity of tomato were evaluated. The use of salt stress mitigating agents resulted in increased growth, yield and quality of tomato compared to control. Among the mitigating agents, salicylic acid (125 ppm), followed by Ca^{2+} (5 mM) showed the greatest mitigation in all salinity levels. Therefore, salicylic acid (125 ppm) or Ca^{2+} (5 mM) can be used to protect plant growth, yield and quality attributes under salinity stress.

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LIST OF ABBREVIATIONS OF TECHNICAL SYMBOLS AND TERMS

Full Word	**Abbreviation/ Symbol**
Agro-Ecological Zone	AEZ
Analysis of Variance	ANOVA
And Others	*et al.*
Coefficient of Variation	CV
Total Soluble Solid	TSS
Completly Randomized Block Design	RCBD
Titratable Acidity	TA
Days After Transplanting	DAT
Food and Agriculture Organization	FAO
Degree of Freedom	DF
Journal	*J.*
Least Significant Difference	LSD
Negative Logarithm of Hydrogen Ion Conc.	pH
World Health Organization	WHO
Sher-e-Bangla Agricultural University	SAU
That is	i.e.

CHAPTER I

INTRODUCTION

Tomato *(Solanum lycopersicum)* is one of the most consumed vegetables in the world including Bangladesh and it plays an important role in the human diet. Worldwide, it is the second most important vegetable crop next to potato (Hossain *et al*., 2010 , Kumar *et al*., 2015). It ranks fourth in respect of production and third in respect of area in Bangladesh (BBS 2016). In 2017-18, the total tomato production was 385000 tons from 66000 acres of land (BBS, 2018).

Tomato is a major component in the daily diet, having several macro and micro nutrients, vitamins and minerals, especially potassium, folic acid, vitamin C and contains a mixture of different carotenoids, including vitamin A and effective β-carotene as well as lycopene (Wilcox *et al*., 2003). Ripe tomatoes having antioxidant-lycopene, which acts as an anti-carcinogen and prevents cancer (Agarwal and Rao, 2000) and also prevent so many diseases.

However tomatoes are frequently exposed to multiple environmental stresses. In particular, salinity is one of the most important environmental constraints affecting plant growth, development, and crop productivity (Dasgan *et al*., 2002; Juan *et al*., 2005; Gunes *et al*., 2007; Khan *et al*., 2010). Salinity alters many physiological and biochemical processes such as mineral nutrition, respiration rate, organic solutes/osmolyte synthesis, seed germination, enzyme activities and photosynthesis (Juan *et al*., 2005; Siddiqui *et al*., 2010).

Salinity is one of the most brutal environmental factor limiting the productivity of crop plants. It has been estimated that worldwide 20% of total cultivated and 33% of irrigated agricultural lands are affected by high salinity and salinized areas are increasing at a rate of 10% annually and more than 50% of the arable land would be salinized by the year 2050 (Jamil *et al*., 2011). Salt stress affect all the major processes like photosynthesis, protein synthesis, energy and lipid metabolism, osmotic stress etc due to excess sodium

and chloride ion in soil solution that decrease osmotic potential of soil solution and water uptake by the root (Apel and Hirt, 2004.

Salinity induced osmotic and ionic toxicity cause physiological, morphological and biochemical modifications and thus resulting growth inhibition and crop yield reduction (Ashraf and Foolad, 2007).

Salt tolerance mechanisms vary from plant species to plant species, from cultivar to cultivar, and rely on complex interacting salinity were also alleviated by exogenous application of Salicylic acid (SA) in tomato plants (Wasti *et al*., 2012). Salicylic acid (SA) is a phenolic compound, one kind of plant growth regulator, non-enzymatic antioxidant which acts as an important signal molecule for modifying plant responses to environmental stresses. SA protects plant growth and induces antioxidant defense system under salt stress (Nazar *et al*., 2011).

SA plays important role in flowering induction, plant growth and development, synthesis of ethylene, opening and closure of stomata and respiration of plants (Raskin, 1992). Plants undergoes damages caused by oxidative stresses through increasing antioxidants enzymes activities, are diminished by SA application (El-Tayeb; 2005, Idrees *et al*., 2011). Exogenous SA alters the activities of antioxidant enzymes and increases plant tolerance to abiotic stress by decreasing generation of ROS (Reactive oxygen species).

Another approach to minimize the effects of salinity on plants consists of substrate nutrient enrichment (as N, P, K, Mg, and Ca) in order to reduce Na^+ and Cl^- injuries in plants (Kaya *et al*., 2002; Song and Roe, 2008). Calcium plays a vital role in salt stress tolerance since it induces antioxidant enzyme activities and reduces lipid peroxidation of cell membranes under abiotic stress (Jiang and Huang, 2001; Khan *et al*., 2010). It has also been shown to stabilize cell membrane surfaces, prevent solute leakage from the cytoplasm, maintain normal photosynthesis and regulate the plant hormone metabolism (Hirschi, 2004; Song and Roe, 2008). Numerous data suggest that Na^+ competes with Ca^{2+} for binding sites under salinity conditions and that apoplastic Ca^{2+} directly alleviates symptoms produced by mineral toxicities. The ameliorative effect of external Ca^{2+} on plants facing salinity may be associated with the maintenance of an optimal

K^+/Na^+ ratio and homeostasis in the cytosol in relation to an inhibition of Na^+ influx and K^+ efflux or promotion of Na^+ efflux and K^+ influx across the plasma membrane (Elphick *et al*., 2001; Demidchik and Tester, 2002; Shabala *et al*., 2006).

Several studies have supported the major role of salicylic acid (SA) or Ca in mediating the response of plants to abiotic and biotic stress by the induction of antioxidant defense. For this reason, we assess the influence of exogenous Salicylic Acid and Calcium applied on tomato behaviour exposed to salinity during the vegetative phase of development with the following objectives:

1. To determine the influences of salt stress on biomass, yield and quality of tomato at various salinity levels.
2. To examine the role of Calcium and Salicylic acid on mitigation of salt stress and find out the optimum level of them.

CHAPTER II

REVIEW OF LITERATURE

Salinity is one of the most important limiting factors for crop production in arid and semiarid regions and it is a great problem in the coastal region of Bangladesh. With this regard, an attempt has been made to find out the performance of tomato at different levels of salinity as well as to find out the possible mitigation ways by using calcium (Ca) salicylic acid (SA) in the salt stressed tomato plants. To facilitate the research works different literatures have been reviewed in this chapter under the following headings.

2.1 Salt stress on tomato plant

Response of tomato *(Lycopersicon esculentum)* to Salinity in hydroponic study was conducted by Jamal *et al*. (2014) to find out the growth and yield of tomato in different salinity level. Five salinity levels were accounted at T_0, Control; T_1, 4 dSm^{-1}, T_2, 8 dSm^{-1}, T_3, 12 dSm^{-1} and T_4, 16 dSm^{-1} treatments respectively and were carried out with completely randomized design (CRD). Significant results were revealed among growth, yield and yield contributing characters. Control (T_0) showed the best performance in plant height, number of fruits $plant^{-1}$, fruit weight, leaf area $plant^{-1}$, total chlorophyll content and plant dry matter compared to the other salinity level. Stomatal resistance was best in 16 dSm^{-1} (T4) treatments. On the other hand, the salinity level 16 dSm^{-1} exhibited highest Na+ and Cl^{-1} uptake which reduced the uptake of K+. At control (0 dSm^{-1}) salinity when Na+ and Cl^{-1} ions were low in water, than the K+ uptake increased. Salinity had a greater impact on stomatal resistance and chlorophyll content of plants.

A field study was conducted by Siddiky *et al.* (2012) to screen out a number of Bangladeshi tomatoes *(Lycopersicon esculentum* L.) varieties for salinity tolerance. Three levels of salinity were 2.0-4.0 dSm^{-1}, 4.1-8.0 dSm^{-1} and 8.1-12.0 dSm^{-1}. Significant varietal and salinity treatment effects were registered on plant height, leaf area, plant growth, yield, dry matter $plant^{-1}$, Na+ and Cl^{-1} accumulation in tomato tissues. Variety BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 consistently showed superior biological activity at moderate salinity (4.1-8.0 dSm^{-1}), based on dry matter

biomass production thus displaying relatively greater adaptation to salinity. Under saline condition, all plant parameters of tomato varieties were reduced compared to the control except number of fruits of BARI Tomato14, BARI Hybrid Tomato 5 and BARI Tomato 2. Thus, BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 can be regarded as a breeding material for development of new tomato varieties for tolerance to salinity in saline areas of Bangladesh. Bahar and Tuzel, (2011) was conducted an study in a greenhouse to determine the response of 4 commercial tomato rootstocks, 21 cultivars and 8 candidate varieties to salinity stress. Seeds were germinated in peat and when the plants were at the fifth-true leaf stage, salt treatment was initiated except control treatment. NaCl was added to nutrient solution daily with 25 mM concentration and had been reached to 200 mM final concentration. On harvest day, genotypes were classified based on the severity of leaf symptoms caused by NaCl treatment. After symptom scoring, the plants were harvested and leaf number, root length, stem length and diameter per plant were measured. The plants were separated into shoots and roots for dry matter production. Our results showed that, on average, NaCl stress decreased all parameters and the root stocks gave the highest performance than genotypes. Among all rootstocks, three varieties (819, 2211 and 2275) and ten genotypes (Astona, Astona RN, Caracas, Deniz, Durinta, Export, Gok9e, Target, YeniTalya and 144 HY) were selected as tolerant with slight chlorosis whereas the genotype Malike was selected as sensitive with severe chlorosis. Candidate varieties 2316 and 1482 were the most sensitive ones. Plant growth and dry matter production differed among the tested genotypes. However no correlation was found between plant growth and dry matter production. Rootstock Beaufort gave the highest shoot dry matter although He man had highest root dry matter. Newton showed more shoot and root dry matter than of her genotypes. It is concluded that screening of genotypes based on severity of symptoms at early stage of development and their dry matter production could be used as a tool to indicate genotypic variation to salt stress.

A research was conducted by (Bahar *et al.* 2011) to determine the salinity level of irrigation water from a dug well, pond and tap water as well as its effect on the yield of a tomato crop at the University of Cape Coast Teaching and Research Farm. Water samples were taken at fortnight intervals to determine the electrical conductivity (dSm^{-1}) using the TOA water quality checker 20A. The averages of the four batches were computed and

used as the three sources fourth period of assessment. Flowering and yield of crop were the parameters used to assess the effect of salinity level on the tomato crop. Electrical conductivity as a measure of salinity was higher in the pond (0.25 dSm^{-1}) than the well and tap water (0.07dSm^{-1} and 0.02 dSm^{-1}, respectively). Flowering and yield of tomato was high with crops treated with well water (45.22%, 99.08$kgha^{-1}$) followed by the pond (27.70%; 43.76 $kgha^{-1}$) and tap water (27.08%; 27.25 $kgha^{-1}$) in that order. There was no significant difference in flowering and in yield of crops between the tap and pond treatments at both 0.05 and 0.01 levels but there was a significant difference in yield between the well treated crops and other sources.

Hamed *et al.* (2011) studied that high salt concentrations in soil and irrigation water restrict establishment and growth of tomato *(Solanum lycopersicum).* Correcting saline condition in field and greenhouse would be expensive and temporary while selection and breeding for salt tolerance can be a wise solution to minimize salinity effects as well as improve production efficiency. In order to find any kind of tolerance to saline condition, effects of four salinity levels in irrigation water (0.5, 2.5, 5, and 10 dSm^{-1}) on seed germination and seedling emergence, and growth of tomato lines LA3770, R205, CT6, Fla, and ME were investigated in a greenhouse. Germination percentage and rate, emergence percentage and rate of all tomato lines were delayed and decreased by salinity increasing from 2.5 dSm^{-1} to 10 dSm^{-1}. All seedling growth characters, except seedling height, were decreased with increasingly salinity levels. At germination and emergence stage, LA 3770 were more tolerant to salinity than others.

A study was conducted by Jogendra *et al.* (2012) using ten genetically diverse genotypes along with their 45F1 (generated by diallel mating) under normal and salt stress conditions. Although, tomato *(Lycopersicon esculentum Mill.)* is moderately sensitive to salinity but more attention to salinity is yet to be, speed of germination, dry weight ratio and Na^+/K^+ ratio in root and shoot, were the parameters as sayed on three salinity levels; control, 1.0 % NaCl and 3.0 % NaCl with Hoagland's solution. Increasing salt stress negatively affected growth and development of tomato. When salt concentration increased, germination of tomato seed was reduced and the time needed to complete germination lengthened, root/shoot dry weight ratio was higher and Na^+ content increased

but K^+ content decreased. It has been shown that crops which are tolerant at seedling stage also show improved salinity tolerance at adult stage.

Ahmet *et al*. (2009) was conducted an experiment in order to determine the predictive screening parameters that can be applied at early development stages of tomato plants^{-1}, 18 tomato cultivars were grown in nutrient solution with 12 dSm NaCl. This study showed that morphologic and physiologic changes were determined depending on increasing NaCl concentrations. With increasing concentrations, it was determined growth parameters were decreased. However, this decrease in salt tolerant cultivars was restricted as compared to salt sensitive cultivars. It was also determined that by increasing NaCl applications, the amount of Na^+ was increased and, the amount of Ca^2+ and K+ ions were decreased in salt tolerant cultivars same with growth parameters.

Shameem *et al.* (2009) using different tomato genotype such as PB-BL-1076, BL- 1079, LO-2576, 017902, LO-3686, 017859, 017860 and 017867 to screening at 10 and 15 dSm^{-1} along with control condition. The result of the study was overall performance of the genotype O17859O was better at both NaCl concentrations for the traits like number of fruits, number of flowers, K^+ concentration and K+/Na+ ratio. The genotype 017867 was the poorest in performance and was affected severely by salinity for the characters like number of flowers, number of fruits, $K^{+/}Na^+$ while all other genotypes showed intermediate response.

2.2 Effect of calcium (Ca)

Tanveer and Gilani (2020) carried out a study to investigate the effect of sodium chloride (NaCl) on germination and growth parameters of tomato plant as well as the role of Ca^{2+}as an ameliorating agent. 100 mM NaCl and two concentrations of calcium (5 and 10 mM) were applied to tomato seeds and seedlings. This study was carried out in a Completely Randomized Design (CRD) with a total of six treatments each comprising of three replicates. The application of 100 mM of NaCl delayed the germination time by 27.60%, reduced the seedling length and seedling vigor by 24.33% and germination stress tolerance by 27.6% as compared to control. Salinity also reduced the plant growth (root and shoot length, root fresh and dry weight, shoot fresh and dry weight, membrane

stability, relative water content and leaf area), whereas the application of calcium mitigated the negative effects of salinity on germination and growth to a greater extent. With increased calcium concentration, growth and germination increased significantly both alone and in the salt-affected plant. 10 mM calcium showed best results and enhanced the promptness index by 20.7%, seedling length and vigor by 15.1% and GSI by 20.7%. It also improved root fresh and dry weight, shoot fresh and dry weight, relative water content and leaf area. Similarly, 5 mM calcium also increased plant height and membrane stability index. The present study suggests that application of Ca^{2+} enhanced the growth of tomato plant under saline conditions.

Nizam *et al*. (2019) stated that salt stress is one of the most subversive abiotic stress which severely affects the agricultural productivity in various ways. The pot experiment was conducted during the period from November 2017 to April 2018. BARI Tomato-5 was used as planting material. Five levels of salinity induced by sodium (Na^{+}) viz., 0, 2, 4, 6 and 8 dS m^{-1} and three levels of Ca^{2+} viz., 0, 5 and 10 mM were used as treatment variables. The results of this experiment showed that, the salt stress reduced the yield parameters and yield of tomato with the increase of salinity. The lowest data was recorded from 8 dS m^{-1} and highest value was observed at control. The present results also showed that, Ca^{2+} significantly increased the yield contributing characters as well as yield of tomato in both saline and non-saline conditions. However, for combined effect, highest number of fruits $plant^{-1}$ (50.8) and the highest yield $plant^{-1}$ (3.88 kg) was produced from 0 dS m^{-1} Na × 10 mM Ca^{2+}; whereas the lowest from 8 dS m^{-1} × 0 mM Ca^{2+} . This result suggests that, exogenous Ca^{2+} can effectively mitigate the deleterious effect of salt stress in tomato.

