EFFECT OF FOLIAR APPLICATION OF SALICYLIC ACID TO ALLEVIATE SALT STRESS IN TOMATO

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CERTIFICATE

*This is to certify that the thesis entitled, "**EFFECT OF FOLIAR APPLICATION OF SALICYLIC ACID TO ALLEVIATE SALT STRESS IN TOMATO**" submitted to the Dept. of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the results of a piece of bona-fide research work carried out by **TAMANNA NASRIN**, Registration No. 11-04450 under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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: June, 2017
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Dedicated to my beloved parents

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ABSTRACT

A pot experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to March 2017. The two factorial experiment was laid out in Complete Randomized Design with four replications,factor A: different levels of salinity viz. S_0: control (without salt), S_1: 4 dS/m, S_2: 8 dS/m, S_3: 12 dS/m and S_4: 16 dS/m and factor B: three concentration of salicylic acid as mitigating agent of salt stress viz. A_0: 0 mM SA, A_1: 0.50mM SA and A_2: 1 mM SA. The experimental results showed that different levels of salinity significantly affects the morphological charactersand yield of tomato.Exogenous application of salicylic acid significantly increased the morphological characters, yield contributing characters and yield of tomato in both saline and non-saline conditions.In case of salinity the highest yield (3.03 kg) was found in S_0 and the lowest (0.59 kg) from S_4 treatment and in case of salicylic acid, the highest yield(2.27kg) was found in A_1 and the lowest(1.86) from A_0. For treatment combination the tallest plant (82.50 cm), highest number of fruit/plant (42.50), maximum weight of individual fruit (77.79 g) and yield/plant (3.30 kg) were produced from S_0A_1 (control + 0.50 mM SA) whereas the lowest value from S_4A_0 (16 dS/m+ no SA). The exhibits result suggests that exogenous application of salicylic acid can effectively alleviate the deleterious effect of salt stress in tomato.

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List of abbreviations

Abbreviations	Full word
@	At the rate
AEZ	Agro Ecological Zone
Agric.	Agriculture
BARI	Bangladesh Agricultural Research Institute
CV	Coefficient of variance
DAT	Days After Transplanting
dS/m	Decisiemens per meter
df	Degrees of Freedom
et al.	And others
etc	Etcetera
gm/kg	Gram per kilogram
J.	Journal
LSD	Least Significant Difference
mM	Milli mole
ppm	Parts per million
Res.	Research
SA	Salicylic Acid
SRDI	Soil Resources Development Institute
TSS	Total Soluble Solid
Var.	Variety

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum*), a popular solanaceous vegetable crop, widely grown many parts of the world due to its excellent adaptability to wider range of soil and climatic conditions. It contains many 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). Worldwide, it is the second most important vegetable crop next to potato (Kumar *et al*., 2015).

Tomato is one of the economically important vegetable crops in Bangladesh. But recent statistics shows that tomato was grown in 76000 acres of land and the total production was approximately 414 thousand tons in 2014-2015 and in 2015-2016 it decreases to 368 thousand tons in an area of 67000 acres (BBS, 2016). The productivity of this vegetable is not increasing in parallel with the food demand due to changing environmental factors both biotic and abiotic. A vast number of insect pests including various fungal, bacterial and virus diseases are serious problem which are biotic stress for crop production. Various abiotic environmental stresses such as drought, salinity, high or low temperature, flooding, metal toxicity etc which poses serious threat to world agriculture. It has been reported that abiotic stresses reduced crop production more than 50% among which salinity is one of the most important environmental factor that hamper agricultural productivity including tomato (Tanji, 2002).

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 disturbs the physiology of plants by changing the metabolism of plants, it also injures cells due to ion toxicity that reduce growth of plants, leaf area, accumulation of dry matter content and also reduces net rate of CO_2 assimilation (Munns and *Tester*, 2008). Salt induced osmotic stress is responsible for the oxidative stress caused by Reactive oxygen species. The toxic effect of Reactive oxygen species can counteracted by enzymatic as well as non enzymatic antioxidative system such as: Superoxide dismutase, Catalase, Ascorbate peroxidase, Glutathione reductase, Ascorbic acid, phenolic compounds etc. (Shi and Zhu, 2008; Sharma and Dietz, 2009; Ashraf, 2009 and Ahmed *et al.*, 2008).

Salicylic acid (SA) is a plant phenolic compound, used as a plant growth regulator (Agamy *et al*., 2013) that promotes various physiological processes, such as germination, growth, photosynthesis, transport and uptake of solutes. SA alleviates abiotic stress-induced damage by eliciting oxidative stress, which enhances the expression and activity of redox-controlled antioxidant enzymes (Ananieva *et al*., 2004; Li *et al*., 2013 and Csiszar *et al*., 2014). Lower concentrations of salicylic acid (SA) improve the tolerance to abiotic stresses from several plant species, through the strengthening of antioxidant capacity (Horvath *et al*., 2007). Seed priming of wheat with SA can significantly improved seedling establishment, and chlorophyll a and b contents of wheat under saline conditions (Kaydan *et al.*, 2007). Application of SA also significantly increased dry weight of roots and top part of barley (Tayeb, 2005), soybeans (Gutierrez *et al.*, 1998) and maize (Khodary, 2004) under saline conditions. The positive effects of SA on tomato plants have also been reported under salinity stress (Stevens *et al.*, 2006 and He and Zhu, 2008). Salt tolerance of two faba bean genotypes was also reported to increase by SA application (Azooz, 2009). Low concentration of SA significantly improved mungbean growth under salinity stress due to decreased concentrations of Na , Cl and H_2O_2 in plants, decreased electrolyte leakage, increased N, P, K and Ca contents and increased antioxidant enzyme activity (Khan *et al.*, 2010). As Bangladesh belongs to one of the seaside countries, the adverse impact of salinity is significant here. Coastal area in Bangladesh constitutes about 20% of the country of which about 53% are affected by different degrees of salinity and out of coastal cultivable saline area, about 328 (31%), 274 (26%) and 190 (18%) thousand hectares of land are affected by very slight (2.0-4.0 dS/m), slight (4.1- 8.0 dS/m) and moderately salinity (8.1-12.0 dS/m) respectively, are scope to successfully crop production (SRDI, 2010).

In this situation appropriate measures need to take to increase the production of economically important tomato in coastal areas and to bring this huge land area under cultivation. Common agronomical practices like irrigation, drainage as well as mulching for reducing soil salinity may be impractical for developing country, due to higher costs and difficulty in use and developing salt tolerant variety is not only promising but also time demanding and still there is no salt tolerant tomato variety in our country. So the role of Salicylic acid to minimize the effect of saline toxicity for improving the yield and quality of tomato fruits is essential to investigate.

Objectives:

Considering the fact described above, the present work was undertaken for the following objectives-

- ✓ To investigate the growth, physiology and yield attributes of tomato under saline condition;
- ✓ To find out the role of salicylic acid to reduce the saline toxicity on tomato; and
- ✓ To find out the best levels of salicylic acid on alleviation of salt stress and higher yield in tomato.

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. Tomato is an important vegetable crop in Bangladesh and it is a great source of vitamins and antioxidants. The scientists of Bangladesh are conducting different experiments to adopt different crops in the saline areas, tomato is one of them. Very limited research works have been conducted to adapt tomato in the saline area of Bangladesh. 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 salicylic acid 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 Literature on the effect of salinity:

Salinity is one of the most important environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity. A considerable amount of land in the world is affected by salinity which is increasing day by day. In most of the cases, the negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by interrupting different plant mechanisms. This may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leading to plant death (Hasanuzzaman *et al*., 2012).