Abdur-Rab *et al*. (2017) investigated the influence of foliar calcium application on tomato crop grown in saline conditions was by exposing tomato plants to 0, 75 and 150 mM salinity; and foliar application of 0.0, 0.25, 0.50, 0.75, 1.0, 1.25% calcium solutions. Salinity stress increased leaf Na^{+} and Na^{+}/K^{+}, fruit firmness and blossom end rot (BER) incidence but significantly decreased the leaf K^{+} and Ca content of the fruit and yield. The foliar calcium application decreased the Na^{+} accumulation, Na^{+} / K^{+} ratio and BER incidence as well as increased the leaf K^{+} and Ca content of tomato fruit, yield and fruit

firmness. The interaction of salinity and calcium significantly affected the yield and BER incidence of tomato fruit. Whereas, the yield of tomato decreased with increasing salinity levels, the decrease in yield was comparatively less with foliar calcium application. By contrast, salinity increased the BER incidence but the salinity-induced increase in BER incidence was lower with calcium application as compared to control plants.

Parvin *et al*. (2016) found that salinity affects almost every aspect of the physiology and biochemistry of plants due to both osmotic stress and ionic toxicity. They studied the variation of ion uptake in tomato cv. BARI Tomato-5 under different levels of salinity (0, 2, 4, 6 and 8 dS m^{-1}) and their mitigation by different concentration of Ca^{2+} (0, 5, 10 mM). The results showed that salt stress significantly affects the stomatal conductance of tomato. Salt treatment markedly increased the uptake of Na^{+} and decreased both K^{+} and Ca^{2+} uptake in the leaves of tomato. The uptake of Na^{+} decreased and uptake of Ca^{2+} and K^{+} increased in tomato when salt stressed plants were treated with Ca^{2+}. Our results revealed that Ca supplementation can effectively reduce the saltinduced ionic toxicity in tomato plants. Exogenous application of Ca^{2+} significantly mitigates the adverse effects of salt induced ionic toxicity.

It has been mentioned in many reports that the proline was mostly accumulated when plant growth was ceased (Lutts *et al.* 1996 and Joly *et al.* 2000). The function of this osmoprotectant is presumed to be protective, with a role in scavenging free radicals (Mansour, 2000). Minimization of reactive oxygen (ROS) as a result of inhibition of photosynthesis and maximization of their removal (scavenging) is likely to be an important response to high salinity, among other stresses (Zhu, 2001).When plants are subjected to stress, the amount of ROS in the cells increases which bring oxidative stress to crops (Xiong and Zhu, 2002)

Calcium nutrition plays an important role in the maintenance of a high growth rate under saline conditions (Marschner, 1995). Several reports show a significant role of Ca in improving the salt tolerance of plants. In studies on the soybean and cucumber, an additional supply of Ca to salt-stressed plants improved the salt tolerance of plants by reducing Na uptake and transport (Dabuxilatu and Ikeda, 2005). According to Husain *et al.* (2004), the major role of Ca in increasing the salt tolerance of plants is related to its

inhibitory effect on the xylem loading of Na and thus decreases in shoot Na concentration.

Song *et al.* (2006) reported that high levels of external Ca are essential for the maintenance of high root uptake and shoot accumulation of Ca and K on saline soils and thus for avoiding salinity damage in plants as shown in rice plants.

The growth and yield of tomato is significantly reduced by high salinity (Feigin *et al.* 1987; Shalhevet and Hsiao, 1986; Smith, *et al.* 1992). The response of tomato to salinity is variable according to lines and cultivars (Shannon et al. 1987). Evlagon, *et al.* (1992) found that the root length was reduced by 54% after 4 days exposure to 0.1 strength Hoagland's solution salinized with 100 mM NaCl, while surface area was reduced by 20% when 100 mM Ca was added to the salinized solution. Tomato shoot and fruit physiological responses to salt stress conditions have been extensively investigated (Niedziela *et al.* 1993).

Tzortzakis (2010) reported that, Salinity either of soil or of irrigation water causes disturbance in plant growth and nutrient balance and reduces crop yields. The effects of NaCl salinity and/or calcium or potassium level on the plant growth and severity of gray mold (Botrytis cinerea [De Bary] Whetzel) were investigated in endive *(Cichorium endivia* L., cv. Green Curled) grown with the nutrient film technique under greenhouse conditions during early spring. Plants were supplied with nutrient solutions containing 40 mmol L^{-1} of sodium chloride (NaCl) and/or 10 mmol L^{-1} potassium sulphate (K_2SO_4). Additionally, plants treated with foliar spray of 15 mmol L^{-1} calcium nitrate [$(CaNO_3)_2$] or distilled water. Salinity or K and Ca enrichment mainly affected the upper part of endive plants and reduced leaf area. However, when salinity combined with either K or Ca enrichment, the negative impact of salinity on plant growth was reversed. Salinized and/or K and Ca enriched, plants did not differ in plant biomass, leaf/root ratio, leaf fresh weight, leaf number, and root length. Salinity did not have any impacts on photosynthetic rate, stomatal conductance, and intercellular CO2 concentration. Indeed, photosynthetic rate and stomatal conductance increased with Ca foliar application and decreased with K while the opposite effects were observed for the intercellular CO_2 concentration. Total nutrient uptake was reduced 2-fold in salt-treated plants compared to controls. No

symptoms of tip-burn or blackheart were recorded throughout the experimental study. Endive grown in the nutrient film technique had tolerance to NaCl salinity, and this method could be used to exploit saline water in soilless culture. These findings also suggest that a proper management of the salt concentration of the nutrient solution plus external elemental enrichment may provide an efficient tool to improve the quality of leafy vegetables with little effect on yield.

Gobinathan (2009) *Pennisetum* plants were grown with NaCl and $CaCl_2$ in order to study the effect of $CaCl_2$ on NaCl induced oxidative stress in terms of osmolyte concentration, proline (PRO)-metabolizing enzymes. The plants were treated with solutions of 100 mM NaCl, 100 mM NaCl with 5 mM $CaCl_2$ and 5 mM $CaCl_2$ alone. Groundwater was used for irrigation of control plants. Plants were uprooted randomly on 40 days after sowing (DAS). NaCl-stressed plants showed increased glycine betaine (GB) and PRO contents, decreased proline oxidase (PROX) activity and increased glutamyl kinase (GK) activity when compared to control. Addition of $CaCl_2$ to NaCl-stressed plants lowered the PRO concentration by increasing the level of PROX and decreasing the gama-GK activities. Calcium ions increased the GB contents. CaCl2 appears to confer greater osmoprotection by the additive role with NaCl in GB accumulation.

Manivannan *et al.* (2007) worked on the ameliorating effect of calcium chloride on sodium chloride-stressed plants of *Vigna radiata* L. Wilczek. Plants were treated with solutions of 100 mM NaCl, 100 mM NaCl with 5 mM $CaCl_2$, or 5 mM $CaCl_2$. Groundwater was used for irrigation as the control. Plants were harvested randomly 30 and 50 days after sowing. NaCl and $CaCl_2$-stressed plants showed reduced growth as indicated by decreased root length, stem length, total leaf area and dry weight. Proline and glycinebetaine content and the activity of the antioxidant enzymes superoxide dismutase, ascorbate peroxidase and catalase were increased under treatment with NaCl alone and $CaCl_2$ alone. When $CaCl_2$ was combined with NaCl, $CaCl_2$ altered the overall plant metabolism to ameliorate the deleterious effects of NaCl stress and increased the vegetative growth of the plants.

Hameda and Ahmed (2013) a greenhouse experiment was carried out to study the response of presoaked tomato seeds *(Lycopersicon esculentum* Mill. var. *Cerasiforme)* in

freshly prepared ascorbic acid (50 ppm ASC) or distilled water (control) for 12 h at natural environmental conditions, to reduce the effect of salinity stress. Generally, the tomato seeds germination occurred after 3 days, while, the germination rate (%) were more faster after soaking the seeds in ascorbic acid (ASC) compared with control (soaked in distilled water). NaCl salt-stress treatments caused a reduction in all growth parameters (fresh and dry weights of plant, leaf area and number per plant) compared control, particularly at high NaCl level (8000 ppm) more reduced. In the meantime, ascorbic acid had reduced the effect NaCl salinity stress on all growth parameters. Photosynthetic pigments (chlorophyll a & b and carotenoids) and chloroplast efficiency were increasing with salinity stress, but the response was more pronounced at 8000 ppm NaCl whether alone or combined with ascorbic acid. Also, salinity stress treatments tended to increase all of the total available carbohydrates (Monosaccharide, Disaccharides & polysaccharides), nitrogenous components (protein, amino acids & proline), antioxidase, (catalase, peroxidase & superoxide dismutases) enzymes activities and inorganic mineral elements (Na^+, K^+, N^3+, P^3+, Ca^{2+}, Mg^2+ and Cl^-) but after soaked the seeds in ascorbic acid (+ASC), these components tended to increased more. Application of NaCl salinity-stress on tomato plant induced the synthesis of nitrogenous components (protein, amino acids, proline), whereas, the tomato seeds soaked before planting in ascorbic acid (ASC) which leads to remarkably increasing more for all nitrogenous components, antioxidase, carbohydrates and inorganic mineral elements content.

Hussein (2012) reported that, irrigation with high salinity water influences plant growth, production of photosynthetic pigments and total phenols, leading to reduction in crop yield and quality. The objective of this study was to investigate the effects of potassium (K) foliar application in mitigating the negative effects of salt stress on pepper plants. A greenhouse experiment was conducted to investigate the effects of foliar application of potassium (K) on pepper plants grown with different salinity water irrigation (3000 and 6000 ppm as compared to tap water with salinity level of 300 ppm). Irrigation using high salinity water decreased plant height, biomass production, and fruit yield as compared to those of the plants irrigated by tap water. Photosynthetic pigments and total phenols increased in the former as compared to those of the latter plants. The most serious affect was for the plants under highest salinity irrigation (6000 ppm) as compared to that of the

plants under moderate salinity irrigation (3000 ppm). Foliar application of potassium mono phosphate (KMP) at 200 ppm concentration increased the plant growth, biomass production, and fruit yield. Chlorophyll a content and total phenols increased significantly with foliar application of 100 ppm KMP. Further increase in foliar KMP concentration to 200 ppm had no significant benefits on photosynthetic pigments and total phenols content.

Chaum *et al.* (2012) reported that Calcium (Ca) is a signaling molecule that plays an active role in regulating various mechanisms involved in recognition and response to abiotic stresses in plants. However, not much has been done to evaluate its role in regulating physiological and biochemical process in response to salt-induced stress. Two rice genotypes viz. Pokkali, salt tolerant and IR29 salt susceptible, grown on liquid Murashige and Skoog medium (MS) supplied by 1.98 mM $CaCl_2$ (control) were compared to 2 (3.96 mM), 4 (7.92 mM) and 8 (15.84 mM) folds exogenous $CaCl_2$ pretreatment subsequently exposed to 200 mM NaCl salt stress. Thus, the present investigation evaluated the potential of exogenous calcium chloride ($CaCl_2$) supply in improving the growth performance and photosynthetic ability in salt stressed rice. In IR29 salt susceptible rice, leaf area of salt-stressed seedling was significantly recovered by exogenous application of 7.92 mM $CaCl_2$, which was greater by 1.38- folds over that in 1.98 mM $CaCl_2$ application. Exogenous $CaCl_2$ (7.92 mM) enhanced proline accumulation in both Pokkali (3.26 |imol g^{-1} FW) and IR29 (4.37 |imol g^{-1} FW) genotypes, and reduced relative electrolyte leakage thereby indicating its positive role in membrane stability. Treatment of 7.92 mM $CaCl_2$ significantly enhanced the photosynthetic abilities, including maximum quantum yield of PSII (Fv/Fm), photon yield of PSII, photochemical quenching (qP) and net photosynthetic rate (Pn), in two genotypes of salt-stressed rice seedlings, especially in salt susceptible IR29 genotypes. The study concludes that an exogenous application of 7.92mM $CaCl_2$ significantly enhanced the photosynthetic abilities and overall growth performances in the photoautotrophic growth of salt-stressed rice seedlings. Exogenous calcium in the culture media may absorb by root tissues, transfer to whole plant and function as salt defense mechanisms including calcium signaling in the abscisic acid (ABA) regulation system and calcium sensing in stomatal closure when plant subjected to salt stress.

2.3 Effect of salicylic acid

Naeem and Basit (2020) conducted a pot experiment to observe the effect of salicylic acid on qualitative and quantitative attributes of tomato plants under salinity stress at Agriculture Research Institute Tarnab, Peshawar during the summer season 2016. The experiment was conducted in a shade house and laid out in a completely randomized design (CRD) having 12 treatments and replicated thrice. After 15 days of transplantation tomato plants (cv. Rio Grande) were subjected to various levels of salinity (0, 30, 60 and 90 mM) and to foliar application of salicylic acid (0, 0.5 and 1 mM) at 6 days after salinity stress. Results revealed that salinity stress (90 mM NaCl) significantly reduced the fruit length (4.71 cm), fruit diameter (3.95 cm), number of fruits plant^{-1} (13), yield pot^{-1} (0.51 kg), fruit dry matter (6.89 g), and pH (4.14) with increase in fruit firmness (2.72 kg · cm^2), total soluble solids (TSS, 8.87 ^{0}Brix) and vitamin C (18.07 mg · 100 ml). The foliar application of salicylic acid at 0.5 mM significantly reduced the harmful effect of salt stress and improved the fruit length (5.02 cm), fruit diameter (4.17 cm), number of fruits plant^{-1} (18.67), yield pot^{-1} (0.86 kg), fruit dry matter (9.04 g), fruit firmness (2.68 kg · cm^2), TSS (9.05 ^{0}Brix), pH (4.33) and vitamin C (17.28 mg · 100 ml). Regarding in interaction both salinity and salicylic acid significantly affected all the variables except fruit firmness, total soluble solids, pH and vitamin C. From the present study it can be concluded that salinity reduced the quantitative attributes while it increased the qualitative attributes except pH. Therefore, salicylic acid at 0.5 mM might be applied to the tomato plant under saline condition up to 90 mM which could effectively alleviates the deleterious effect of salt stress.

Souri and Tohidloo (2019) conducted a study and in this study, the effects of root or leaf pretreatment, and leaf treatment with 100 mg L^{-1} salicylic acid were evaluated on growth characteristics of tomato seedlings (*Solanum lycopersicum* Mill) under salinity stress. The plants were grown 3 weeks in sand that were fed with Hoagland nutrient solution with or without 100 mM NaCl. The results showed that salinity signifcantly reduced tomato seedling growth and traits of plant height, leaf area, shoot fresh weight, and nutrient concentration of potassium, calcium, iron and zinc compared to control plants. However, leaf SPAD value, root fresh and dry weights, leaf concentration of sodium,

proline and soluble sugars were signifcantly increased under 100 mM NaCl salinity compared to control plants. Application of salicylic acid particularly by foliar pretreatment increased the tomato plant growth and those traits that were reduced by NaCl salinity. Application of SA, particularly foliar pretreatment, also increased the root fresh and dry weights, leaf proline and soluble sugars concentrations as compared with salinity alone. Foliar SA pretreatment signifcantly increased leaf K and Fe concentrations, whereas leaf Ca was signifcantly increased by either root or leaf pretreatment with SA under salinity. The results indicate that the most to least efective method of SA application was leaf pretreatment, root pretreatment and leaf treatment, respectively, to recover the reduced growth parameters of tomato plant under salinity stress.

Mimouni (2016) conducted an experiment to examine multiple plant growth related endpoints, whether SA applied through the rooting medium could mitigate the adverse effects of salinity on tomato (*Solanum lycopersicum*) cv. Marmande. The latter is a hitherto understudied tomato plant from the above perspective; it is a classic variety that produces the large ribbed tomatoes in the Mediterranean and consumed worldwide. They found salt stress negatively affected the growth of cv. Marmande tomato plants. However, the SA-treated plants had greater shoot and root dry mass, leaf area compared to untreated plants when exposed to salt stress. Application of SA restores photosynthetic rates and photosynthetic pigment levels under salt (NaCl) exposure. Leaf water, osmotic potential, stomatal conductance transpiration rate, and biochemical parameters were also ameliorated in SA-treated plants under saline stress conditions. Overall, these data illustrate that SA increases cv. Marmande tomato growth by improving photosynthesis, regulation and balance of osmotic potential, induction of compatible osmolyte metabolism, and alleviating membrane damage. We suggest salicylic acid might be considered as a potential growth regulator to improve tomato plant salinity stress resistance, in the current era of global climate change.

Highest fruit number in panicle and highest fruit number in bush obtained by mean of 1.5 and 66.75 in SA_1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control and the highest amount of fruit weight and also fruit diameter

was measured in SA_1 (SA at 10^{-2} M) with mean of 61.50 g and 51.75 mm, respectively. Lakzayi *et al.* (2014) reported that effect of drought is among the environmental constraints that affect crop growth and crop production worldwide. Drought or water deficit stress elicits many different physiological responses in plants. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo- oxidation and chlorophyll degradation. Relative water content (RWC), leaf water potential, stomatal resistance, the rate of transpiration, leaf temperature and canopy temperature are important characteristics that influence plant water relations. Salicylic acid (SA) as a potent signaling molecule in plants is involved in eliciting specific responses to biotic and abiotic stresses.

Kazemi (2014) conducted a study to find out the effect of salicylic acid and methyl jasmonate as pre-harvest treatments on the tomato vegetative growth, yield and fruit quality. These factors included salicylic acid in 2 levels (0.5 and0.75 $mmolL^{-1}$) and methyl jasmonate in 3 levels (0.25, 0.5 and 0.75 $mmolL^{-1}$) applied on tomato. Results indicated that salicylic acid (0. 5 $mmolL^{-1}$) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased dry weight. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid. To study the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits an experiment was conducted by Kazemi (2014b). The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, while reduced blossom end rot. On the contrary, MJ (1 mM) application significantly decreased vegetative growth while increasing reproductive growth. The application of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content.

In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato. (Guzman-Tellez *et al.* 2014) carried out a study to determine the change in the SA leaf concentration over time in response to the SA spraying in leaves of

greenhouse grown tomato. In sprayed leaves the SA concentration showed changes over time similar to the reported responses to environmental stress. Two days after the first application, the SA foliar concentration reached the maximum of 8 pg-g^{-1}, equivalent to twice the amount observed in the control plants. SA decreased until it reached the level of control plants eight days later. A second application showed actually the same response, but with a faster decline of SA in two days.

Hafeznia *et al.* (2014) conducted an experiment using salicylic acid (SA) on tomato Sopera based with foliar application of SA, with 10^{-1} molar concentration, performed 20 days after transplanting with 15 days interval, from planting to harvesting the products, planting to the flowering, flowering period up to the fruiting, and water spray as a control. Results revealed that the maximum leaf area, number of clusters and number of fruits $plant^{-1}$, sucrose, fructose, glucose, total soluble solid (TSS), vitamin C and lycopene were related to SA spray from planting up to harvesting. Sucrose became triple by utilizing of SA throughout planting period. Consequently, foliar application of SA in growth duration lead to biomass accumulation which guide to enhance of carbohydrates, TSS and vitamin C. Kowalska and Smolen (2013) carried out a study to evaluate the effect of an increased salt concentration in a nutrient solution and foliar application of salicylic acid (SA) and KMnO4 on the yield, fruit quality and nutritional status of tomato plants. The experiment included two sub-blocks with two EC levels (2.5 and 4.5 mS cm^{-1}). Within each sub-block, the following foliar application variants were distinguished: control (without foliar application) salicylic acid (SA) and SA/ KMnO4. Data revealed that irrespective of the EC of the nutrient solution, foliar application of SA as well as SA/ KMnO4 had no significant effect on the tomato yield, total acidity and dry matter or soluble sugar content in fruits.

Javaheri *et al.* (2012) carried out an experiment to study the effects of salicylic acid on yield quantity and quality of tomato, at research center of Shirvan Agricultural Faculty. Foliar application of five concentrations of salicylic acid (0, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} M) were used. Results showed that application of salicylic acid affected tomato yield and quality characters of tomato fruits so that tomato plants treated with salicylic acid 10^{-6} M significantly had higher fruit yield (3059.5 g per bush) compared to non-treated plants

(2220 g $bush^{-1}$) due to an increase in the number of bunch per bush. Results also indicated that application of salicylic acid significantly improved the fruit quality of tomato. Application of salicylic acid increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits. Fruit of tomato plants treated with salicylic acid 10^{-2} M significantly had higher vitamin C (32.5 mg 100 g of $fruit^{-1}$ fresh weight) compared to non-treated plants (24 mg 100 g fruit-1 fresh weight). Salicylic acid concentration 10^{-2} M also increased the diameter of fruit skin (0.54 mm) more than two fold compared to 10^{-2} M (0.26 mm). Fruit Brix index of tomato plants treated with salicylic acid significantly increased (9.3) compared to non-treated plants (5.9). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Consequently pot experiment was conducted by Salehi *et al.* (2011) to evaluate the effect of SA on tomato growth under salt stress condition. The experiment was complete randomized block with 3 replications, 4 levels of irrigation water salinity (0, 4, 8 and 12 dSm^{-1}) and 4 levels of SA concentration (0, 10^{-6}, 10^{-4} and 10^{-2} M) which was foliar sprayed. There was highly significant reduction in shoot fresh and dry weights and number of flowers per plant with increasing salinity. There was no significant difference between shoot fresh and dry weighs and number of flowers per plant for SA treated plants and control. However, fresh weight of plants treated with 10^{-4} M SA was significantly higher than the other two concentrations. Within each salinity level, SA application did not have significant effects on the measured plants characteristics. Based on these results, under this experimental condition, SA acid did not improve the salt tolerance of tomato. However, lower concentrations of SA needs to be evaluated.

Zahra *et al.* (2010) planted tomato seeds in pots containing per liter were put in a growth chamber under controlled conditions of 27 ± 2^0C and 23 ± 2^0C temperature, 16 hour lightness and 8 hour darkness, 15 lux light intensity and 75% humidity; NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.5, 1 and 1.5 mM were used. Salinity increases the soluble sugar in leaf and root tissues, and salicylic acid decreases it. The leaf protein level decreased because of salinity effect, but salicylic acid could increase it. In the root, salinity increases protein, but salicylic acid

with 1.5 mM concentration decreases it. Salinity increases the proline level in leaf and root, and salicylic acid did not significantly change in low salinity levels. Tomato seeds planted by Zahra *et al.* (2010) in pots containing per lite in a growth chamber under controlled conditions of 27 ± 2^0C and 23 ± 2^0C temperature, 16 hours lightness and 8 hours darkness respectively, 15 Klux light intensity and 75% humidity; NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.5, 1 and 1.5 mM. Results show that germination was decreased with salinity increasing. At low levels of salinity, SA leads to decrease in germination and had no effect in high levels of salinity. The length of shoots was not affected by salinity but decrease with increase in SA concentration. Low salinity concentrations led to significant increase in root length and high concentrations don't have significant difference with control. SA also had no effect on it. The highest amount of a, b, c and total chlorophyll and carotenoid was show in 50 mM salinity levels.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from October 2018 to March 2019 to study the Mitigation of salt stress in tomato using calcium and salicylic acid. This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, transplanting of seedling, intercultural operations, harvesting, data collection and statistical analysis. The materials and methods those were used and followed for conducting the experiment have been presented under the following headings.

3.1 Experimental site

This study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is 23°74´N latitude and 90°35´E longitude at an altitude of 8.6 meter above the sea level. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207, which have been shown in the Appendix I.

3.2 Climatic condition of the experimental site

The experimental site was situated under the subtropical monsoon climatic zone. This zone having heavy rainfall during Kharif season (April to September) and during Rabi season (rest month of the year) having limited rainfall. Enough sunshine and moderately low temperature prevail during Rabi season (October to March), which are suitable for growing of tomato in Bangladesh. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season October 2018 to March 2019 have been presented in Appendix II.

3.3 Characteristics of soil that used in pot

The soil of the experimental area belongs to the Modhupur Tract (Anon., 1989) under AEZ No. 28. The characteristics of the soil under the experiment were analyzed in the Laboratory of Soil science Department, SAU, Dhaka. The nutrient status of the farm

soil under the experimental pot was collected and analyze in the Soil Research and Development Institute, Dhaka and result has been presented in Appendix III.

3.4 Planting materials and Seedling raising

Seeds (3 gram) of BARI Tomato-15 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Bangladesh. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials. BARI Tomato-15 is a high yielding winter variety of Tomato with higher shelf life because of its thick skin and also resistant to Yellow leaf curl virus, which was developed by BARI, Joydebpur, Gazipur, Bangladesh. It was released in 2009. Total duration of this crop is about 100-110 days after transplanting.

Tomato Seedlings were raised in seedbed at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3 m × 1 m. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. Weeding and removing of stubbles were done when necessary and 5 kg well rotten cowdung was applied during seedbed preparation. The seeds were sown in the seedbed at 20 October, 2018 to get 30 days old seedlings. After sowing, seeds were covered with light soil to a depth of about 6 cm. Sevin was applied as precautionary measure against ants and worm around the seedbed. Seedlings emergence was visible within 5 to 6 days after sowing. Necessary shading by coconut leaves was provided over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were provided when necessary and required and no chemical fertilizer was used in this seedbed.

3.5 Treatments of the experiment

The experiment consisted of two factors and carried out to study the field performance of BARI Tomato 15 by applying calcium (Ca) and salicylic acid (SA) under different salinity levels. The following two factors were included in the experiment as follows:

Factor A: Different levels of salinity

1. S_0 = Control (no salinity added)
2. S_1 = 4 ds/m
3. S_2 = 8 ds/m
4. S_3 = 12 ds/m

Factor B: Different levels of mitigating component; Calcium and salicylic acid

1. T_0 = Control (no Ca or SA application)
2. T_1 = 5 mM Ca^{+2}
3. T_2 = 10 mM Ca^{+2}
4. T_3 = 125 ppm SA
5. T_4 = 250 ppm SA

There were total 20 (4 × 5) Treatment Combinations, such as:

S_0T_0 = No Salt + No Ca and SA/ Control Treatment
S_0T_1 = No Salt + 5 mM of Ca
S_0T_2 = No Salt + 10 mM of Ca
S_0T_3 = No Salt + 125 ppm of SA
S_0T_4 = No Salt + 250 ppm of SA
S_1T_0 = 4 dS^{-1} Salt + Control Treatment
S_1T_1 = 4 dS^{-1} Salt + 5 mM of Ca
S_1T_2 = 4 dS^{-1} Salt + 10 mM of Ca
S_1T_3 = 4 dS^{-1} Salt + 125 ppm of SA
S_1T_4 = 4 dS^{-1} Salt + 250 ppm of SA
S_2T_0= 8 dS^{-1} Salt + Control Treatment
S_2T_1 = 8 dS^{-1} Salt + 5 mM of Ca
S_2T_2 = 8 dS^{-1} Salt + 10 mM of Ca
S_2T_3 = 8 dS^{-1} Salt + 125 ppm of SA
S_2T_4 = 8 dS^{-1} Salt + 250 ppm of SA
S_3T_0 = 12 dS^{-1}Salt+ Control Treatment
S_3T_1 = 12 dS^{-1} Salt + 5 mM of Ca
S_3T_2 = 12 dS^{-1} Salt + 10 mM of Ca
S_3T_3 = 12 dS^{-1} Salt + 125 ppm of SA
S_3T_4 = 12 dS^{-1} Salt + 250 ppm of SA

3.6 Experimental design

The two factor experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. There were 60 pots all together. The experimental area

was divided into three equal blocks. Each block was divided into 20 pots where 20 treatment combinations were allotted at random. The distance between two blocks and two pots were 1.0 m and 0.5 m respectively. The diameter of each pot was 35 cm (14 inches) and height 30 cm (12 inches). The experiment was placed in the Horticulture farm of Sher-e-Bangla Agricultural University.

3.7 Pot preparation

A ratio of 1:3 well rotten cowdung and soil were mixed. Pots were filled 15 days before transplanting. All 60 pots were filled on 8 th November 2018. Weeds and stubbles were completely removed from the soil and brought into desirable fine tilth by hand mixing. Each pot contained 10 kg of prepared soil. The soil was treated with insecticides (Cinocarb 3G @ 4kg/ha) at the time of final pot preparation to protects young plants from the attack of soil inhibiting insects such as cutworms and mole cricket.

3.8 Application of fertilizer

Required amount of urea, TSP and MP fertilizer were added to each pot @ 550, 450 and 250 kg ha^{-1}, respectively (recommended by BARI, 2010). The entire amounts of TSP and MP were applied during the final pot preparation. Urea was applied in three equal installments at 21, 35 and 50 days after seedling transplanting. Well rotten cowdung @ 12 t ha^{-1} also applied during final soil preparation.

3.9 Uprooting and Transplanting the Seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 23 November 2018, each pot containing two seedlings in each pot. The seedbed was irrigated before uprooting from the seedbed, which helps to minimize damage to roots by ensuring maximum retention of roots. The seedlings were also irrigated after transplanting. . Some extra seedlings were kept in the seedbed for further gap filling for the experiment.

3.10 Preparation and Application of the treatments

The levels of the treatment of this experiment were control (no salt added), 4 dS/m, 8 dS/m and 12 dS/m NaCl in concentration. So, required amount of sodium chloride (Normal salt) (0, 25.6, 51.2, 76.8 g) was weighed by an electric balance respectively and mixed with 1 L water. The weighed salt was mixed properly with water and irrigation was done with the help of 1 L watering cane in each pot containing 10 kg of soil. In addition, fresh water irrigation was done in every one day interval. These total amounts of salts were applied through irrigation water in three splits at 25, 45 and 65 days after transplanting.

As a Na^+ stress mitigation agent, Ca^{2+} was used in the form of $CaSO_4.2H_2O$ at 5 and 10 mM concentration was sprayed exogenously at 25, 45 and 65 DAT.

Salicylic acid ($C_7H_6O_3$) , as a salt stress mitigation agent was sprayed exogenously at 125 ppm and 250 ppm concentrations were maintained per liter of water and 0.1% of tween-20 was used as an adhesive material. Spraying was done at 25, 45 and 65 DAT. SA solutions were sprayed by a hand sprayer at 4 pm.

3.11 Intercultural operations:

After raising of 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.

3.11.1 Irrigation

Light watering was provided with water cane immediately after transplanting the seedlings and this technique of irrigation was used as every day at early morning and sometimes also in evening throughout the growing period. But the frequency of irrigation became less in harvesting stage. Irrigation in those days when treatment was applied was done at evening as salt was applied with irrigation water. The amount of irrigation water was limited up to that quantity which does not leached out through the bottom. As such the salinity status was maintained in the desired level.

3.11.2 Thinning and Staking

After healthy establishment of two seedlings in the pot, thinning was done keeping one healthy seedling in each pot. When the plants were well established, staking was given to each plant by bamboo sticks. This is done to give support to keep the plant erect.

3.11.3 Weeding

Weeding was done whenever it was necessary, mostly in vegetative stage.

3.11.4 Earthing-up

Earthing up was done at 25 and 45 days after transplanting by taking the soil from the boundary side of pots by hand at the basement of plant.

3.11.5 Plant Protection Measures

Spraying Diathane M-45 fortnightly @2 gm per L of water at the early vegetative stage was done as precautionary measure against disease attack of tomato during foggy weather. Ridomil gold was also applied @ 2 gm per L of water against blight disease of tomato.

3.12 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color. Harvesting was started from 22 February 2019 and was continued up to 2nd week of March 2019.

3.13 Data recording

Experimental data were recorded from 30 days after transplanting and continued until harvest. The following data were recorded during the experimental period.

3.13.1 Growth and morphological characters

1. Plant height (cm) at 30, 50 and 75 DAT
2. Number of leaves plant^{-1} at 30, 50 and 75 DAT
3. Number of branches plant^{-1} at 40, 60 and 75 DAT

4. SPAD value at flowering and fruiting stage

3.13.2 Yield contributing parameters

1. Number of flowers plant^{-1}
2. Number of fruits plant^{-1}
3. Length of Fruit (cm)
4. Diameter of Fruits (cm)
5. Percent fruit dry matter (%)

3.13.3 Yield parameters

1. Individual fruit weight (g)
2. Fruit weight plant^{-1} (kg)

3.13.4 Quality parameters

1. Total Soluble Solid (TSS)
2. pH
3. Vitamin-C Content
4. Titrable Acidity (TA)
5. Lycopene content

3.14 Detailed procedures of data recording

A brief outline of the data recording procedure followed during the study is given below:

3.14.1 Growth and morphological characters

3.14.1.1 Plant height (cm)

Plant height was measured at 30, 50 and 75 DAT. The height of the plant was determined in centimeter by measuring the distance from the soil surface to the tip of the highest leaf.

3.14.1.2 Number of Leaves per plant

Leaf number was counted at 30, 50 and 75 DAT. The number of leaves per plant was counted from each plant.

3.14.1.3 Number of branches per plant

The total number of branches per plant was counted from each plant at 40, 60 and 75 DAT. There is no option to make average value from collected value due to only one plant was maintained per pot.

3.14.1.4 SPAD value

Leaf chlorophyll content was measured by using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). For each evaluation, five leaves from five different positions per plant were selected, then their SPAD value was recorded at flowering and fruiting stages. The average of the value from each plant was used for analysis.