Tomato is a crop with the greatest economic importance in the world and salinity stress causes are reduction in the quantity and quality of crop production. Today the main challenge in world agriculture is to sustain the continuously growing global population, and this becomes more difficult due to climatic change, as this imposes further abiotic stress. On considering this a study was carried out by Ahmed *et al*. (2016) to find out the salinity effect on tomato production. The study was initiated at the Irrigation and Water Management (IWM) research field of Bangladesh Agricultural University (BAU), Bangladesh. The experiment was carried out in a randomized complete block design (RCBD) with 3 replications where the treatments were control, 4 dS/m, 6 dS/m, 8 dS/m and10 dS /m of Electrical conductivity. The researcher found that the control treated plant gives the highest fruit yield/ plant (1.52 kg) whereas the lowest yield (0.67 kg) was obtained from the higher level of saline water treatment T_5 (10 dS/m).

A field study was conducted by Siddiky *et al*. (2012) to screen out a number of tomato (*Lycopersicon esculentum* L.) varieties for salinity tolerance. Three levels of salinity were 2.0-4.0 dS/m, 4.1-8.0 dS/m and 8.1-12.0 dS/m. Significant varietal and salinity treatment effects were registered on plant height, leaf area, plant growth, yield, dry matter/plant, Na ion and Cl^- 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 dS/m), 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 Tomato 14’, ‘BARI Hybrid Tomato 5’ and ‘BARI Tomato 2’. Thus, ‘BARI Tomato 14’, ‘BARI Hybrid Tomato 5’ and ‘BARI Tomato 2’ were regarded as a breeding material for development of new tomato varieties for tolerance to salinity in saline areas of Bangladesh.

Islam *et al*. (2011) conducted a pot experiment to study the salt tolerance of eight tomato genotypes *viz*., ‘J 5’, ‘Binatomato-5’, ‘BARI tomato 7’, ‘CLN 2026’, ‘CLN 2366’, ‘CLN 2413’, ‘CLN 2418’ and ‘CLN 2443’ at Bangladesh

Institute of Nuclear Agriculture. Three levels of salinity *viz*., control, 6 and 10 dS/m were imposed at pre-flowering stage of tomato genotypes. Plant height, primary branches, flower cluster, fruit cluster, number of fruits and total fruit yield/plant, individual fruit weight, amino acid content in leaves gradually decreased while total sugar and reducing sugar content in leaves increased with the increase in salinity levels. It was therefore concluded that 'BARI tomato 7', 'CLN 2026', 'CLN 2413', 'CLN 2418', 'CLN 2366' and 'CLN 2443' had shown better performance with salinity and identified to be better tolerant.

A pot experiment was conducted by Islam *et al*. (2012) at Bangladesh Institute of Nuclear Agriculture, Mymensingh to assess the effects of salinity on some morpho-physiological attributes and yield of lentil genotypes, namely 'N_1M 134', 'N_1M1 49', 'N_1M 214', 'N_5M 507', 'N_5M 573', 'N_4M 606', 'E_4M 934', 'Binamasur 3', 'Barimasur 4' and 'L 5'. There were three salinity levels *viz*. control (only water), 4 dS/m and 6 dS/m. Salinity was developed by adding salt solution of $NaCl_2$, Na_2SO_4, $NaHCO_3$, $CaCl_2$, $MgCl_2$, $MgSO_4$ at 45 days after sowing. The results showed that plant height, number of branches, number of leaves/plant, leaf area, total dry matter, total chlorophyll content, nitrate reductase activity in leaves, number of pods, number of seeds/plant, 1000-seed weight, seed yield/plant and harvest index were gradually decreased with the increase in salinity level compared to control. However, total sugar and reducing sugar content in leaves increased with increasing salinity level. The genotype 'N_5M 507' produced the highest root dry weight, total dry matter, number of seeds and seed yield plant^{-1} under salinity. 'N_1M 214' also produced statistically similar yield to that of 'N_1M 507'. They concluded that these two genotypes indicated tolerance to salinity compared to other genotypes.

An experiment was accomplished by Shimul *et al*. (2014) at Horticulture Research Center (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, to find out the growth and yield of tomato in different salinity level. The treatments were T_0: Control; T_1: 4 dS/m; T_2: 8 dS/m; T_3: 12 dS/m and T_4:

16 dS/m, 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, fruit weight, leaf area/plant, total chlorophyll content and plant dry matter compared to the other salinity level. Stomatal resistance was best in 16 dS/m (T_4) treatments. On the other hand, the salinity level 16 dS/m exhibited highest Na ion and Cl ion uptake which reduced the uptake of K ion. At control (0 dS/m) salinity when Na and Cl ions were low in water, than the K^+ uptake increased. Salinity had a greater impact on stomatal resistance and chlorophyll content of plants.

A greenhouse experiment was conducted by Bhatt *et al*. (2008) at Saurashtra University, India to assess the effects of soil salinity on emergence, growth, water content, proline content and mineral accumulation of seedlings of *Ziziphus mauritiana* Lam. Sodium chloride (NaCl) was added to the soil to maintain electrical conductivity at 0.3, 3.9, 6.0, 7.9, 10.0 and 11.9 dS/m. Salinity caused reduction in seedling emergence, water content and water potential of seedling organs (leaves, stems, tap roots and lateral roots). Consequently, shoot and root elongation, leaf expansion and dry matter accumulation in seedling organs significantly decreased while proline content increased with increasing soil salinity. A significant increase of K content in all organs of the seedlings with increasing soil salinity evinced high selectivity of this tree species for K^+. There were no effective mechanisms to control net uptake of Na on root plasma membrane and subsequently its transport to shoot tissue. Nitrogen, phosphorus, calcium and magnesium content in seedling organs significantly decreased as soil salinity increased.

Siddiky *et al*. (2014) accomplished a solution culture experiment to screen out a number of tomato germplasms for salinity tolerance by giving up to 120 mM NaCl (salt stress). Salinity tolerance of tomato germplasms was evaluated with respect to severity of leaf symptoms, shoot and root dry matter production, shoot Na^+, K^+, Ca^{2+} accumulation and their respective ratio. The salinity tolerance scale ranges from 1.00 (most tolerant) to 3.50 (most sensitive). Based on the severity of leaf symptoms caused by the NaCl treatment 'BT14 (BARI Tomato 14)' and 'BHT5 (BARI Hybrid Tomato 5)' were found the most tolerant germplasm to salinity with score 1.0. Reduction of dry weight was found to be 19% (shoot) and 15% (root) in BT14 and BHT5, 30-76% (shoot) and 27-83% (root) in other germplasm when salinity was added. Higher correlation was found between salinity tolerance scale classes and the reduction of shoot/root dry weight, Na^+ concentration, K^+/Na^+, and Ca^{2+}/Na^+ ratios. Thus, they regarded 'BT14' and 'BHT5' as a breeding material for development of new tomato varieties for tolerance to salinity.

Sardoei and Mohammadi (2014) conducted a field research to evaluate the response of tomato genotypes ['Cal-ji', 'Flat Ch irani', 'Chef Flat America', 'Primo Earily' and 'Chef'] against five salinity levels [distilled water as control, 25, 50, 75 and 100 mM] and observed at germination and early seedling stages. Results indicated that interaction of salt × genotype had significant effect on growth indices in all the cases. With increase in salinity level, germination percentage was significantly decreased. Concerning germination percentage, there was no difference between Chef and Cal ji cultivars across all the salt levels, however in the salt level of 25 mM the two cultivars were significantly different from 'primo early' and 'chef flat America'. In the salt level of 25 mM cultivar 'primo early' showed 66.27% germination whereas the germination percentage of chef and calji was 62.13 and 77.68, respectively.

Anastasia and Ilias (2013) reported that application of moderate salt stress on tomato plants can enhance lycopene and potentially other antioxidant concentrations in fruits. The increase in lycopene in response to salt stress in the tomato fruits varied from 20% to 80%. Although the specific biological mechanisms involved in increasing fruit lycopene deposition has not been clearly elucidated, evidence suggests that increasing antioxidant concentrations is a primary physiological response of the plant to salt stress.