3.14.2 Yield contributing parameters

3.14.2.1 Number of flowers plant^{-1}

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

3.14.2.2 Number of fruits plant^{-1}

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

3.14.2.3 Length of fruit (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 randomly selected marketable fruits from each pot and there average was taken and expressed in cm.

3.14.2.4 Diameter of fruit (cm)

Diameter of fruit was measured at the middle portion of 10 randomly selected marketable fruit from each pot with a slide calipers and there average was taken and expressed in cm.

3.14.2.5 Percent fruit dry matter (%)

After harvesting, randomly selected 100 g fruit sample from each treatment combination were collected and sliced into very thin pieces and dried. Then those were put into envelop and placed in oven maintaining at 70°C 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 in gram. The dry matter contents of fruit were computed by the following formula:

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

3.14.3 Yield parameters

3.14.3.1 Individual fruit weight (g)

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

$$\text{Individual fruit weight} = \frac{\text{Total weight of fruits per plants}}{\text{Total number of fruits per plant}}$$

3.14.3.2 Fruit weight plant^{-1} (kg)

Fruit yield per plant was calculated by taking the weight of total number of fruits per plant and expressed in kilogram (kg).

3.15.4 Quality parameters

3.14.4.1 Total Soluble Solid (TSS)

The total soluble solids of the pulp for each treatment was estimated by hand Refractometer of 0-800 Brix range. A drop of tomato juice squeezed from the fruit pulp

on the prism of the refractometer. Then percent TSS was obtained from the direct reading of the instruments.

(Ranganna, 1991).

3.14.4.2 pH of tomato fruits

Fully ripened fruits were collected from each of the treatment and blended it in liquid form. All the samples were taken in clean and transparent plastic pots. Electric p^H meter (model H-12211-p^H/OPR meter of Hanna Company) was adjusted in buffer solution of p^H 7.0; later on again it was adjusted in buffer solution containing p^H 4.0. Finally, Electric p^H meter was inserted in first sample and data was recorded. The same procedure was repeated to measure p^H of all other samples.

3.14.4.3 Vitamin C content of tomato fruits

Vitamin-C was measured by using Oxidation Reduction Titration Method. Single fruit was taken and exatract of tomato was filtrated by Whatman No.1 filter paper. After that, It was mixed with 3% metaphosphoric acid solution. The titration was conducted in presence of glacial acetic acid and metaphosphoric acid to inhibit aerobic oxidation with dye solution (2,6-dichlorophenol indophenol). The solution was titrated with dye. The observations mean will give, the amount of dye required to oxidize definite amount of L-ascorbic acid solution of unknown concentration, using L-ascorbic acid as known sample. It was measured in Biochemistry Lab of Sher-e-Bangla Agriculture University, Dhaka.

3.14.4.4 Titrable Acidity (TA)

The acid content of the must is determined by titrating a sample (a given volume) with a base such as sodium hydroxide solution to a phenolphthalein end point or alternatively, to a pH of 8.2. The titratable acidity is expressed as grams of tartaric acid per 100 ml. TA can be measured by the following formula:

$$\text{TA as tartaric acid (g/100 ml)} = \frac{V \times N75 \times 100}{1000\ v}$$

V= ml of sodium hydroxide solution used for titration

N = Normality of sodium hydroxide solution

v = sample volume (ml)

3.14.4.5 Lycopene content

Lycopene content of tomato is determined by Spectrophotometric determination by extraction with hexane/ethanol/acetone and absorbance measurement at 503 nm.

Lycopene levels in the hexane extracts were calculated according to:

Lycopene (mg/kg fresh wt.) = $(A_{503} \times 537 \times 8 \times 0.55)/(0.10 \times 172)$ ----- (1)

$$= A503 \times 137.4 \text{ ------- (2)}$$

where 537 g/mole is the molecular weight of lycopene, 8 mL is the volume of mixed solvent, 0.55 is the volume ratio of the upper layer to the mixed solvents, 0.10 g is the weight of tomato added, and 172 mM^{-1} is the extinction coefficient for lycopene in hexane.

Statistical analysis

The data obtained from different parameters were statistically analyzed following the analysis of variance (ANOVA) technique by using MSTAT-C computer package program. The significance of the difference among the treatment combinations of means was estimated by least significant difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the effect of calcium (Ca) and salicylic acid (SA) to mitigate salt stress in tomato. The effects due to different levels of salt stress, and application of Ca and SA and their interaction on the growth, yield and yield contributing characters have been presented in figures and tables. Results of the different parameters studied in the experiment have been presented and discussed under the following headings.

4.1 Growth and morphological characters

4.1.1 Plant height

Effect of salinity

Plant height is an important growth character for development and production of crop. Salinity effect on plant height is appeared at first. Significant variation was found for plant height at different growth stages influenced by different salinity levels (Figure 1 and Appendix IV). The highest plant height (35.72, 57.34 and 84.92 cm at 30, 50 and 75 DAT) was recorded from control treatment S_0 (no salinity) which was significantly different to other salinity levels. The lowest plant height (28.70, 45.82 and 69.13 cm at 30, 50 and 75 DAT) was recorded from the treatment S_3 (12 dSm^{-1}). Generally different salinity level significantly reduce the plant height of tomato at different crop duration and reduction was quite incremental with the increase of NaCl concentration. The natural plants height increased with increasing age but decreased with increasing salinity. The reduction of plant height might be due to inhibitory behavior of salt stress on cell division and cell expansion (Hernandez *et al*. 2002). Similar results were also recorded by many other authors like Ashraf and Mcnilly (2004) in Brassica, Islam *et al*. (2011) in tomato and Ramoliya and Pandey (2006) in Rhamnaceae etc. Salinity affects cell growth directly by lowering the osmotic potential of the soil solution and affects growth by lowering cell turgor pressure. Sudden decreases in turgor pressure responsible for the inhibition of growth induced by rapid increase in external solute concentrations (Volkamar *et al*.,

1998).Due to plant height decreasing, most yield agentss were decreased and therefore fruit yield was reduced (Ashraf and Mcneilly, 2004).

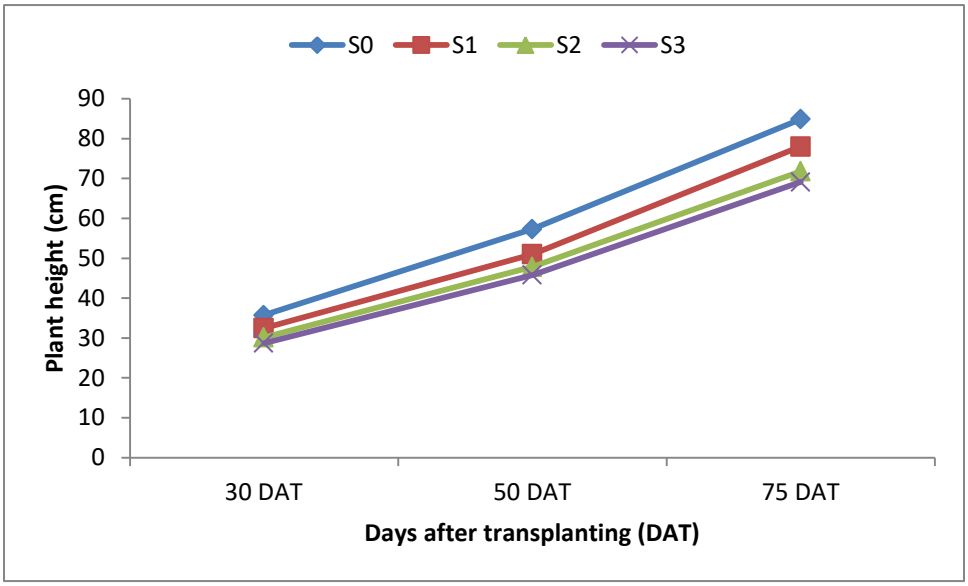

Figure 1. Plant height of tomato influenced by different salinity levels

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

At different growth stages plant height showed significant variation among the treatments influenced by different mitigation agentss (calcium and salicylic acid) (Figure 2 Sand Appendix IV). Among the different treatment levels, T_3 (125 ppm SA) gave the highest plant height (33.55, 52.99 and 79.72 cm at 30, 50 and 75 DAT) and the lowest plant height (28.71, 46.50 and 70.00 cm at 30, 50 and 75 DAT) was found from control treatment T_0 (no Ca or SA application) which were significantly different to other treatments. From this result it was observed that salicylic acid increased the plant height as compared with control where the best result was found from 125 ppm SA concentration. Gharib (2007) also reported that salicylic acid increased plant height. Fathy *et al*., (2003) reported the same result in case of eggplant.

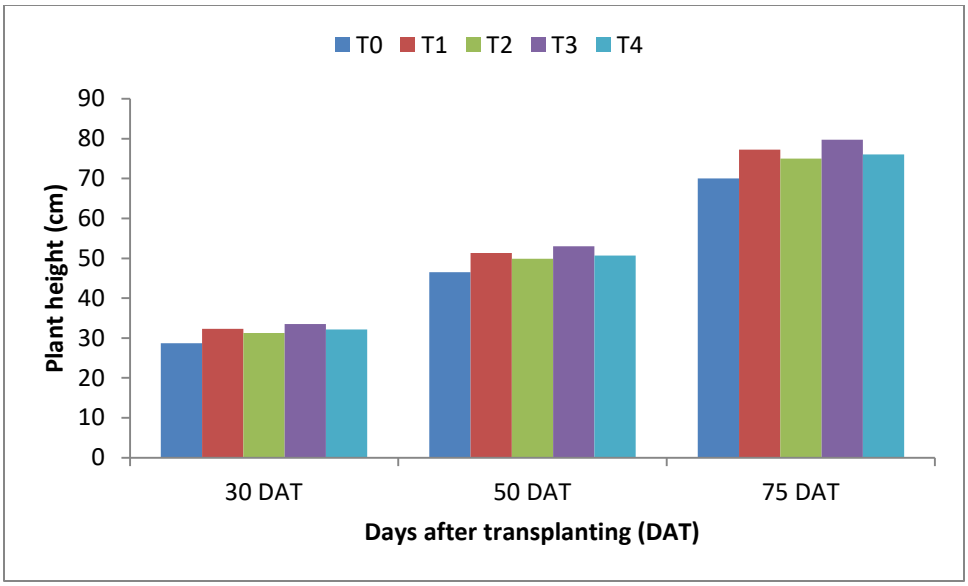

Figure 2. Plant height of tomato influenced by different mitigating agents

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Combined effect of salinity and mitigating agents; Ca and SA

Plant height of tomato was significantly varied due to combined effect of salinity and mitigation agents (calcium and salicylic acid) (Table 1 and Appendix IV). It was found that the maximum plant height (36.52, 58.64 and 87.64 cm at 30, 50 and 75 DAT, respectively) was found from the treatment combination S_0T_3 , which was statistically identical to the treatment combination S_0T_1 . The minimum plant height (25.43, 41.96 and 63.24 cm at 30, 50 and 75 DAT, respectively) was found from the treatment combination S_3T_0, which was closely followed by S_2T_0 at all growth stages. The treatment combination S_1T_3 (33.75, 53.87 and 81.52 cm at 30, 50 and 75 DAT, respectively) showed highest mitigation among all salinity levels and it reduced 0.46 % plant height compared to treatment control S_0T_0 (34.90, 56.20 and 81.90 cm at 30, 50 and 75 DAT, respectively). It was closely followed by treatment combination S_1T_1 (33.48, 52.64 and 81.27 cm at 30,50 and 75 DAT).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 1: Plant height of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatment	Plant height (cm)		
	30 DAT	50 DAT	75 DAT
S_0T_0	34.90 c	56.20 b	81.90 c
S_0T_1	36.18 a	58.48 a	86.52 a
S_0T_2	35.12 bc	56.44 b	84.14 b
S_0T_3	36.52 a	58.64 a	87.64 a
S_0T_4	35.88 ab	56.92 b	84.38 b
S_1T_0	28.94 j	45.73 i	71.40 g
S_1T_1	33.48 d	52.64 cd	81.27 c
S_1T_2	32.92 de	50.79 ef	77.33 d
S_1T_3	33.75 d	53.87 c	81.52 c
S_1T_4	33.24 de	52.18 de	78.56 d
S_2T_0	25.56 l	42.10 j	63.46 j
S_2T_1	31.76 fg	50.24 fg	75.21 e
S_2T_2	30.36 i	48.00 h	71.88 g
S_2T_3	32.44 ef	50.52 f	75.92 e
S_2T_4	30.80 hi	48.33 h	72.67 fg
S_3T_0	25.43 l	41.96 j	63.24 j
S_3T_1	31.20 ghi	48.62 h	73.24 f
S_3T_2	26.64 k	44.24 i	66.63 i
S_3T_3	31.48 gh	48.94 gh	73.80 f
S_3T_4	28.75 j	45.32 i	68.75 h
$LSD_{0.05}$	0.958	1.553	1.282
CV(%)	6.05	8.8	9.91

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m
T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.1.2Number of leaves plant^{-1}

Effect of salinity

Leaf is considered as an important growth character of plant because of its physiological role in photosynthetic activities. Salinity adversely affects total leaf number per plant of tomato. Number of leaf plant^{-1} of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Figure 3 and Appendix V). Results indicated that the highest number of leaves plant^{-1} (17.64, 37.37 and 63.60 at 30, 50 and 75 DAT, respectively) was recorded from control treatment S_0 (no salinity) which was significantly different to other treatments respectively. The lowest number of leaves plant^{-1} (13.28, 29.07 and 52.90 at 30, 50 and 75 DAT, respectively) was recorded from the treatment S_3 (12 dSm^{-1}). These results have been confirmed by the results of Karen et al. (2002), with their study on *Cirer arietinum* L. and Raul et al. (2003), with their study on the leaf of the teprary bean (*Phaseolus acutifolius* L.), cowpea (*Vigna unguiculata* L.), and wild bean (*Phaseolus filiformis* L). They mention that, the treatment of sodium chloride reduced the number of leaf compared with control plants. Similar observation was also observed by Alaa El-Din Sayed Ewase (2013) who reported that number of leaves plant^{-1} decreased with the increase of NaCl concentration in coriander. Mohammad et al. (1998) also reported increasing salinity stress accompanied by significant reduction in number of leaves plant-1. Jafari (2009), Saberi et al. (2011b), Islam (2004), and Angrish et al. (2001) also obtained reduced leaves number plant-1 under salinity stress.

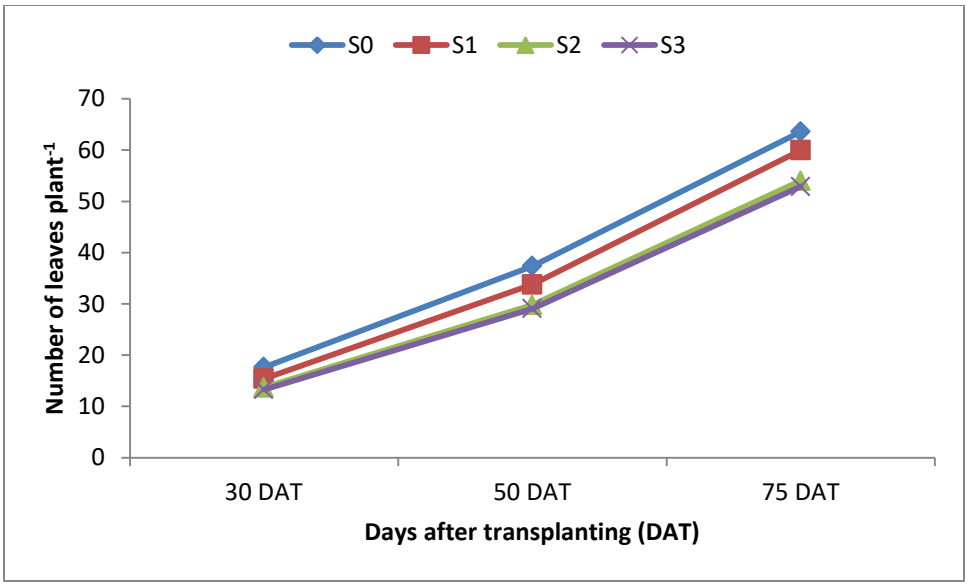

Figure 3. Number of leaf plant^{-1} of tomato influenced by different salinity levels

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

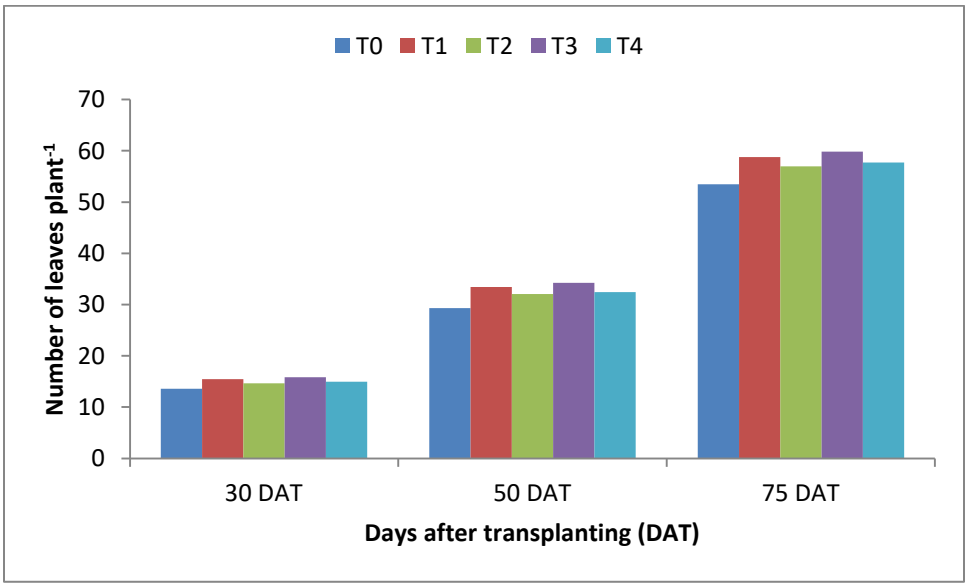

Figure 4. Number of leaf plant^{-1} of tomato influenced by different mitigating agents

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was recorded for number of leaves plant^{-1} at different growth stages influenced by different mitigation agentss (calcium and salicylic acid) (Figure 4 and Appendix V). Among the different treatment levels, the highest number of leaves plant^{-1} (15.83, 34.25 and 59.85 at 30, 50 and 75 DAT, respectively) was found from the treatment T_3 (125 ppm SA). The lowest number of leaves plant^{-1} (13.59, 29.31 and 53.44 at 30, 50 and 75 DAT, respectively) was found from control treatment T_0 (No Ca or SA application). This fact was supported by other authors like Tzortzakis (2010) in leafy vegetables, Lolaei et al. (2012) in tomato and Al- Mohshileh (2004) in potato. Similar result was also found from Mohsen Kazemi *et al*. (2014).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed statistically significant variation for number of leaves plant^{-1} at 30, 50 and 75 DAT (Table 2 and Appendix V). Results indicated that the highest number of leaves plant^{-1} (18.60, 38.44 and 64.45 at 30, 50 and 75 DAT, respectively) was found from the treatment combination of S_0T_1 which was statistically similar to the treatment combination of S_0T_3. The lowest number of leaves plant^{-1} (12.48, 25.63 and 48.22 at 30, 50 and 75 DAT, respectively) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_2T_0 at all growth stages. The treatment combination S_1T_3 (15.88, 34.67 and 61.80 at 30, 50 and 75 DAT, respectively) showed highest mitigation among all salinity levels and it reduced 2.2 % number of leaves plant^{-1} compared to treatment control S_0T_0 (17.12, 36.74 and 63.18 at 30, 50 and 75 DAT, respectively).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 2. Number of leaves plant^{-1} of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	Number of leaves plant^{-1}		
	30 DAT	50 DAT	75 DAT
S_0T_0	17.12 c	36.74 b	63.18 ab
S_0T_1	18.44 a	38.12 a	64.27 a
S_0T_2	17.36 bc	37.63 ab	63.72 a
S_0T_3	18.60 a	38.44 a	64.45 a
S_0T_4	17.92 ab	38.00 a	63.78 a
S_1T_0	13.40 hi	31.20 e	55.36 g
S_1T_1	15.64 d	33.92 cd	60.73 cd
S_1T_2	15.26 de	33.40 d	60.13 d
S_1T_3	15.88 d	34.67 c	61.80 bc
S_1T_4	15.52 d	33.64 d	60.44 cd
S_2T_0	12.60 j	25.72 h	48.36 j
S_2T_1	14.52 f	31.73 e	56.90 ef
S_2T_2	13.18 hij	28.85 fg	53.24 h
S_2T_3	14.76 ef	33.15 d	57.75 e
S_2T_4	13.33 hi	29.60 f	53.80 h
S_3T_0	12.48 j	25.63 h	48.22 j
S_3T_1	13.67 gh	31.40 e	56.12 fg
S_3T_2	12.87 ij	28.36 g	50.75 i
S_3T_3	14.33 fg	31.48 e	56.47 efg
S_3T_4	13.04 hij	28.50 g	52.92 h
$LSD_{0.05}$	0.705	1.022	1.536
CV(%)	5.84	7.9	8.61

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.1.3 Number of branches plant^{-1}

Effect of salinity

Branch number is an important crop growth character for successful crop production. Number of branches plant^{-1} at different growth stages showed significant variation as influenced by different salinity levels (Figure 5 and Appendix VI). Results revealed that

the highest number of branches plant^{-1}(5.51, 9.11 and 11.74 at 30, 50 and 75 DAT, respectively) recorded from control treatment S_0 (no salinity) which was significantly different to other treatments . The lowest number of branches plant^{-1} (3.81, 6.52 and 8.98 at 30, 50 and 75 DAT, respectively) was recorded from the treatment S_2 (8 dSm^{-1}) which is statistically similar to S_3 (12 dSm^{-1}). Uddin et al., 2005 also found that number of branch decreased with the increased salinity in Brassica species. Similar observation was also found in rice where tiller number decreased in response to salinity which was reported by Mortazainezhad et al., 2006. Many other authors like LingHe et al., 2000; Burman et al., 2002; WeonYoung et al., 2003; Islam, 2004; Rashid, 2005.

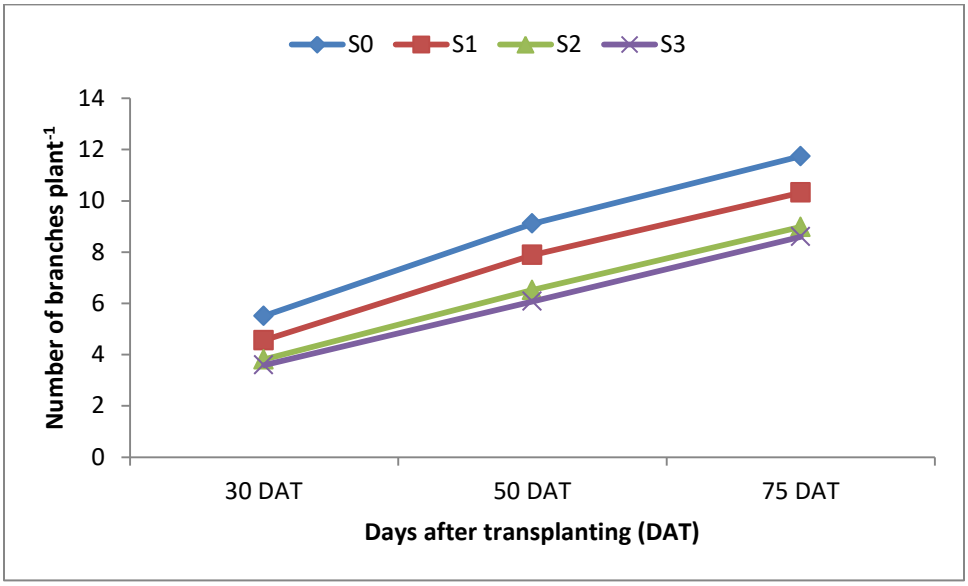

Figure 5. Number of branches plant^{-1} of tomato influenced by different salinity levels

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was recorded for number of branches plant^{-1} at different growth stages influenced by different mitigation agentss (calcium and salicylic acid) (Figure 6 and Appendix VI). However, the highest number of branches plant^{-1}(4.80, 8.17 and 10.55 at 30, 50 and 75 DAT, respectively) was found from the treatment T_3 (125 ppm SA). While the lowest number of branches plant^{-1} (3.78, 6.44 and 8.92 at 30, 50 and 75 DAT, respectively) was found from control treatment T_0 (No Ca or SA application). Arzandi

(2014) stated that SA increasing the number of branching in case of coriander. Similar result was found from Mohsen Kazemi *et al*. (2014).

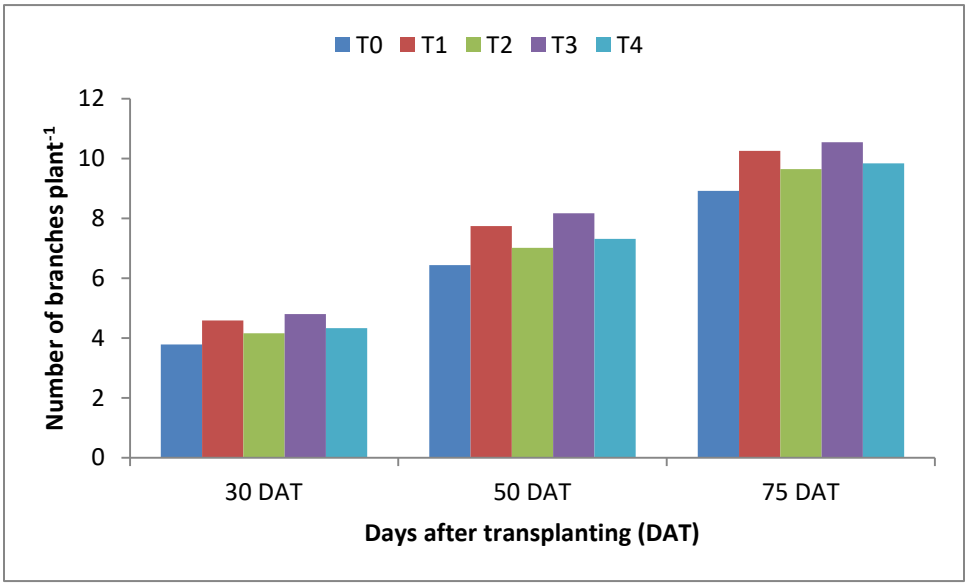

Figure 6. Number of branches plant^{-1} of tomato influenced by different mitigating agents

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed statistically significant variation on number of branches plant^{-1} at different growth stages (Table 3 and Appendix VI). The highest number of branches plant^{-1} (5.92, 9.75 and 12.24 at 30, 50 and 75 DAT, respectively) was found from the treatment combination of S_0T_3 which was closely followed by the treatment combination of S_0T_1 at all growth stages. The lowest number of branches plant^{-1} (3.15, 5.24 and 7.65 at 30, 50 and 75 DAT, respectively) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_2T_0. The treatment combination S_1T_3 (15.88, 34.67 and 61.80 at 30, 50 and 75 DAT, respectively) showed highest mitigation among all salinity levels and it reduced 1.77 % number of branches plant^{-1} compared to treatment control S_0T_0 (5.10, 8.67 and 11.32 at 30, 50 and 75 DAT, respectively) .

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 3. Number of branches plant^{-1} of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	Number of branches plant^{-1}		
	40 DAT	60 DAT	75 DAT
S_0T_0	5.10 cd	8.67 d	11.32 d
S_0T_1	5.78 a	9.46 ab	12.10 ab
S_0T_2	5.33 bc	8.80 cd	11.48 cd
S_0T_3	5.92 a	9.75 a	12.24 a
S_0T_4	5.64 ab	9.12 bc	11.75 bc
S_1T_0	3.88 jk	6.75 i	9.120 jk
S_1T_1	4.75 ef	8.27 e	10.64 e
S_1T_2	4.48 fg	7.64 f	10.18 fg
S_1T_3	4.90 de	8.44 de	11.12 d
S_1T_4	4.60 efg	8.12 e	10.36 ef
S_2T_0	3.18 mn	5.33 kl	7.800 n
S_2T_1	4.27 ghi	7.24 gh	9.720 hi
S_2T_2	3.50 lm	6.20 j	8.670 lm
S_2T_3	4.40 gh	7.48 fg	9.880 gh
S_2T_4	3.72 kl	6.36 j	8.840 kl
S_3T_0	3.15 n	5.24 l	7.650 n
S_3T_1	4.00 ijk	6.90 hi	9.240 jk
S_3T_2	3.33 mn	5.40 kl	8.270 m
S_3T_3	4.13 hij	7.18 gh	9.440 ij
S_3T_4	3.36 mn	5.67 k	8.400 m
$LSD_{0.05}$	0.347	0.366	0.4214
CV(%)	7.64	7.74	6.09

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m
T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.1.4 SPAD value

Effect of salinity

SPAD value at different crop duration (flowering and fruiting stages) showed significant variation as influenced by different salinity levels (Figure 7 and Appendix VII). The highest SPAD value at flowering stage (58.10) was recorded from control level of salinity S_0 (no salinity) whereas the lowest SPAD value at flowering stage (49.67) was recorded from the level S_3 (12 dSm^{-1}) which was statistically similar to the level S_2 (8 dSm^{-1}). The highest SPAD value at fruiting stage (56.69) was also recorded from control salinity level S_0 (no salinity) whereas the lowest SPAD value at fruiting stage (39.30) was also recorded from the level S_3 (12 dSm^{-1}) which was statistically similar to the level S_2 (8 dSm^{-1}). The results were consistent with Jamal et al., (2014), Nawaz et al., (2010) and Taffouo et al. (2010).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was recorded for SPAD value at flowering and fruiting stages influenced by different mitigation agentss (calcium and salicylic acid) (Figure 8 and Appendix VII).The highest SPAD value at flowering stage (55.42) was found from the treatment T_3 (125 ppm SA) whereas the lowest SPAD value at flowering stage (50.43) was found from control treatment T_0 (No Ca or SA application). The highest SPAD value at fruiting stage (50.46) was also achieved found from the treatment T_3 (125 ppm SA). The lowest SPAD value at fruiting stage (40.73) was also found from control treatment T_0 (No Ca or SA application). Similar result was also observed by Souri and Tohidloo (2019) and Lakzayi *et al.* (2014) who found increased SPAD value with salicylic compounds.

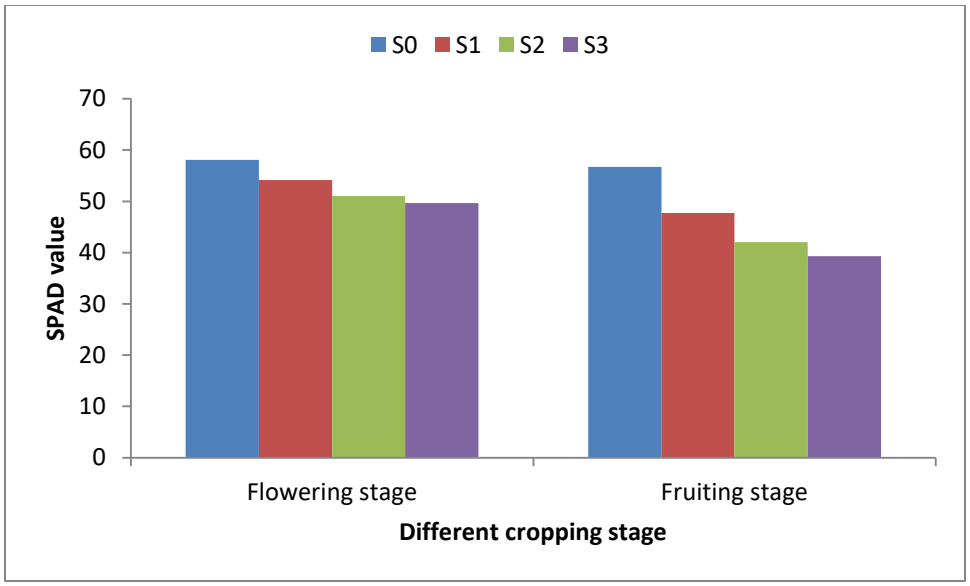

Figure 7. SPAD value of tomato leaves as influenced by different salinity levels

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

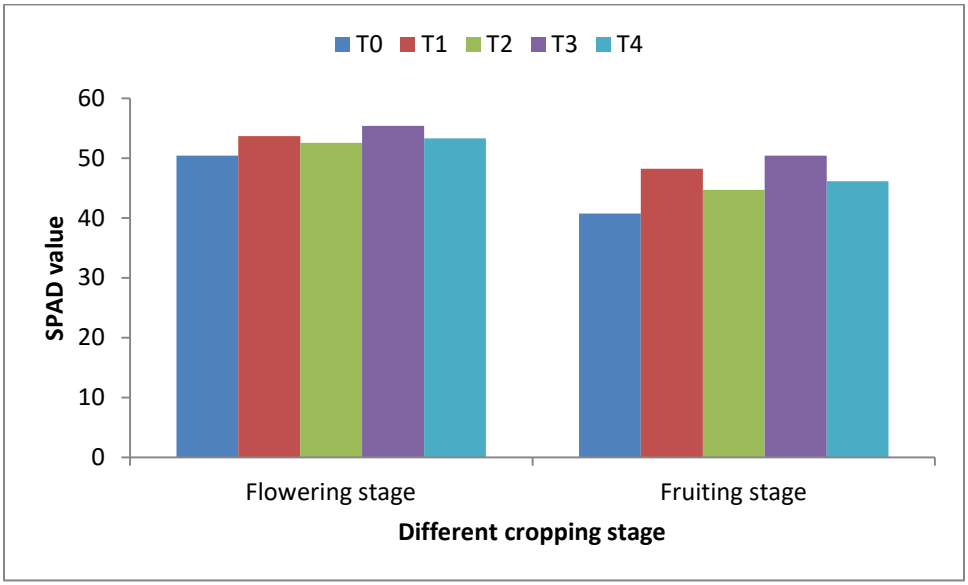

Figure 8. SPAD value of tomato leaves as influenced by different mitigating agents