The effects of irrigation water salinity on eggplant growth, yield, water consumption and mineral matter accumulation in leaves and fruits were investigated by Ali *et al*. (2007). For this purpose, the researcher used five saline irrigation waters with electrical conductivities of 1.5, 2.5, 3.5, 5.0, 7.0 dS/m and tap water as a control treatment. Plant water consumption and water use efficiency decreased with increasing salinity. The crop yield coefficient was 2.3. Salinity caused a decrease in K content, and increased Cl content of leaves.

A pot experiment was conducted by Hassan *et al*. (2010) in Rice Research Institute at Rasht, at the North of Iran to show the effect of salinity on rice plants. Four levels of water salinity: 2, 4, 6, and 8 dS/m were applied at 4 different growth stages: tillering, panicle forming, heading and ripening stages. Results showed a considerable sensitivity of the chosen rice variety to salinity. Salinity had significant effects on yield, number of filled panicle ($p<0.01$), biomass and harvest index ($p<0.05$). The highest yield was obtained from fresh water (no salinity) with 21.5 g/pot while salinity treatments of 2, 4, 6 and 8 dS/m yielded at 18.71, 17.79, 14.87 and 12.59 g/pot, respectively representing 21, 25, 37 and 47% yield losses.

The effect of salt stress on some physiological traits of wheat (*Triticum aestivum* L.) was studied by Ghogdi *et al*. (2012) under greenhouse condition. Salinity treatments carried out in four levels (1.3 dS/m as control, 5, 10, 15 dS/m). Wheat genotypes included four cultivars, 'Sistani' and 'Neishabour' as tolerant cultivars, and 'Tajan' and 'Bahar' as sensitive cultivars. Salinity stress decreased relative water content (RWC), K^+ content, K^+/Na^+ ratio and grain yield however Na^+ content in all the genotypes and in both stages were increased. 'Sistani' and 'Neishabour' cultivars had more amounts of K^+

content, K^+/Na^+ ratio and RWC under salt conditions. 'Bahar' showed the highest Na^+ content and the most reduction in yield.

Hakim *et al.* (2014) observed the effect of salinity on the growth, nutrient accumulation and yield of rice genotypes. Five Malaysian genotypes ('MR 33', 'MR 52', 'MR 211', 'MR 232' and 'MR 219'), two salt sensitive ('BRRI dhan 29' and 'IR20') and one salt tolerant genotypes (Pokkali) were evaluated in four levels of salinity. Two factors complete randomized design (CRD) was used with four replications. Dry weight of root, shoot and yield significantly decreased with the increase of salinity levels, while 'MR232' and 'MR211' were less affected. Na^+ ions accumulations increased in the root and shoot with the increase of salinity, while the lowest accumulation was in 'MR211'.Finally they concluded that, genotypes 'MR211' and 'MR232' were found to be relatively tolerant to salt than the other genotypes.

Botella *et al.* (2000) conducted an experiment to investigate the effect of different salinity levels on fruit fresh weight of tomato. Saline treatments were applied at different times at the beginning of the plant growth period, and at the developmental stages of flowering of the first cluster and growth. They reported that salinity decreased the final fruit weight.

Homma (2016) studied the effect of salinity stress on some growth parameters of diploid potato genotypes and determined the heritability of these traits and their association. Ninety four potato genotypes which were progeny from a cross between parents C and E were evaluated in hydroponics with a salinity level of 120 mM NaCl. Potato genotypes showed reduction in growth parameters due to salinity stress. The result indicated that the highest reduction (75%) was observed on shoot fresh weight followed by leaf area (72%), shoot dry weight (69%), root dry weight (64%), root fresh weight and shoot length (49%). The number of new leaves showed reduction by 53% under salt stress relative to the control. Heritability of growth parameters ranged from 46% to 83% under control and from 69% to 90 % under salt stress condition.

Kaplan *et al.* (1999) carried out an experiment to determine the effects of different levels of irrigation water salinity and fertilizer application and the interaction between two factors on the growth and yield of tomato plants grown under greenhouse conditions. The interaction between water and fertilizer applications had significant effect on the yield. The researchers concluded that the salinity level of the irrigation water was a factor that should be considered in the fertilization programmed and if the EC level of the irrigation water was high low doses of fertilizer should be preferred in practice.

Alam (2013) performed a pot experiment at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh to evaluate the effects of different salinity level on growth and yield of five onion varieties *viz*. ‘BARI Piaz 1’, ‘BARI Piaz 2’, ‘BARI Piaz 3’, ‘BARI Piaz 4’, ‘BARI Piaz 5’ and four levels of salt (NaCl) concentration, *viz.* control (no salt, water only), 50 mM NaCl, 100 mM NaCl and 200 mM NaCl. Result showed that the yield and yield components varied significantly with varieties and different levels of salt concentrations. The maximum percentage of plant survivability (95.00 %), plant height (24.08 cm), number of leaves per plant (4.13), bulb length (3.23 cm), bulb diameter (2.48 cm), individual bulb weight (8.14 g), dry matter content of bulb (21.46 %), yield of bulb per pot (18.47 g) and yield of bulb per hectare (11.08 t/ha) were produced by ‘BARI Piaz 4’. Most of the parameters showed decreasing trend with the highest level of salinity (200 mM NaCl) producing the lowest bulb yield (4.15 t/ha).

Ghosh *et al*. (2001) studied the effect of salt stress on emergence, growth, yield, carbohydrate, mineral contents, and nitrate reductase activity of potato plants *(Solanum tuberosum* L.) using two cultivars (‘May Queen’ and ‘Dejima’). Salt stress was achieved by the application of NaCI (0, 10, 20, and 30 g pot-1 and the corresponding EC values were 0.20, 0.77, 1.37, and 1.95 dS/m, respectively). Emergence was delayed, plant growth and dry matter production, especially in tubers, depressed with the increase in the salt level.

The salt stress decreased the total and marketable tuber yield due to the decrease in the tuber number per plant and average tuber weight.

Islam *et al.* (2011) performed an experiment to study the salt tolerance of eight tomato genotypes *viz*., ‘J 5’, ‘Binatomato 5’, ‘BARI tomato 7’, ‘CLN 2026’, ‘CLN 2366’, ‘CLN 2413’, ‘CLN 2418’ and ‘CLN 2443’ at Bangladesh Institute of Nuclear Agriculture. Three salinity level *viz*., control, 6 and 10 dS/m were used in this experiment. Plant height, primary branches, flower cluster, fruit cluster, number of fruits and total fruit yield/plant, individual fruit weight, amino acid content in leaves gradually decreased while total sugar and reducing sugar content in leaves increased with the increase in salinity levels. ‘BARI tomato 7’, ‘CLN 2026’, ‘CLN 2413’, ‘CLN 2418’, ‘CLN 2366’ and ‘CLN 2443’ had show better performance with salinity and identified to be better tolerant.

Kalhoro *et al*. (2016) stated that that with increasing salinity(4, 6, 8 and 10 dS/m) there was an increase in the EC, Na^+ , Ca^{2+}, Mg^{2+} and Cl^- and decrease in the K^+ , SAR and ESP values of the soil. Increasing salinity, progressively decreased wheat plants height, spike length, number of spikelet’s/spike, 1000 grain weight and yield (straw and grain). Adverse effects of salts on plants were associated with the accumulation of less K^+ and more Na^+ and Cl^- in their flag leaf sap, grains and straw. These results indicated that the effects of salts stress were greater at 10 than at 8, 6 and 4 EC dS/m.

Biabani *et al*. (2013) was conducted a study to assess the effect of salinity on germination of wheat (*Triticum aestivum*) cultivars in the laboratory of Gonbad Kavoos University by using NaCl to simulate salinity and tap water as a control. Treatments included wheat cultivars (Morvarid , 17 Line, Koohdosht and Daria) and four levels of salinity (0, 5, 10 and 15 dS/m). The results of experiment showed that the concentrations of salt and cultivars had significant effect on all measured characteristics.