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Table 4. SPAD value at different cropping stages of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	SPAD value at different cropping stage	
	Flowering stage	Fruiting stage
S_0T_0	55.47 c	53.00 d
S_0T_1	60.43 a	58.60 b
S_0T_2	55.97 bc	53.17 d
S_0T_3	60.97 a	63.27 a
S_0T_4	57.77 b	55.70 c
S_1T_0	50.80 d	43.07 h
S_1T_1	55.00 c	49.57 e
S_1T_2	54.77 c	46.13 f
S_1T_3	55.37 c	52.70 d
S_1T_4	54.87 c	46.97 f
S_2T_0	48.73 e	36.73 l
S_2T_1	51.23 d	45.23 fg
S_2T_2	49.90 de	40.97 ij
S_2T_3	54.63 c	45.23 fg
S_2T_4	50.80 d	41.97 hi
S_3T_0	46.80 f	30.43 m
S_3T_1	51.00 d	43.70 gh
S_3T_2	49.73 de	38.63 k
S_3T_3	51.07 d	43.77 gh
S_3T_4	49.77 de	39.97 jk
$LSD_{0.05}$	1.874	1.827
CV(%)	9.64	8.32

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m
T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed statistically significant variation for SPAD value at flowering and fruiting stages (Table 4 and Appendix VII). The highest SPAD value at flowering stage (60.97) was found from the treatment combination of S_0T_3 which was statistically identical to the treatment combination of S_0T_1. The lowest SPAD value at flowering stage (46.80) was found from

the treatment combination of S_3T_0 which was significantly different to other treatment combinations. At fruiting stage, the highest SPAD value (63.27) was also observed from the treatment combination of S_0T_3 which was significantly different to other treatment combinations followed by S_0T_1. The lowest SPAD value at fruiting stage (30.43) was also obtained from the treatment combination of S_3T_0. The treatment combination S_1T_3 (55.37 and 52.70 at flowering and fruiting stages, respectively) showed highest mitigation among all salinity levels and it reduced 0.18% and 0.57% SPAD value of plant compared to treatment control S_0T_0 (55.47 and 53.00 at flowering and fruiting stages, respectively) .

It was revealed that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.2 Yield contributing parameters

4.2.1 Number of flowers plant^{-1}

Effect of salinity

Number of flowers plant^{-1} of tomato showed significant differences in response to different salinity levels (Table 5 and Appendix VIII). The highest number of flowers plant^{-1} (46.82) was recorded from control treatment S_0 (no salinity) which was significantly different to other treatments. The lowest number of flowers plant^{-1} (26.98) was recorded from the treatment S_3 (12 dSm^{-1}) which was significantly similar with S_2 (8 dSm^{-1}). Salinity reduced the number of flowers /plant which was reported by Olympios *et al*. (2003) and Jamal *et al*., (2014). Salinity adversely affects reproductive development by inhibiting microosporogenesis, stamen filament, ovule abortion and senescence of fertilized embryo.

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Calcium and Salicylic acid as mitigation agent had significant effect on total number of flowers plant^{-1} of tomato (Table 5 and Appendix VIII). Table 5 reveals that, the highest number of flowers plant^{-1} (39.47) was found from the treatment T_3 (125 ppm SA) . On the contrary, the lowest number of flowers plant^{-1} (29.45) was found from control treatment T_0 (No Ca or SA application). Javaheri *et al*. (2014) reported the highest

flowers number in bush obtained by mean of 66.75 in the application of SA1 (SA at 10^{-2} M) which is support the present study. Similar result was also found from Alireza Pazoki (2015).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed significant variation on number of flowers plant^{-1} of tomato (Table 6 and Appendix VIII). Table 6 showed that the highest number of flowers plant^{-1} (48.44) was found from the treatment combination of S_0T_3 which was statistically similar to S_0T_1. The lowest number of flowers plant^{-1} (21.60) was found from the treatment combination of S_3T_0 which was statistically identical to S_2T_0.The treatment combination S_1T_3 (41.88) showed highest mitigation among all salinity levels and it reduced 5.33 % number of flowers plant^{-1} compared to treatment control S_0T_0 (44.24).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.2.2Number of fruits plant^{-1}

Effect of salinity

Number of fruits plant^{-1} of tomato showed significant differences in response to different salinity levels (Table 5 and Appendix VIII). The highest number of fruits plant^{-1} (37.07) was recorded from control treatment S_0 (no salinity) which was significantly different to other treatments. The lowest number of fruits plant^{-1} (19.00) was recorded from the treatment S_3 (12 dSm^{-1}). Salinity reduced the number of fruit/plant which was also related with the number of flower/plant and ultimately reduced the fruit yield which is also supported by Olympios et al. (2003), Jamal et al., (2014), Sixto et al. (2005). Salinity adversely affects reproductive development by inhibiting microosporogenesis, stamen filament, ovule abortion and senescence of fertilized embryo.

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Calcium and Salicylic acid as mitigation agent had significant effect on total number of fruits plant^{-1} of tomato (Table 5 and Appendix VIII). Table 5 reveals that, the highest number of fruits plant^{-1} (31.42) was found from the treatment T_3 (125 ppm SA) which was significantly different to other treatments, respectively. On the contrary, the lowest number of fruits plant^{-1} (20.75) was found from control treatment T_0 (No Ca or SA application). Javaheri *et al*. (2014) reported the highest fruit number in bush obtained by mean of 66.75 in the application of SA1 (SA at 10^{-2}M) which is support the present study. Similar result was also found from Alireza Pazoki (2015).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed significant variation on number of fruits plant^{-1} of tomato (Table 6 and Appendix IX). Table 6 showed that the highest number of fruits plant^{-1} (39.67) was found from the treatment combination of S_0T_3 which was statistically similar to S_0T_1.The lowest number of fruits plant^{-1} (13.00) was found from the treatment combination of S_3T_0 which was statistically identical to S_2T_0. The treatment combination S_1T_3 (33.33) showed highest mitigation among all salinity levels and it reduced 2.91 % number of fruits plant^{-1} compared to treatment control S_0T_0 (34.33).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.2.3 Fruit length(cm)

Effect of salinity

Length of fruits showed statistically significant variation due to different levels of salinity (Table 5 and Appendix VIII). Table 5 showed that the maximum fruit length (8.12cm) was recorded from control treatment S_0 (no salinity; 0 dSm^{-1}) which was significantly different to other treatments. The lowest fruit length (7.34 cm) was recorded from the treatment S_3 (12 dSm^{-1}).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Different levels of calcium and salicylic acid as mitigating agent against salt stress showed non-significant difference for the length of tomato fruit (Table 5 and Appendix VIII). However, the highest fruit length (7.89 cm) was found from the treatment T_4 (250 ppm SA) whereas the lowest fruit length (7.30cm) was found from control treatment T_0 (No Ca or SA application).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed statistically significant variation for length of fruit (Table 6 and Appendix VIII). Results indicated that the highest fruit length (8.25 cm) was found from the treatment combination of S_0T_3 which was statistically identical to S_0T_1, S_0T_2 and S_0T_4. The lowest fruit length (6.81 cm) was found from the treatment combination of S_3T_0 which was statistically identical to S_2T_0. The treatment combination S_1T_3 (7.84 cm) showed highest mitigation among all salinity levels and it gave the same fruit length compared to treatment control S_0T_0 (7.84).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.2.4 Fruit diameter (cm)

Effect of salinity

Fruit diameter showed statistically significant variation due to different levels of salinity (Table 5 and Appendix VIII). Results revealed that the highest fruit diameter (10.19 cm) was recorded from control treatment S_0 (no salinity) which was significantly different to other treatments. The lowest fruit diameter (8.55 cm) was recorded from the treatment S_3 (12 dSm^{-1}) which was statistically identical to S_2 (8 dSm^{-1}).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Different levels of calcium and salicylic acid as mitigating agent showed non-significant variation on diameter of fruit (Table 5 and Appendix VIII). However, the highest fruit

diameter (9.79 cm) was found from the treatment T_3 (125 ppm SA) whereas the lowest fruit diameter (8.60 cm) was found from control treatment T_0 (no Ca or SA application).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed statistically significant variation for fruit diameter of tomato (Table 6 and Appendix VIII). It was observed that the highest fruit diameter (10.48 cm) was found from the treatment combination of S_0T_3 which was statistically similar to

the treatment combination of S_0T_1. The lowest fruit diameter (7.87 cm) was found from the treatment combination of S_3T_0 which was statistically identical to S_2T_0. The treatment combination S_1T_3 (9.69 cm) showed highest mitigation among all salinity levels and it reduced 0.2 % fruit diameter compared to treatment control S_0T_0 (9.71).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 5. Yield contributing parameters and yield of tomato influenced by salinity and mitigation agents

Treatments	Yield contributing parameters				
	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Length of Fruit (cm)	Diameter of Fruits (cm)	Percent fruit dry matter (%)
Effect of salinity					
S_0	46.82 a	37.07 a	8.12 a	10.19 a	8.57 a
S_1	37.71 b	29.47 b	7.79 b	9.51 b	8.09 b
S_2	29.81 c	21.07 c	7.42 c	8.88 c	7.49 c
S_3	26.98 c	19.00 c	7.34 c	8.55 c	7.14 d
$LSD_{0.05}$	5.435	3.044	0.099	0.445	0.178
CV(%)	6.71	5.24	6.20	5.04	10.95
Effect of different levels of mitigating agents; Ca and SA					
T_0	29.45 d	20.75 d	7.30	8.60	7.33 c
T_1	36.79 b	28.62 b	7.75	9.50	7.98 a
T_2	33.94 c	24.58 c	7.62	9.05	7.60 b
T_3	39.47 a	31.42 a	7.89	9.79	8.26 a
T_4	35.16 b	25.92 c	7.68	9.26	7.78 b

$LSD_{0.05}$	2.120	1.867	NS	NS	0.131
CV(%)	6.71	5.24	6.20	5.04	10.95

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m
T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.2.5 Fruit dry matter (%)

Effect of salinity

Fruit dry matter (%) of tomato showed significant differences in response to different salinity levels (Table 5 and Appendix VIII). The highest fruit dry matter (8.57 %) was recorded from control treatment S_0 (no salinity) whereas the lowest fruit dry matter (7.14 %) was recorded from the treatment S_3 (12 dSm^{-1}). The findings of Patil et al. (1996) were partially in consonance with the present findings. They reported that dry matter production reduced with increasing salinity. Similar result also found by Zhani *et al*. (2012) in case of chili.

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Calcium and Salicylic acid as mitigation agent had significant effect on percent fruit dry matter of tomato (Table 5 and Appendix VIII). Table 6 reveals that, the highest fruit dry matter (8.03%) was found from the treatment T_3 (125 ppm SA) which was statistically identical to T_2 (10 mM Ca^{+2}). The lowest fruit dry matter (7.33 %) was found from control treatment T_0 (no Ca or SA application).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed significant variation on percent fruit dry matter of tomato (Table 6 and Appendix VIII). Table 6 showed that the highest fruit dry matter (9.00%) was found from the treatment combination of S_0T_3 which was statistically similar to S_0T_1. The lowest fruit dry matter (6.67%) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_2T_0 and S_3T_2. The treatment combination S_1T_3 (8.33 %) showed highest mitigation among all salinity levels and it increased 0.96 % fruit dry matter compared to treatment control S_0T_0 (8.25).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 6. Yield contributing parameters and yield of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	Yield contributing parameters				
	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Length of Fruit (cm)	Diameter of Fruits (cm)	Percent fruit dry matter (%)
S_0T_0	44.24 c	34.33 d	7.84 b	9.710 c	8.25 cde
S_0T_1	48.32 a	38.33 ab	8.23 a	10.43 a	8.82 ab
S_0T_2	45.72 bc	36.00 c	8.15 a	10.10 b	8.25 cde
S_0T_3	48.44 a	39.67 a	8.25 a	10.48 a	9.00 a
S_0T_4	47.36 ab	37.00 bc	8.15 a	10.23 ab	8.54 bc
S_1T_0	30.20 hi	22.33 i	7.69 bc	8.900 f	7.45 f
S_1T_1	39.80 e	31.67 e	7.83 b	9.680 c	8.33 cd
S_1T_2	37.25 f	29.33 f	7.78 b	9.633 c	8.14 de
S_1T_3	41.88 d	33.33 d	7.84 b	9.690 c	8.33 cd
S_1T_4	39.40 e	30.67 ef	7.81 b	9.660 c	8.18 de
S_2T_0	21.75 k	13.33 m	6.84 e	7.907 h	6.93 gh
S_2T_1	34.67 g	27.67 g	7.71 bc	9.600 cd	7.95 e
S_2T_2	28.40 i	17.67 k	7.31 d	8.440 g	7.07 g
S_2T_3	35.75 fg	27.33 g	7.75 b	9.640 c	8.08 de
S_2T_4	28.50 i	19.33 j	7.47 cd	8.833 f	7.41 f
S_3T_0	21.60 k	13.00 m	6.81 e	7.873 h	6.67 h
S_3T_1	31.72 h	24.67 h	7.69 bc	9.187 e	7.48 f
S_3T_2	24.40 j	15.33 l	7.23 d	8.037 h	6.93 gh
S_3T_3	31.80 h	25.33 h	7.70 bc	9.340 de	7.61 f
S_3T_4	25.36 j	16.67 kl	7.27 d	8.333 g	7.00 g
$LSD_{0.05}$	1.893	1.614	0.27	0.282	0.301
CV(%)	6.71	5.24	6.20	5.04	10.95

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.3 Yield parameters

4.3.1 Individual fruit weight (g)

Effect of salinity

Significant difference was recorded on individual fruit weight with different salinity levels (Table 7 and Appendix IX). Among the different salinity levels, control treatment S_0 showed highest individual fruit weight (50.71 g). The lowest individual fruit weight (36.08 g) was recorded from the treatment S_3 (12 dSm^{-1}). The result was consistent with Humayun *et al*. (2010) and Jamal *et al*. (2014).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was found for individual fruit weight influenced by different mitigation agentss (calcium and salicylic acid) (Table 7 and Appendix IX). Among the different treatments of calcium and salicylic acid including control, the highest individual fruit weight (44.90 g) was found from the treatment T_3 (125 ppm SA) . The lowest individual fruit weight (33.38 g) was found from control treatment T_0 (no Ca or SA application). Wasternack et al.(2002) repored that JA improves fruit characters. Similarly Humayun et al.(2010) states that SA enhances growth and yield elated characters.

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed statistically significant variation for individual fruit weight (Table 8 and Appendix IX). The highest individual fruit weight (53.42 g) was found from the treatment combination of S_0T_3 which was statistically identical to the treatment combination of S_0T_1. The lowest individual fruit weight (29.02 g) was found from the treatment combination of S_3T_0 which was significantly different to other treatment combinations and it reduced 34% individual fruit weight compared to treatment control S_0T_0 (44g) . The treatment combination S_1T_3 (43.91g) showed highest mitigation among all salinity levels and it reduced 0.2% individual fruit weight compared to treatment control S_0T_0 (44g). Thus, upto 99% mitigation can be possible.