The impact of salt stress under different salinity level (0, 25, 50, 75, 100, 125, 150 mM NaCl) on five varieties of Wheat viz., ‘HOW 234’, ‘HD 2689’, ‘RAJ 4101’, ‘RAJ 4123’, and ‘HD 2045’ was conducted by Datta *et al*. (2009). The data showed that different level of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 125 mM. Fresh weight and dry weight of root and shoot were reduced significantly with subsequent treatment. Regarding germination maximum germination was found in variety ‘HD 2689’. Regarding biochemical analysis the sugar, proline content increased with increasing salinity level where as protein content decreased in the physiologically active leaves of different treatments for all the varieties of wheat.

Zhani *et al*. (2012) reported that increasing salinity stress, for cultivars of pepper, had a negative impact on roots (length, fresh and dry weights) and leaves (number and area), chlorophyll (a and b) content with decrease of yield

Sharma *et al*. (2012) observed the effect of salt stress on biochemicals of chili. The plants were hydroponically grown in half-strength NaCl solution for 20 days followed by treatments with 0, 50, 100 and 200 mM NaCl for 18 days. Growth parameters of 45 day old plants were recorded. The plants were harvested and analyzed for the amount of chlorophyll, proline, catalase (CAT) and peroxidase (POD). The low (50 mM NaCl) level of salinity treatment had no deleterious effects on vegetative growth parameters, at higher concentration of NaCl (100 and 200 mM), growth parameters were drastically reduced.

An experiment was conducted by Ahmed *et al*. (2010) to investigate the effects of salinity stress (NaCl) on growth of lettuce (*Lactuca sativa* L.) under closed-recycled nutrient film technique. Different salinity levels i.e. 50 mM and 100 mM along with control (0 mM) were used. It was observed that number of leaves, plant fresh weight, shoot fresh weight, shoot dry weight, shoot dry matter percentage, root fresh weight, root dry weight, root dry weight percentage, leaf area and leaf area index were significantly affected by salinity levels, while shoot and root water contents percentage, ratio of the shoot to root fresh weight and ratio of the shoot to root dry weight showed insignificant effect in response to salinity.

The response of eight maize hybrids against five different salinity levels namely 0, 60, 120, 180 and 240 mM) were studied at germination and early seedling stage by Khodarahmpour *et al*. (2011). Supplementary analysis showed that there were significant differences ($P < 0.05$) between hybrids for germination percentage, germination rate, mean germination time and seed vigor in all salinity levels. Results also indicated that maximum reduction in germination percentage (77.40%), germination rate (32.40%), length of radicle (79.50%) and plumule (78.00%), seedling length (78.10%) and seed vigor (95.00%) were obtained in highest level of salinity (240 mM).

An experiment was conducted by Ramoliya and Pandey (2007) to find out the effects of salt stress on emergence, growth and physiological attributes of seedlings of *Ziziphus mauritiana* in Gujarat, India. A mixture of chlorides and sulfates of Na, K, Ca and Mg was added to the soil and salinity was maintained at 4.1, 5.2, 6.0, 7.1, 8.0 and 9.2 dS/m. A negative relationship between seed germination percentage and salinity concentration was obtained. Seedlings did not emerge when soil salinity exceeded 8.0 dS/m. Seedlings survived and grew up to soil salinity of 8.0 dS/m and eventually this species is salt tolerant at seedling stage too. Elongation of stem and root was retarded by increasing salt stress. Reduction in growth of all tissues of seedlings was obtained with increasing soil salinity.

A study was conducted by Aliu *et al*. (2011) to investigate the effect of salinity stress on seed germination and chlorophyll content in maize. In the study, two maize hybrids were included (‘Bc 678’ and ‘Bc 408’) originating from the Bc Institute at Rugvica near Zagreb (Croatia) and two maize populations (‘LMP-1’ and ‘LMP-2’) originating from Kosovo. The experiment was conducted in four replicates of 100 seeds, which were germinated on top of double-layered papers, each with 10 ml of salt solution of NaCl and $CaCl_2$ in

Petri dishes. The effects of the NaCl and $CaCl_2$ concentrations accounted for a high proportion of the variance in all analyses. The results showed that both germination percentage and germination index decreased significantly in all cultivars at the highest salt concentrations. The significant differences between different concentrations of salinity were also found in all cultivars for the content of chlorophyll 'a' and 'b' and for the content of carotenoids.

2.2 Effect of salicylic acid on plant under salinity stress

Salicylic acid (SA) is an endogenous growth regulator of phenolic nature, generally which participates in the regulation of physiological processes in plants such as growth, photosynthesis, nitrat metabolism, ethylene production, heat production and flowering (Hayat *et al*., 2010) and also provides protection against biotic and abiotic stresses such as salinity (Kaya *et al*., 2002).

It functions as an indirect signal stimulating, many physiological, biochemical and molecular processes and therefore it affects the plant growth and development (Klessing and Malamy, 1994). Numerous studies have documented the influence of endo and exogenous SA on the content of photosynthetic pigments in leaves (Yildirim *et al*., 2008), on plant photosynthesis (Fariduddin *et al*., 2003) and on nitrogen metabolism owing to SA producing a positive impact on the activity of nitrate reductase (Miguel *et al*., 2002), on the synthesis of secondary plant metabolites and on antioxidant activity (Eraslan *et al*., 2007) or the improved plant tolerance to heavy metals. In the context of the present study, the following findings seem particularly interesting the beneficial effect of SA on plant adaptation (resistance, increased tolerance) to stress factors including heat (Liu *et al*., 2006; Shi *et al*., 2006; Larkindale and Huang, 2005), low temperature (Kang *et al*., 2003), fungal or bacterial infection (Lee *et al*., 1995) and excessive salinity of soil or nutrient solutions, i.e. osmotic stress (Arfan *et al*., 2007; Sawada *et al*., 2006; Stevens *et al*., 2006 and Tari *et al*., 2002). Studies on tomato cultivation have revealed that exogenous application of SA into a nutrient solution (Tari *et al*., 2002), soil

(Stevens *et al*., 2006) or sprayed over leaves (He and Zhu, 2008) improved the plant's tolerance to osmotic stress caused by high concentration of NaCl.

Imposition of salt stress reduced the net CO_2 assimilation rate, chlorophyll (Chl), anthocyanin and carotenoid contents, stomatal conductance and soluble sugar contents oftomato (*Lycopersicon esculentum* Mill.). Pre-treatments of plant with 10^{-4} M salicylic acid (SA) could partially restore the CO_2 fixation rate and photosynthetic pigment levels under 100 mM NaCl exposure (Katalin *et al*., 2008).

An experiment was conducted by Agamy *et al*. (2013) in Fayoum University, Egypt to find out the acquired resistant motivated by salicylic acid applications on salt stressed tomato plants. In his experiment tomato plants were treated with NaCl solution at concentrations of 0, 40, and 80 mM and then sprayed with 0.50 mM salicylic acid (SA). Results revealed that, salt stress plants especially at the highest level significantly reduced growth parameters and yield. While, exogenous application of SA promoted growth and yield and counteracted the salt stress-induced growth inhibition of salt stressed plants. The improvement in photosynthetic pigments, total soluble proteins, total soluble carbohydrates, total proline, total phenols and leaves relative water content were associated with SA application. On the other hand, salt treatment significantly reduced photosynthetic pigments and leaves relative water content, while significantly increased total soluble proteins, total soluble carbohydrates, total proline, total phenols and electrolyte leakage. He concluded that salicylic acid applications induced the plant defense system to resist the dreadful effects of salt stress via the epigenetic.

Ahmed *et al*. (2011) carried out an experiment with salicylic acid on growth and some physiological characters of salt stressed tomato plants. He used salicylic acid at low concentration (0.01 mM) in culture medium riched with NaCl 100 mM (6 g/L). The applied of SA in saline medium induce: (i) an increase in chlorophyll content; (ii) a better supply of essential elements in plant growth, such as K^+ (iii) a decrease in toxic ions such Na^+ and Cl^- in aerial organs; and (iv) an additional synthesis of organic solutes and osmoprotectors like proline and proteins. Finally the researcher suggests that salicylic acid could be successfully used in alleviating depressive effects of salt on the productivity of the cultivated tomato.

Kazemi (2014) studied the role of pre-application with salicylic acid (SA) (0.50 and 1 mM) and methyl jasmonate (MJ) (0.50 and 1 mM) and their combination on yield quantity and quality of tomato fruits. The results showed that the foliar spray of SA (0.50 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 0.50 mM MJ + 0.50 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content. The researcher concluded that, application of 0.50 mM MJ + 0.50 mM SA improved the yield and fruit quality of tomato.

Zahra *et al*. (2010) observed the effect of salicylic acid on the tomato sugar, protein and proline contents under salinity stress (NaCl). NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.50, 1 and 1.5 mM were used in the form of factorial experiment in a complete randomized design (CRD) and she concluded that salicylic acid could increase the leaf protein contents.

Singh *et al*. (2015) investigate the accumulation of salicylic acids in 2 weeks old maize (*Zea mays* L.) plants grown under salt stress (0, 50, 100, 150 and 200 mM NaCl) in presence and absence of 0.50 mM SA. The results showed sever reduction in plant dry weight, leaf relative water content and photosynthetic pigments. Exogenous application of SA significantly alleviated the growth inhibition of plants caused by NaCl, and was accompanied by higher leaf relative water contents, photosynthetic pigments, and lower total phenolics. It was concluded that the presoaking application of SA was an effective way to improve the salt tolerance of maize plants.

Two field experiments were conducted by Mady (2009) to study the effect of foliar application with 50 & 100 ppm of salicylic acid (SA) and 100 & 200 ppm of vitamin E (VE) and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, flowering, fruiting and fruit quality of tomato Plants were sprayed two times at 30 and 45 days after transplanting. The result showed that the highest early and total yields were obtained with salicylic acid 50 ppm + vitamin E 200 ppm followed by SA 100 ppm + VE 200 ppm, respectively. In addition, chemical composition of minerals and some bioconstituents such as carbohydrates, vitamin C, total soluble solids in tomato fruits were also increased at the same treatments.

A pot experiment was conducted by Butt *et al*. (2016) to assess the role of foliar application of SA to improve the salt tolerance in chilli genotypes. Two chilli genotypes namely 'Plahi' and 'A-120' were grown under 50 mM NaCl saline condition. Various concentrations of SA (0.40, 0.60, 0.80, 1.00 and 1.20 mM) were applied as a foliar spray on one month old seedlings. Salt stress imposed negative impact on growth (Shoot and root length, plant fresh and dry mass), ionic (K^+) and physiological (photosynthetic rate and transpiration rate) attributes in both the studied chilli genotypes except Na+ which increased under salinity stress. However, maximum reduction was observed in 'A-120' as compared to 'Plahi' genotype. In contrast, foliar application of SA under salt stress conditions stimulated shoot and root length, plant fresh and dry mass, photosynthetic rate, transpiration rate and antioxidant enzyme activities were noted under salt stress in both the genotypes. However, maximum increase was observed in 'Plahi' genotype relative to 'A-120'. Moreover, among all SA concentrations, 0.80 mM proved to be the best concentration regarding growth, physiological, ionic and biochemical attributes in both the genotypes.

Mohsina *et al*. (2008) conducted an experiment to study the effect of salicylic acid seed priming on growth and some physiological attributes in wheat (*Triticum aestivum* L.) grown under saline conditions. Wheat seeds were soaked in water and 100 mg/L salicylic acid solution for 24 hours and sown in sand salinized with 0, 50 or 100 mM NaCl. She concluded that Salt stress significantly reduced all growth parameters (shoot and root length, and shoot and root dry weights) and salicylic acid treatment alleviated the adverse effect of salinity on growth.

Exogenous application of salicylic acid enhanced the photosynthetic rate and also maintained the stability of membranes, thereby improved the growth of salinity stressed barley plants (Tayeb, 2005). SA added to the soil also had an ameliorating effect on the survival of maize plants during salt stress and decreased the Na^+ and Cl^- accumulation (Gunes *et al*., 2007). The Lipid peroxidation and membrane permeability, which were increased by salt stress, were lower in SA treated plants (Horvath *et al*., 2007).

Tufail *et al.* (2013) reported that SA treatment induces physiological and biochemical changes in two genotypes of maize (Sahiwal-2002 and EV-20) in the presence and absence of salt. Salicylic acid at 0, 0.25 and 0.50 mM along with 120 mM NaCl and Hogland's nutrient solution were applied as rooting medium to 25 days old plants. Application of SA reduce Na^+ but increased K^+ and Ca^{2+} concentration, shoot biomass under salt stress. Exogenous application of various concentrations of SA upgrade photosynthetic rate, transpiration rate, stomatal conductance, sub-stomatal CO_2 concentration, chlorophyll b contents and carotenoids in both genotypes of maize under salt stress regulated by mineral nutrients.

Torabian (2010) reported that pre-treatment with SA induced adaptive responses in *Medicago sativa* plant under salinity stress and consequently, encouraged protective reactions in biotic membranes which improved the growth of seedlings. SA pre-treatment improved growth and resulted in higher resistance of plants to salinity, so it increased germination percentage, seed vigor index and growth parameters of the seedlings. Also, salinity intensified electrolyte leakage, whereas, SA diminished it and this decrease was stronger at SA concentration

Foliar applied SA increases the growth and photosynthetic rate of sunflower under salt stress condition, particularly at 200 mg/L SA level. Two varieties of sunflower seed were grown under greenhouse and different concentration (100, 200, 300 mg/L) of SA were applied as a foliar spray at vegetative state. SA treatment increased the growth rate (shoot dry weight) and antioxidant capacity of sunflower plant in salt stress conditions, but this was mainly regulated by peroxides activity (Noreen *et al.*, 2009).

Hadi *et al*. (2014) used three types of SA application methods (soil, foliar and priming) and four SA concentrations (0, 0.10, 0.50 and 1.00 mM) of salt stressed white bean. In his findings 0.10 mM soil applied SA was the most effective method on chlorophyll a, chlorophyll b, total chlorophyll, carotenoids, proline, protein and soluble sugars of NaCl stressed white bean.

Strawberry is considered as salinity sensitive species (Saide *et al.*, 2005) and it has been shown to reduce leaf number, leaf area, shoot dry weight and number of crowns and low yield under salt stress (Pirlak and Esitken, 2004). Salt stress affected the growth, chlorophyll content and mineral uptake of strawberry plants. Strawberry plants treated with SA often had greater shoot fresh weight, shoot dry weight, root fresh weight and root dry weight as well as higher chlorophyll content under salt stress (Karlidag *et al*., 2009).

Tayeb (2005) found that SA application to barley induced a pre-adaptive response to salt stress, enhanced the synthesis of Chl a, Chl b and maintained membrane integrity, leading to improvement of plant growth. SA-pretreated plants exhibited less Ca^{2+} and more accumulation of K^+ and soluble sugars in roots under saline condition.