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 7. Yield contributing parameters and yield of tomato influenced by salinity and mitigating agents

Treatments	Yield parameters	
	Individual fruit weight (g)	Fruit weight plant^{-1} (kg)
Effect of salinity		
S_0	50.71 a	1.84 a
S_1	41.83 b	1.23 b
S_2	37.68 c	0.81 c
S_3	36.08 c	0.70 c
$LSD_{0.05}$	1.635	0.155
CV(%)	6.24	9.47
Effect of different levels of mitigating agents; Ca and SA		
T_0	33.38 d	0.79 e
T_1	41.96 b	1.25 b
T_2	39.89 c	1.02 d
T_3	44.90 a	1.44 a
T_4	41.26 b	1.12 c
$LSD_{0.05}$	1.344	0.036
CV(%)	6.24	9.47

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

4.3.2 Fruit weight plant^{-1} (kg)

Effect of salinity

Significant difference was recorded on fruit weight plant^{-1} with different salinity levels (Table 7 and Appendix IX). Results showed that the control treatment S_0 gave the highest fruit weight plant^{-1} (1.84 kg) which was significantly different to other treatments . The salinity level S_3 (12 dSm^{-1}) gave the lowest fruit weight plant^{-1} (0.70 kg). Similar results was found from Humayun *et al*. (2010) and Siddiky et al. (2012).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was found for fruit weight plant^{-1} influenced by different mitigation agentss (calcium and salicylic acid) (Table 7 and Appendix IX). The highest fruit weight plant^{-1} (1.44 kg) was found from the treatment T_3 (125 ppm SA) which was significantly different to other treatments whereas the lowest fruit weight plant^{-1} (0.79 kg) was found from control treatment T_0 (no Ca or SA application). Sibgha *et al*. (2008) concluded that SA have ample effect on fruit related characters, similarly Sheteawi (2007) revealed that JA also improves yield and yield related characters.

Table 8. Yield contributing parameters and yield of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	Yield parameters	
	Individual fruit weight (g)	Fruit weight plant^{-1} (kg)
S_0T_0	44.00 d	1.51 d
S_0T_1	52.73 a	2.02 a
S_0T_2	46.73 c	1.68 c
S_0T_3	53.42 a	2.12 a
S_0T_4	49.95 b	1.85 b
S_1T_0	38.39 h	0.86 j
S_1T_1	42.52 de	1.34 ef
S_1T_2	42.07 ef	1.22 fg
S_1T_3	43.91 d	1.46 de
S_1T_4	42.25 ef	1.29 f
S_2T_0	32.73 k	0.43 mn
S_2T_1	41.09 efg	1.11 ghi
S_2T_2	36.00 ij	0.65 kl
S_2T_3	41.55 efg	1.15 gh
S_2T_4	37.02 hi	0.72 k
S_3T_0	29.02 l	0.37 n
S_3T_1	40.09 g	0.99 ij
S_3T_2	34.74 j	0.53 lm
S_3T_3	40.73 fg	1.03 hi
S_3T_4	35.82 ij	0.60 kl
$LSD_{0.05}$	1.520	0.138

CV(%)	6.24	9.47

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed statistically significant variation for fruit weight plant^{-1} (Table 8 and Appendix IX). The treatment combination of S_0T_3 gave the highest fruit weight plant^{-1} (2.12 kg) which was statistically identical to the treatment combination of S_0T_1. The lowest fruit weight plant^{-1} (0.37 kg) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_2T_0. Treatment combination S_3T_0 reduced 75.5% fruit weight plant^{-1} compared to treatment control S_0T_0 (1.51 kg). The treatment combination S_1T_3 (1.46 kg) showed highest mitigation among all salinity levels and it reduced only 3.31 % fruit weight plant^{-1} compared to treatment control S_0T_0 (1.51 kg). Thus, maximum 96% mitigation can be possible.

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.4 Quality parameters

4.4.1Total Soluble Solid (TSS)

Effect of salinity

Total soluble solid (TSS) was affected significantly due to different salinity levels (Table 9 and Appendix X). The highest TSS (7.27) was recorded from the treatment S_3 (12 dSm^{-1}) whereas the lowest TSS (6.60) was recorded from the control treatment S_0 (no salinity; 0 dSm^{-1}) which was statistically identical to S_1 (4 dSm^{-1}) and S_2 (8 dSm^{-1}). Similar result was also observed by Guiseppe (2006).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Non-significant variation was found for total soluble solid (TSS) influenced by different mitigation agentss (calcium and salicylic acid) (Table 9 and Appendix X). However, the highest TSS (7.50) was found from the treatment T_3 (125 ppm SA) whereas he lowest TSS (6.33) was found from control treatment T_0 (no Ca or SA application).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agent (calcium and salicylic acid) showed significant different for total soluble solid (TSS) (Table 10 and Appendix X). The highest TSS (8.00) was found from the treatment combination of S_3T_3 which was significantly different to other treatment combinations whereas the lowest TSS (6.00) was found from the treatment control S_0T_0 .

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.4.2 p^H

Effect of salinity

Non-significant difference was recorded on p^H content affected by different salinity levels (Table 9 and Appendix X). However, the highest p^H (4.05) was recorded from control treatment S_0 (no salinity; 0 dSm^{-1}) whereas the lowest p^H (3.83) was recorded from the treatment S_3 (12 dSm^{-1}). Similar results was found from yosef (1982)

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Non-significant variation was recorded for p^H content influenced by different mitigation agentss (calcium and salicylic acid) (Table 9 and Appendix X). However, the highest p^H (3.97) was found from the control treatment T_3 (125 ppm SA) and the lowest p^H (3.89) was found from the treatment T_0 (no Ca or SA application)

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed non-significant variation for p^H content (Table 10 and Appendix X). However, the highest p^H (4.14) was found from the treatment combination of S_0T_3 whereas the lowest p^H (3.80) was found from the treatment combination of S_3T_0. The treatment combination S_1T_3 (3.97) showed highest mitigation among all salinity levels and it reduced 0.25% p^H content compared to treatment control S_0T_0 (3.98).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.4.3Vitamin-C Content

Effect of salinity

Non-significant difference was recorded on vitamin C content affected by different salinity levels (Table 9 and Appendix X). However, the highest vitamin C content (0.61) was recorded from control treatment S_0 (no salinity; 0 dSm^{-1}) whereas the lowest vitamin C content (0.36) was recorded from the treatment S_3 (12 dSm^{-1}). Fanasca *et al*. (2007) found similar result with the present study.

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Non-significant variation was recorded for vitamin C content influenced by different mitigation agentss (calcium and salicylic acid) (Table 9 and Appendix X). However, the highest vitamin C content (0.53) was found from the treatment T_3 (125 ppm SA) whereas the lowest vitamin C content (0.44) was found from treatment T_0 (control).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed significant variation for vitamin C content (Table 10 and Appendix X). The highest vitamin C content (0.70) was found from the treatment combination of S_0T_3 which was statistically identical to the treatment combination of S_0T_1 whereas the lowest vitamin C

content (0.30) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_3T_2. The treatment combination S_1T_3 (0.53) showed highest mitigation among all salinity levels and it reduced 1.85 % vitamin C content compared to treatment control S_0T_0 (0.54).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.4.4 Titratble acidity (TA)

Effect of salinity

Non-significant difference was recorded on titratable acidity affected by different salinity levels (Table 9 and Appendix X). However, the highest titratable acidity (1.21) was recorded from control treatment S_0 (no salinity; 0 dSm^{-1}) whereas the lowest titratable acidity (0.61) was recorded from the treatment S_3 (12 dSm^{-1}).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Titratable acidity influenced significantly by different mitigation agentss (calcium and salicylic acid) (Table 9 and Appendix X). The highest titratable acidity (0.99) was found from the treatment T_3 (125 ppm SA) whereas the lowest titratable acidity (0.83) was found from control treatment T_0 (no Ca or SA application).

Combined effect of salinity and mitigating agents; Ca and SA

Titratable acidity influenced significantly by combined effect of salinity and mitigation agents (calcium and salicylic acid) (Table 10 and Appendix X). The highest titratable acidity (1.30) was found from the treatment combination of S_0T_3 which was statistically similar to the treatment combination of S_0T_1. The lowest titratable acidity (0.57) was found from the treatment combination of S_3T_0 which was statistically similar to the treatment combination of S_3T_1, S_3T_2 and S_3T_4. The treatment combination S_1T_3 (1.10) showed highest mitigation among all salinity levels and it reduced 2.65 % titratable acidity compared to treatment control S_0T_0 (1.13).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

4.4.5 Lycopene content (mg/kg fresh wt.)

Effect of salinity

Significant difference was recorded on lycopene content affected by different salinity levels (Table 9 and Appendix X). The highest lycopene content (0.36 and 0.29 mg kg^{-1} at 472 and 503 nm, respectively) was recorded from control treatment S_0 (no salinity) whereas the lowest lycopene content (0.13 and 0.12 mg kg^{-1} at 472 and 503 nm, respectively) was recorded from the treatment S_3 (12 dSm^{-1}).

Effect of mitigating agents; calcium (Ca) and salicylic acid (SA)

Significant variation was recorded for lycopene content influenced by different mitigation agentss (calcium and salicylic acid) (Table 9 and Appendix X). The highest lycopene content (0.25 and 0.21 mg kg^{-1} at 472 and 503 nm, respectively) was found from the treatment T_3 whereas the lowest lycopene content (0.21 and 0.16 mg kg^{-1} at 472 and 503 nm, respectively) was found from treatment T_0 (control).

Combined effect of salinity and mitigating agents; Ca and SA

Combined effect of salinity and mitigation agents (calcium and salicylic acid) showed significant variation for lycopene content (Table 10 and Appendix X). The highest lycopene content (0.401 and 0.317 mg kg^{-1}at 472 and 503 nm, respectively) was found from the treatment combination of S_0T_3 which was statistically similar to the treatment combination of S_0T_1 whereas the lowest lycopene content (0.118 and 0.107 mg kg^{-1} at 472 and 503 nm, respectively) was found from the treatment combination of S_3T_0. The treatment combination S_1T_3 (0.244 and 0.221 mg kg^{-1} at 472 and 503 nm, respectively) showed highest mitigation among all salinity levels and it reduced 21.79% and 6.35 % lycopene content compared to treatment control S_0T_0 (0.312 mg kg^{-1} and 0.236 mg kg^{-1} at 472 and 503 nm, respectively).

So, It was found that treatment T_3 (125 ppm SA), followed by treatment T_1 (5 mM Ca^{2+}) gave the highest mitigation in all levels of salinity compared to other mitigating agents.

Table 9. Quality parameters of tomato influenced by salinity and mitigating agents

Treatments	Quality parameters					
	Total Soluble Solid (TSS)	p^H	Vitamin-C Content	Titrable Acidity (TA)	Lycopene content (mg/kg fresh wt.)	
					472 nm	503 nm
Effect of salinity						
S_0	6.60 b	4.05	0.61 a	1.21 a	0.36 a	0.29 a
S_1	6.86 b	3.94	0.51 b	1.01 b	0.24 b	0.20 b
S_2	6.80 b	3.87	0.46 b	0.80 c	0.19 c	0.15 c
S_3	7.27 a	3.83	0.36 c	0.61 d	0.13 d	0.12 c
$LSD_{0.05}$	0.365	NS	0.071	0.036	0.152	0.104
CV(%)	6.86	7.66	10.24	5.70	7.36	6.88
Effect of different levels of mitigating agents; Ca and SA						
T_0	6.33 d	3.89	0.44	0.83	0.21	0.16
T_1	6.73 c	3.93	0.49	0.92	0.24	0.19
T_2	6.75 c	3.90	0.46	0.87	0.22	0.18
T_3	7.50 a	3.97	0.53	0.99	0.25	0.21
T_4	7.00 b	3.92	0.48	0.92	0.23	0.19
$LSD_{0.05}$	0.136	NS	NS	NS	NS	NS
CV(%)	6.86	7.66	10.24	5.70	7.36	6.88

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm SA

Table 10. Quality parameters of tomato influenced by combined effect of salinity and mitigating agents; Ca and SA

Treatments	Quality parameters					
	Total Soluble Solid (TSS)	p^H	Vitamin-C Content	Titrable Acidity (TA)	Lycopene content (mg/kg fresh wt.)	
					472 nm	503 nm
S_0T_0	6.00 f	3.98	0.54 bc	1.13 bc	0.312 d	0.236 c
S_0T_1	6.33 e	4.11	0.67 a	1.23 ab	0.385 ab	0.304 a
S_0T_2	6.67 d	4.00	0.55 bc	1.17 abc	0.348 c	0.271 b
S_0T_3	7.33 b	4.14	0.70 a	1.30 a	0.401 a	0.317 a
S_0T_4	6.67 d	4.03	0.57 b	1.20 ab	0.362 bc	0.298 ab
S_1T_0	6.33 e	3.92	0.50 cd	0.90 ef	0.227 efg	0.190 ef
S_1T_1	7.33 b	3.95	0.50 cd	1.03 cde	0.241 ef	0.204 de
S_1T_2	6.33 e	3.93	0.50 cd	0.97 def	0.227 efg	0.197 def
S_1T_3	7.33 b	3.97	0.53 bc	1.10 bcd	0.244 e	0.221 cd
S_1T_4	7.00 c	3.94	0.50 cd	1.03 cde	0.236 ef	0.203 de
S_2T_0	6.33 e	3.85	0.40 e	0.70 hij	0.164 jk	0.124 ij
S_2T_1	6.67 d	3.88	0.47 d	0.87 fg	0.201 ghi	0.157 gh
S_2T_2	6.67 d	3.85	0.47 d	0.73 ghi	0.179 ij	0.136 hi
S_2T_3	7.33 b	3.91	0.47 d	0.87 fg	0.214 fgh	0.172 fg
S_2T_4	7.00 c	3.88	0.47 d	0.83 fgh	0.191 hij	0.140 hi
S_3T_0	6.67 d	3.80	0.30 g	0.57 j	0.118 l	0.107 j
S_3T_1	7.00 c	3.84	0.38 ef	0.63 ij	0.144 kl	0.121 ij
S_3T_2	7.33 b	3.82	0.33 fg	0.60 ij	0.124 l	0.113 ij
S_3T_3	8.00 a	3.85	0.40 e	0.67 ij	0.146 kl	0.124 ij
S_3T_4	7.33 b	3.83	0.37 ef	0.60 ij	0.135 l	0.118 ij
$LSD_{0.05}$	0.245	NS	0.052	0.157	0.029	0.027
CV(%)	6.86	7.66	10.24	5.70	7.36	6.88

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

S_0 = 0 ds/m, S_1 = 4 ds/m, S_2 = 8 ds/m, S_3 = 12 ds/m

T_0 = Control (no Ca and SA), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm SA, T_4 = 250 ppm S

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted to observe the effect of calcium (Ca) and salicylic acid (SA) as mitigation agent against salt stress in tomato. This study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2018 to March 2019. The experiment consisted of two factors: Factor A (salinity level): S_0 = No salinity (0 dSm-1), S_1 = 4 dSm^{-1}, S_2 = 8 dSm^{-1} and S_3 = 12 dSm^{-1} and Factor B (mitigation agent): T_0 = Control (No Ca or SA application), T_1 = 5 mM Ca^{+2}, T_2 = 10 mM Ca^{+2}, T_3 = 125 ppm salicylic acid (SA) and T_4 = 250 ppm salicylic acid (SA). The experiment was laid out in Randomized Complete Block Design with three replications. Various morphological, physiological and yield contributing characters varies due to increasing salinity and also application of calcium and salicylic acid had significant mitigating effect against salt stress.

Significant variations were recorded due to different levels of salinity in different growth and yield contributing parameters. Regarding growth parameters,

At 30, 50 and 75 DAT, control treatment S_0 (no salinity) gave the highest plant height (35.72, 57.34 and 84.92 cm, respectively), highest number of leaves $plant^{-1}$ (17.64, 37.37 and 63.60, respectively) and highest number of branches $plant^{-1}$ (5.51, 9.11 and 11.74, respectively) whereas the lowest plant height (28.70, 45.82 and 69.13 cm, respectively), lowest number of leaves $plant^{-1}$ (13.28, 29.07 and 52.90, respectively) and lowest number of branches $plant^{-1}$ (3.59, 6.08 and 8.60, respectively) were recorded from S_3 (12 dSm^{-1}) treatment. Again, the highest SPAD value at flowering and fruiting stage (58.10 and 56.69, respectively) was recorded from control treatment S_0 but the lowest SPAD value at flowering stage and fruiting stage (49.67 and 39.30, respectively) was recorded from the salinity levels of S_3 (12 dSm^{-1}).

Considering yield contributing parameters and yield of tomato affected by salinity, the highest number of flowers $plant^{-1}$ (46.82) , highest number fruits $plant^{-1}$ (37.07), highest fruit length (8.12 cm), highest fruit diameter (10.19 cm), highest fruit dry matter (8.57

%), highest individual fruit weight (50.71 g) and highest fruit weight plant^{-1} (1.84 kg) were recorded from control treatment S_0. The lowest number of flowers plant^{-1} (26.98), lowest number of fruits plant^{-1} (19.00), lowest fruit length (7.53 cm), lowest fruit diameter (8.55 cm), lowest fruit dry matter (7.14%), lowest individual fruit weight (36.08 g) and lowest fruit weight plant^{-1} (0.70 kg) were recorded from S_3 (12 dSm^{-1}) treatment.