Khan *et al*. (2010) found that foliar spraying of SA (0.10, 0.50, and 1.00 mM) under 50 mM NaCl stressed mungbean decreased Na^+, Cl^-, H_2O_2, and thiobarbituric acid reactive substances, and electrolyte leakage. SA treatment exhibit increased N, P, K, and Ca content, activity of antioxidant enzymes, glutathione content, photosynthesis, and yield under control and saline condition. Application of 0.50 mM SA alleviate the negative effects of NaCl on decreased the content of leaf Na^+, Cl^-, H_2O_2 , and electrolyte leakage, and increased leaf N, P, K, and Ca content, and activity of antioxidant enzymes and glutathione. This treatment resulted in reduced negative effects of salt stress on growth, photosynthesis, and yield while 1.00 mM SA proved inhibitory or there was no additional benefits.

Foliar spraying of SA (0.50 mM) on mung bean under salt stress condition induces glycinebetaine accumulation through increased methionine and suppresses ethylene formation under salt stress and enhances antioxidant system resulting in alleviation of adverse effects of salt stress on photosynthesis and growth. These effects of SA were substantiated by the findings that application of SA-analogue, 2, 6, dichloro-isonicotinic acid and ethylene biosynthesis inhibitor, amino ethoxyvinylglycine resulted in similar effects on Methionine, glycinebetaine, ethylene production, photosynthesis and growth under salt stress (Khan *et al*., 2014).

Lee *et al*. (2010) found that high concentration of SA affects the seed germination in salt induced conditions. In contrast, lower level of SA concentration increased the seed germination rate, decrease H_2O_2 level by reducing oxidative damage under salt stress condition. So, salt induced negative effects were significantly diminished by SA pretreatment of the plants.

Jayakannan *et al*. (2013) has done an experiment where *Arabidopsis* seeds were grown in hydroponic and soil cultures and three weeks old plants were supplemented with different concentration (10, 50, 100 and 500 μM) of SA and exposed to salt stress. Pretreatment of SA in both soil and hydroponic culture under salt stress condition increase the shoot development, relative water content and biomass of the plant. 10, 50 and 100 μM SA treatment reduced the salt induced K^+ efflux and H^+ influx from the matured root zones and also enhanced the K^+ retention in the cytosol. SA treatment increase the H^+ -ATPase activity, lower the membrane depolarization and decreased the K^+ leakage through depolarization under salt stress. He concluded that SA concentration 10, 50 and 100 μM showed the more beneficial activity under salt stress conditions.

An enhanced tolerance against salinity stress was observed in wheat seedlings raised from the grains soaked in SA (Hamada *et al*., 2005). Exogenous application of SA increases the proline content in wheat seedlings under salinity stress, thereby alleviating the deleterious effects of salinity. Further, the treatment also lowered the level of active oxigen species and therefore the activities of super oxide dismutase and peroxidase were also lowered in the roots of young wheat seedlings (Shakirova *et al*., 2003). These findings indicate that the activities of these antioxidant enzymes are directly or indirectly regulated by SA, thereby providing protection aganist salinity stress. SA treatment caused accumulation of both ABA and IAA in *T. aestivum* seedlings under salinity. The SA treatment did not influence on cytokinin content. Thus, protective SA action includes the development of anti stress programs and acceleration of normalization of growth processes after removal of stress factors (Sakhabutdinova *et al*., 2003).

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted during the period from November 2016 to March 2017 to study alleviation of salt stress on growth and yield of tomato by exogenous application of salicylic acid. This chapter presents a brief description about experimental period, site description, and climatic condition, planting materials, treatments, experimental design, data collection and statistical analysis.

3.1 Experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University, Dhaka. It was located in 23°74′N latitude and 90°35′E longitudes. The altitude of the location was 8m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207, which have been shown in the Appendix I.

3.2 Soil of the experimental field

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with adequate irrigation facilities and remains fallow during previous growing season. 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 II.

3.3 Climate

The experimental site was under the sub-tropical climate, which is characterized by high temperature, high humidity, heavy precipitation with occasional gusty winds and relatively long in kharif season (April-September) and scanty rainfall associated with moderately low temperature, low humidity and short day period during Rabi season (October-March). Weather information regarding the atmospheric temperature, relative humidity, rainfall, sunshine hours and soil temperature prevailed at the experimental site during the entire period of investigation as recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III. (DATA)

3.4 Collection of planting materials

The research work was operated with tomato variety named BARI Hybrid Tomato 5. Seeds were collected from Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.5 Treatments of the experiments

The experiment consisted of two factors and carried out to study the field performance of BARI Hybrid Tomato 5 by applying salicylic acid under different salinity levels. The following two factors were included in the experiment

Factor A: Different levels of Salinity

i.) S_0: Control (without salt)
ii.) S_1: 4 dS/m
iii.) S_2: 8 dS/m
iv.) S_3: 12 dS/m
v.) S_4: 16 dS/m

Factor B: Different levels of Salicylic Acid (SA)

i.) A_0: Control ie. no salicylic acid
ii.) A_1: 0.5 mM SA and
iii.) A_2: 1 mM SA

3.6 Design and layout of the experiment

The two factors experiment was laid out in Complete Randomized Design (CRD) with five levels of salinity and three levels of salicylic acid. Four replications were maintained in this experiment. The total number of unit pots was 60. 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 Raising of seedlings

Seedlings were raised in a seedbed. The soil was well pulverized and converted into loose fragile. All weeds and stubbles were removed from the soil. Five grams of seeds were sown in the seedbed on 2nd November 2016. After sowing, seed beds were covered with banana leaf. Heptachlor 40 WP was applied around the seedbed at the rate of 4 kg/ha as precautionary measure against ants and worm. The emergence of seedlings took place within 5 to 6 days after sowing.

3.8 Preparation of pot soil

The soil was collected from a selected field and cow dung from nursery near the Horticulture Farm, SAU, Dhaka. Plant parts, visible insects pests were eliminated from soil by sieving and cattle manure was dried in open sun to reduce moisture. Then soil was properly mixed with cow dung and fertilizer before filling the pots. Cow dung and soil were mixed at 1:3 ratio. Each pot contained 10 kg of prepared soil. Furadan 10G was applied during pot preparation as soil insecticide.

3.9 Transplanting and crop management

Twenty six days old healthy seedlings were uprooted from the seedbed and transplanted in the experimental pots during late afternoon on 28 November, 2016. This allowed an accommodation of one plants per pot. Immediately after planting, the seedlings were watered. Seedlings were also planted around the pot experiment for gap filling.

3.10 Application of fertilizer

Required amount of urea, TSP and MP fertilizer were added to each pot @ 550, 450 and 250 kg/ha, respectively (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 cow dung @ 12 t/ha also applied during final soil preparation.

3.11 Preparation and application of treatment

The levels of the treatment of this experiment were 0 dS/m, 4 dS/m, 8 dS/m, 12 dS/m and 16 dS/m NaCl in concentration. So, required amount of sodium chloride (Normal salt) was weighed by an electric balance respectively and mixed with 1L water. The weighed salt was mixed properly with water and irrigation was done with the help of 1 L watering cane in each pot. In addition, fresh water irrigation was done in every one day interval. As a salt stress mitigation agent, salicylic acid (SA) was sprayed exogenously at 0, 0.5 and 1 mM concentrations which were maintained by adding 0, 0.07 and 0.14 g SA, respectively per liter of water and 0.1% of tween-20 was used as an adhesive material. Spraying was done at 25, 40 and 60 DAT. The SA solution was sprayed by a hand sprayer at 4 pm.

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3.12 Intercultural operations

The following intercultural operations were accomplished for better growth and development of the plants during the period of the experiment.

3.12.1 Weeding

Weeding and mulching were executed as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust.

3.12.2 Gap filling

When the tomato seedlings were well established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy seedlings of the same stock material grown in nearby plot where initial planted seedlings failed to survive.

3.12.3 Staking

After 20 days of transplanting when the tomato plants were well established, staking was performed using jute sticks to keep the plants erect.

3.12.4 Irrigation

The young seedlings in the pots were irrigated just after planting. At very beginning the seedlings were irrigated with normal water till the establishment of the seedlings. After establishment of the seedlings saline irrigation was done as per treatments by a watering cane.

3.12.5 Plant protection measures

Plant protection measures were done whenever they were necessary. Malathion 57EC was applied at the rate of 2 ml/L as preventive measure against insect pests like cut worms, leaf hoppers and fruit borers. The insecticides were applied fortnightly as a routine work from a week after transplanting to a week before first harvesting. Dithane M-45 was applied @ 2 g/L at the early stage against late blight of tomato.

3.13 Harvesting of fruits

Fruits were harvested during early ripening stage when they attained yellow to red color. Harvesting was started on 2nd February 2017 and completed by first week of March, 2017. Hand harvesting was done from each plant.

3.14 Data recording

3.14.1. Plant height

The height of the plants was measured from each pot after 45 days of transplanting and continues up to 75 days after transplanting at 15 days interval. The height was measured from the soil surface to the tip of the plant in centimeter by a measuring scale.

3.14.2. Number of leaves per plant

The number of leaves per plant was counted individually after 45 days of transplanting and continued up to 75 days after transplanting at an interval of 15 days.

3.14.3. Number of branches per plant

Number of branches per plant was recorded individually at 40, 55 and 75 DAT. Branch number was counted individually from each plant.

3.14.4. Diameter of the stem

Diameter of the stem was measured at 25 and 65 DAT with slide calipers at the basal portion of the stem. The average diameter of the stem was expressed in centimeter.

3.14.5. SPAD value of leaf

SPAD value was measured from the leaves of each plant by using an automatic SPAD meter at 50 and 70 DAT. During measurement data is collected from five leaves of different position from each plant.

3.14.6. Leaf area

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

3.14.7. Days to first flowering

Date of first flowering was recorded, and the number of days required for first flowering was calculated.

3.14.8. Number of flower clusters per plant

The number of flower clusters was counted from each plant periodically, and average number of flower clusters produced per plant was recorded.

3.14.9. Number of flower per clusters

The number of flower per cluster was counted from each plant on the basis of number of flower clusters per plant.

3.14.10. Dry matter content of shoot (%)

After harvesting fresh weight of shoot was taken from each treatment and sun dried for two days, then sliced into very thin pieces and were put into envelop and placed in an oven maintaining at 70□ C for 72 hours. The samples were then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken in gram and dry matter % was calculated by the following formula:

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

3.14.11. Dry matter content of fruit (%)

After harvesting fresh weight of 100 gm fruit was taken from each treatment and sun dried then sliced into pieces and were put into envelop and placed in an oven maintaining at 70□ C for 72 hours. The samples were then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken in gram and dry matter percent was calculated by the following formula:

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

3.14.12. Number of total flowers per plant

The number of total flower was recorded from each plant throughout the plant growth and average number of flower produced per plant was recorded.

3.14.13. Number of fruit per plant

The number of fruits per plant was counted from each plant periodically and average number of fruits produced per plant was recorded.

3.14.14. Fruit length

The length of fruit was measured with a slide calipers from the neck of the fruit to bottom of five randomly selected fruits from each plant, and their average was calculated in centimeter.

3.14.15. Fruit diameter

Diameter of fruit was measured at the middle portion of five randomly selected fruits from each plant with a slide calipers, and their average was calculated in centimeter.

3.14.16. Individual fruit weight

The mature fruits were harvested and weight of these fruits was measured by using a measuring balance. Individual fruit weight was determined by the following formula:

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

3.14.17. Fruit yield per plant

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

3.15. Analysis of data

The data in respect of growth, yield contributing characters and yield were statistically analyzed to find out the statistical significance of the experimental results. The means for all the treatments were calculated and the analyses of variance for all the characters were performed by F test. The significance of difference between the pairs of means was separated by LSD test at 5% levels 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 salicylic acid to alleviate salt stress in tomato. The effects due to different levels of salt stress, and application of salicylic acid 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 Plant height

The effect of salinity on the growth of tomato plant is first shown in plant height. Naturally plant height increased with increasing age but decreased with increasing salinity in tomato. Plant height of tomato varied significantly at 45, 60 and 75 DAT due to different levels of salinity (Figure 1 and Appendix IV). At 45 DAT, the highest plant height (61.46 cm) was recorded in case of S_0 and the lowest value (47.50 cm) was found from S_4. At 60 DAT, the highest plant height (74.93 cm) was recorded from S_0 and the lowest value (54.33 cm) was observed in case of S_4 treatment. At 75 DAT, the highest plant height (77.33 cm) was found from S_0 (control) where the lowest value (54.43 cm) was found from S_4 (16 dS/m salinity). Result showed that plant height gradually decreased with increased levels of salinity and the highest declaration occurs in S_4 treatment. 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 (2007) 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 components were decreased and therefore fruit yield was reduced (Ashraf and Mcneilly, 2004).

Plant height of tomato varied significantly at different DAT due to application of SA. As shown in Figure 2 and appendix IV, salicylic acid significantly increased plant height at 45, 60 and 75 DAT. At 45 DAT, the highest plant height (55.78 cm) was found from A_1 where the lowest value (50.83 cm) was recorded from A_0. At 60 DAT, the highest plant height (67.40 cm) was recorded from A_1 and the lowest value (60.32 cm) was found from A_0. At 75 DAT, the highest plant height (69.71 cm) was recorded from A_1 (0.50 mM SA) and the lowest value (62.50 cm) was found from A_0 (control). From this result it was observed that salicylic acid increased the plant height as compared with control where the best result was found from 0.50 mM concentration. Gharib (2007) also reported that salicylic acid increased plant height. Fathy *et al.,* (2003) reported the same result in case of eggplant.

The variations in plant height at different DAT due to combined effect of salinity and SA were found to be statistically significant at 45, 60 and 75 DAT (Table 1 and appendix IV). At 45 DAT, the highest plant height (64.00 cm) was found from S_1A_1 which was statistically identical with S_0A_0 (60.50 cm), S_0A_1 (63.30 cm) and S_0A_2 (60.90 cm), where the lowest value (41.90 cm) was recorded from S_3A_0. At 60 DAT, the highest plant height (78.75 cm) was recorded from S_0A_1 which was statistically identical with S_0A_2 (78.25 cm) and the lowest value (52.00 cm) was found from S_4A_0. At 75 DAT, the highest plant height (82.50 cm) was found from S_0A_1 (control + 0.50 mM SA) which was statistically identical (79.00 and 78.75 cm) with S_0A_2 and S_1A_1, respectively where the lowest value (52.00 cm) was recorded from S_4A_0 (16 dS/m + no SA) which was statistically identical with S_4A_2 (54.50 cm) treatment combination.

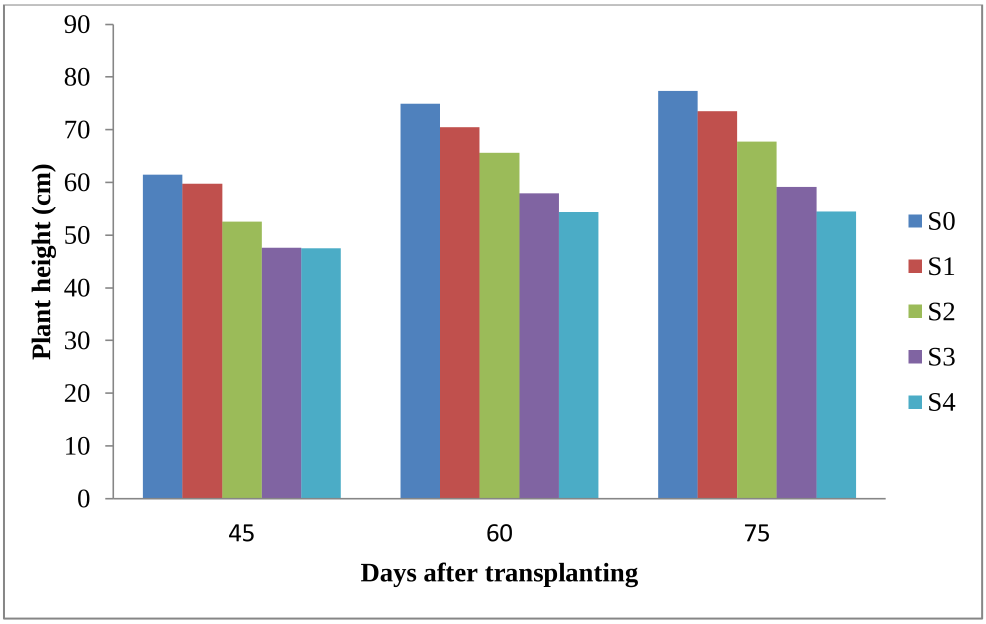

Figure 1. Effect of different levels of salinity on the plant height of tomato

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m)