The highest TSS content (7.27) was recorded from S_3 (12 dSm^{-1}) whereas the highest p^H (4.05), highest vitamin C content (0.61) and highest titratable acidity (1.21) were recorded from control treatment S_0. Control treatment S_0 also showed lowest TSS content (6.60) whereas the lowest p^H (3.83) and lowest titratable acidity (0.61) were recorded from S_3 (12 dSm^{-1}) but the lowest vitamin C content (0.36) was recorded from S_3 (12 dSm^{-1}). The highest lycopene content (0.36 and 0.29 at 472 nm and 503 nm) was found from S_0 (control) and the lowest was (0.13 and 0.12 at 472 nm and 503 nm) found from S_3 (12 dSm^{-1}) .

Different levels of Ca and SA showed significant variation on different studied parameters. At 30, 50 and 75 DAT, the treatment T_3 (125 ppm SA) gave the highest plant height (33.55, 52.99 and 79.72 cm, respectively). The highest number of branches plant^{-1} (4.80, 8.17 and 10.55, respectively), the highest number of leaves plant^{-1} (15.83, 34.25 and 59.85, respectively) was also found from T_3 (125 ppm SA) treatment which also showed highest SPAD value at flowering and fruiting stage (55.42 and 50.46, respectively). Again, at 30, 50 and 75 DAT, the lowest plant height (28.71, 46.50 and 70.00 cm, respectively), lowest number of leaves plant^{-1} (13.59, 29.31 and 53.44, respectively) and lowest number of branches plant^{-1} (3.78, 6.44 and 8.92, respectively) were found from control treatment T_0 (No Ca or SA application) and this treatment also showed lowest SPAD value at flowering and fruiting stage (50.43 and 40.73, respectively).

Similarly, the treatment T_3 (125 ppm SA) gave the highest number of flowers plant^{-1} (39.47), highest number of fruits plant^{-1} (31.42),highest length of fruit (7.89) , highest fruit diameter (9.79 cm), highest fruit dry matter (8.26 %), highest individual fruit weight (44.90 g) and highest fruit weight plant^{-1} (1.44 kg) while the control treatment T_0 showed lowest number of flowers plant^{-1} (29.45) , fruits plant^{-1} (20.75), lowest fruit length (7.30

cm), lowest fruit diameter (8.60 cm), lowest fruit dry matter (7.39%), lowest individual fruit weight (33.38 g) and lowest fruit weight plant^{-1} (0.79 kg).

The highest p^{H} (3.97) content, the highest TSS (7.50), the highest vitamin C content (0.53) and the highest titratable acidity (0.99) were found from T_3 (125 ppm SA) treatment. The lowest TSS (6.33) and lowest titratable acidity (0.83), the lowest p^{H} (3.89) and the lowest vitamin C content (0.44) was found from T_0 (control) . The highest lycopene content (0.25 and 0.21 at 472 nm and 503 nm) was found from T_3 (125 ppm SA) and the lowest was (0.21 and 0.16at 472 nm and 503 nm) from T_0 (control).

At 30, 50 and 75 DAT, The highest plant height (36.52, 58.64 and 87.64 cm, respectively) and highest number of branches plant^{-1} (5.92, 9.75 and 12.24, respectively), the highest number of leaves plant^{-1} (18.60, 38.44 and 64.45, respectively) were recorded from the treatment combination of S_0T_3 and this treatment combination also showed highest SPAD value at flowering and fruiting stage (60.97 and 63.27, respectively). At 30, 50 and 75 DAT, the lowest plant height (25.43, 41.96 and 63.24 cm respectively), lowest number of leaves plant^{-1} (12.48, 25.63 and 48.22, respectively) and lowest number of branches plant^{-1} (3.15, 5.24 and 7.65, respectively) were found from the treatment combination of S_3T_0 and this treatment combination also showed lowest SPAD value at flowering and fruiting stage (46.80 and 30.43, respectively).

Again, the highest number of flowers plant^{-1} (48.44) , fruits plant^{-1} (39.67), highest fruit length (8.25 cm), highest fruit diameter (10.48 cm), highest fruit dry matter (9.00%), highest individual fruit weight (53.42 g) and highest fruit weight plant^{-1} (2.12 kg) were found from the treatment combination of S_0T_3. The treatment combination of S_0T_1 also showed higher individual fruit weight (52.73 g) and highest fruit weight plant^{-1} (2.02 kg) which were statistically same with S_0T_3. The lowest number of flowers plant^{-1} (21.60) , fruits plant^{-1} (13.00), fruit length (6.81 cm), lowest fruit diameter (7.87 cm), lowest fruit dry matter (6.67%), lowest individual fruit weight (29.02 g) and lowest fruit weight plant^{-1} (0.37 kg) were found from the treatment combination of S_3T_0

The highest TSS (8.00) was found from the treatment combination of S_3T_3 while the highest p^H (4.14), the highest vitamin C content (0.70) and the highest titratable acidity (1.30) were found from the treatment combination of S_0T_3 respectively. Whereas the lowest TSS (6.00) was found from the treatment combination of S_0T_0 while the lowest p^H (3.80), the lowest vitamin C content (0.38) and the lowest titratable acidity (0.57) were found from the treatment combination S_3T_0. The highest lycopene content (0.401 and 0.317 at 472 nm and 503 nm) was found from the treatment combination of S_0T_3 and the lowest was (0.118 and 0.107 at 472 nm and 503 nm) from the treatment combination of S_3T_0 .

In case of mitigation of salt stress, treatment combination S_1T_3 showed maximum result in plant height (33.75, 53.87 and 81.52 cm, respectively) , number of branches plant^{-1} (4.90, 8.44 and 11.12, respectively), number of leaves plant^{-1} (15.88, 34.67 and 61.80, respectively), SPAD value at flowering and fruiting stage (55.37 and 52.70, respectively) among all salinity levels compared to control condition S_0T_0.

Again, maximum mitigation in number of flowers plant^{-1} (41.88) , number of fruits plant^{-1} (33.33), fruit length (7.84 cm), fruit diameter (9.69 cm), fruit dry matter (8.33%), individual fruit weight (43.91 g) and fruit weight plant^{-1} (1.46 kg) were found from the treatment combination S_1T_3 compared to control condition S_0T_0. In case of quality parameters, maximum mitigation in p^H (3.97), vitamin C content (0.53), titratable acidity (1.10) and lycopene content (0.244 and 0.221 at 472 nm and 503 nm) were also found from the treatment combination S_1T_3 respectively, compared to control condition S_0T_0.

Treatment combination S_1T_3 was closely followed by treatment combination S_1T_1 in all parameters.

Considering the above mentioned results, it may be concluded that morphological parameters, yield contributing characters and yield of tomato plant gradually decreased with the increase of salinity levels and this reduction rate was decreased by exogenous application of calcium and salicylic acid. Among the entire mitigating agent used against salt stress, T_3 (125 ppm SA) showed best performance and next to T_1 (5 mM Ca^{+2}) and

both gave better performance on growth, physiology and yield parameters as compared to control. Hence, to increase the yield of tomato in saline area, 125 ppm salicylic acid next to 5 mM Ca^{+2} application is suitable to control salt stress.

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v

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

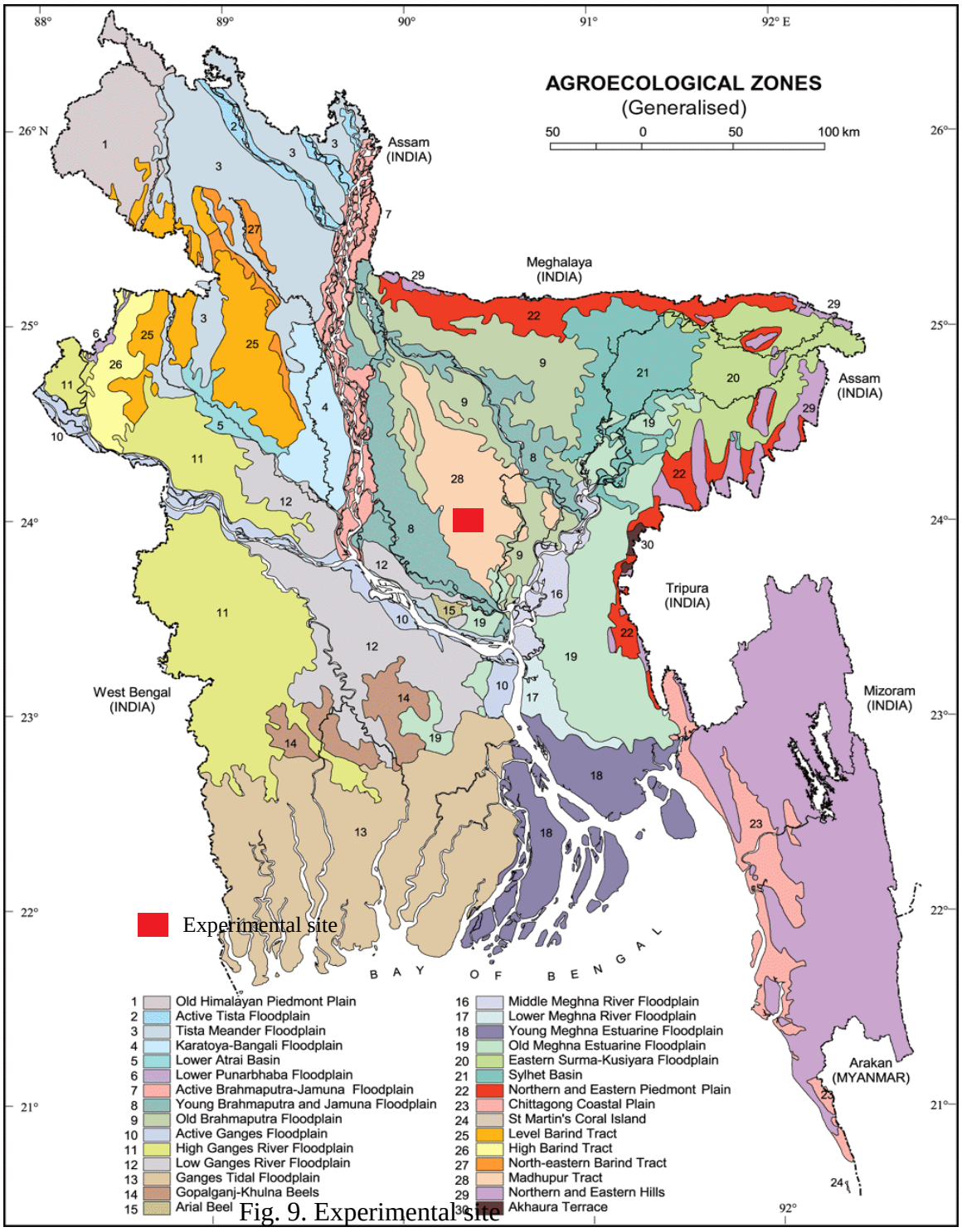


Fig. 9. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2018 to March 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	October	30.42	16.24	23.33	68.48	52.60
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0
2019	March	35.20	21.00	28.10	52.44	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Plant height of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of plant height (cm)		
		30 DAT	50 DAT	75 DAT
Replication	2	0.384	15.504	1.685
Factor A	3	140.13*	380.25*	740.657*
Factor B	4	34.342*	62.270**	123.676*
AB	12	7.579**	10.938**	25.297*
Error	38	0.936	5.883	2.102

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Number of leaves plant^{-1} of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of number of leaves plant^{-1}		
		30 DAT	50 DAT	75 DAT
Replication	2	0.322	0.360	0.983
Factor A	3	NS	200.59*	365.18*
Factor B	4	NS	42.854*	49.920*
AB	12	4.964**	18.442*	23.246*
Error	38	0.182	0.382	0.863

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Number of branches plant^{-1} of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1}		
		40 DAT	60 DAT	75 DAT
Replication	2	0.984	0.300	0.441
Factor A	3	10.31**	27.29*	28.358*
Factor B	4	NS	1.828**	2.044*
AB	12	0.901**	2.049*	1.949**
Error	38	0.594	0.329	0.365

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. SPAD value at different cropping stages of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of SPAD value at different cropping stage	
		Flowering stage	Fruiting stage
Replication	2	19.162	24.589
Factor A	3	202.67*	826.60*
Factor B	4	11.166**	79.458*

AB	12	16.069*	63.502*
Error	38	45.28	138.22

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Yield contributing parameters and yield of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters				
		Number of flowers plant^{-1}	Number of fruits plant^{-1}	Length of Fruit (cm)	Diameter of Fruits (cm)	Percent fruit dry matter (%)
Replication	2	5.112	4.550	0.991	0.085	0.479
Factor A	3	834.28*	960.99*	1.978*	7.762**	6.058*
Factor B	4	211.72*	115.10*	NS	NS	0.765**
AB	12	64.78*	72.411*	0.166**	0.703**	0.411**
Error	38	2.537	1.954	0.226	0.219	0.733

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Yield contributing parameters and yield of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of yield parameters	
		Individual fruit weight (g)	Fruit weight plant^{-1} (kg)
Replication	2	23.797	0.018
Factor A	3	470.89*	3.544*
Factor B	4	57.073*	0.297**
AB	12	51.436*	0.297**
Error	38	44.846	0.028

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Quality parameters of tomato influenced by salinity and mitigation components

Sources of variation	Degrees of freedom	Mean square of quality parameters					
		Total Soluble Solid (TSS)	p^H	Vitamin-C Content	Titrable Acidity (TA)	Lycopene content (mg/kg fresh wt.)	
						472 nm	503 nm
Replication	2	0.117	0.002	0.001	0.003	0.021	0.007
Factor A	3	1.244*	NS	NS	NS	1.052**	1.036**
Factor B	4	NS	NS	NS	0.175**	NS	NS
AB	12	0.953	NS	0.027**	0.195**	0.104**	0.092**
Error	38	0.222	0.001	0.004	0.003	0.003	0.002

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

CHAPTER VIII : SOME PLATES RELATED TO THE THESIS WORK

A B C

Plate-1 : Different stages of seedlings ; (A) Germination of seedlings (B) young seedlings (C) 30 days old seedlings.

A B C

Plate-2 : (A) Pot preparation ,(B) Transplanting of seedlings , (C) Stalking of seedlings

A B C

Plate-3 : (A)Mitigating agents – Ca and SA ,(B) Preparation for Treatment application , (C) Foliar spray of mitigating agents.

A B

Plate-4: (A) Data collection , (B) Experimental plot

Plate-5 : Flowering and Fruiting stages of tomato plant

Plate-6: SPAD meter reading at flowering and fruiting stage

Plate-7: Harvest of fruits and Data collection

A B C

D E

Plate-8: (A) &(B) Fruits were sliced into pieces and sundried ,(C) Sundried fruits were put into envelop and placed in oven maintaining 70°C for 72 hours, (D) Final dry weight recorded, (E) Fresh weight of 100 gm fruit recorded for estimation of Dry matter percentage of fruit (%).

Plate-9: Procedures of measuring pH of fruits by Electric pH meter

Plate-10: Procedures of measuring TA of fruits

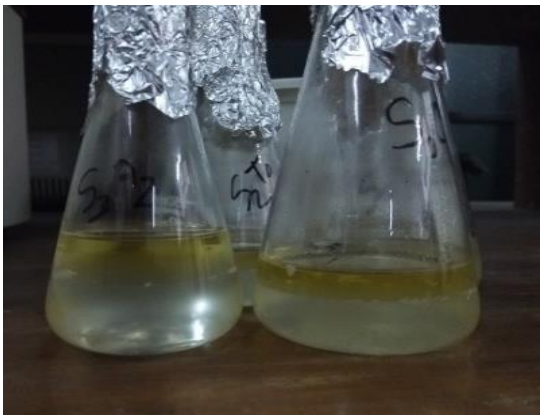
A B

Plates-11 : (A) Extraction of juice for measuring TSS of Fruits , (B) Refractometer for measuring TSS of fruits.

A B C D

Plate-12: Procedures of measuring Vit-C content of fruits ;(A) Dye solution, (B) Preparation of Metaphosphoric Acid solution, (C) Extraction of fresh tomato juice, (D) Preparation of titration.

A



B

C

Plate-13: Procedures of measuring Lycopene content of fruits ; (A) Shaking of flasks for 30 min in magnetic stirrer plate for separation of lycopene containing layer , (B) Distinct layer containing Lycopene content , (C) Spectrophotometer for measuring Lycopene content.