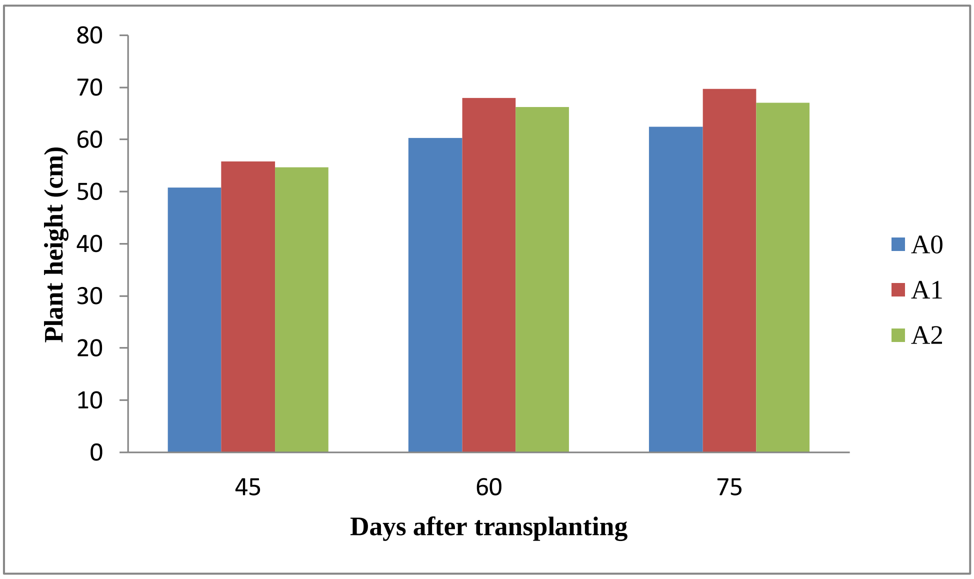

Figure 2. Effect of different levels of salicylic acid on the plant height of tomato

(Here, A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 1. Combined effect of different levels of salinity and salicylic acid on the plant height of tomato at different days after transplanting

Treatment combinations	Plant height (cm)		
	45 DAT	**60 DAT**	**75 DAT**
S_0A_0	60.50 ab	67.80 c-e	70.50 bc
S_0A_1	63.00 a	78.75 a	82.50 a
S_0A_2	60.90 ab	78.25 a	79.00 a
S_1A_0	56.25 cd	64.30 ef	68.25 cd
S_1A_1	64.00 a	75.50 ab	78.75 a
S_1A_2	58.90 bc	71.75 bc	73.50 b
S_2A_0	50.25 fg	62.00 fg	65.75 d
S_2A_1	54.40 de	68.50 cd	70.50 bc
S_2A_2	52.90 d-f	66.40 de	67.00 cd
S_3A_0	41.90 i	55.50 ij	56.00 g
S_3A_1	49.00 g	58.25 g-i	60.00 ef
S_3A_2	52.00 e-g	60.00 gh	61.30 e
S_4A_0	45.25 hi	52.00 j	52.00 h
S_4A_1	48.50 gh	56.50 hi	56.80 fg
S_4A_2	48.75 gh	54.50 ij	54.50 gh
$LSD_{(0.05)}$	3.351	3.773	3.661
CV (%)	4.37	4.09	5.89

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

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

4.2 Number of leaf per plant

Leaf is an important parameter of crop plant because of its physiological role in photosynthetic activities. Salinity adversely affects total leaf number per plant of tomato. Number of leaf per plant of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Figure 3 and Appendix V). At 45 DAT, the highest number of leaf per plant (36.16) was recorded from S_0 which was statistically identical with S_1 (35.58) and followed by S_2 (33.50) and the lowest number of leaf per plant (28.65) from S_4. At 60 DAT, the highest number of leaf per plant (53.10) was recorded from S_0 and the lowest number of leaf per plant from S_4 (37.83). At 75 DAT, the highest number (56.66) of leaf per plant was recorded from S_0 (control) which was statistically identical (55.41) with S_1 (4 dS/m salinity), while the lowest number (38.33) of leaf per plant from S_4 (16 dS/m salinity) treatment. 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.

Number of leaf per plant of tomato varied significantly due to different doses of salicylic acid at DAT (Figure 4 and Appendix V). At 45 DAT, the highest number of leaf per plant (34.30) was recorded from A_2 which was statistically identical with A_1 (32.55), while the lowest number of leaf per plant (30.60) from A_0. At 60 DAT, the highest number of leaf per plant (48.90) was recorded from A_2 which was statistically identical with A_1 (47.25) and the lowest number of leaf per plant (44.45) from A_0. At 75 DAT, the highest number of leaf (53.00) per plant was recorded from A_2 (1 mM SA) which was followed by A_1 (50.70) and the lowest number (47.35) of leaf per plant from A_0 (control). Thus, these results suggested that the salicylic acid application increased the number of leaf by reducing the effect of salt.

This fact was supported by other authors like Tari *et al*. (2002), Gemes *et al.* (2008) and Horvath *et al*. (2005) in tomato.

Combined effect of saline water and salicylic acid showed statistically significant variation for number of leaf per plant at 45, 60 and 75 DAT (Table 2 and Appendix V). At 45 DAT, the highest number of leaves per plant (37.75) was found from S_0A_0 and the lowest value (26.00) was found from S_3A_0. At 60 DAT, the highest number of leaves per plant (56.50) was found from S_0A_2 and the lowest value (37.00) found from S_4A_0 which was statistically identical with S_4A_1 (38.50) and S_4A_2 (38.00). At 75 DAT, the highest number of leaves per plant (61.50) was found from S_0A_2 (control + 1 mM SA) which was statistically identical (59.50) with S_1A_2 and the lowest value (37.00) was found from S_4A_0 (16 dS/m salinity + no SA) which was statistically identical (38.50) with S_4A_1 treatment combination. From this result, it was found that leaf number gradually increased with the increasing age and the supplementation of salicylic acid along with salt.

4.3 Number of branch per plant

Different levels of salinity showed significant effect on branch per plant of tomato at 40, 55, and 75 DAT ((Figure 5 and Appendix VI). At 40 DAT the highest number of branch per plant (3.91) was found from S_0 which was statistically similar (3.75 and 3.25) to S_1 and $S_{2,}$ respectively while the lowest value (2.83) was recorded from S_4. At 55 DAT, the highest number of branch per plant (8.25) was observed from S_1 which was statistically similar (7.66) to S_0 treatment and the lowest value (5.00) was found from S_4. At 75 DAT the highest number of branch per plant (10.66) was found from S_1 (4 dS/m salinity) which was statistically similar (10.58) to S_0 and the lowest value (6.00) was recorded from S_4 (16 dS/m salinity). Similar observation was also found in rice where the number of primary tiller was decreased in response to salinity which was reported by Ali *et al.* (2004) and Zeng *et al.* (2000).

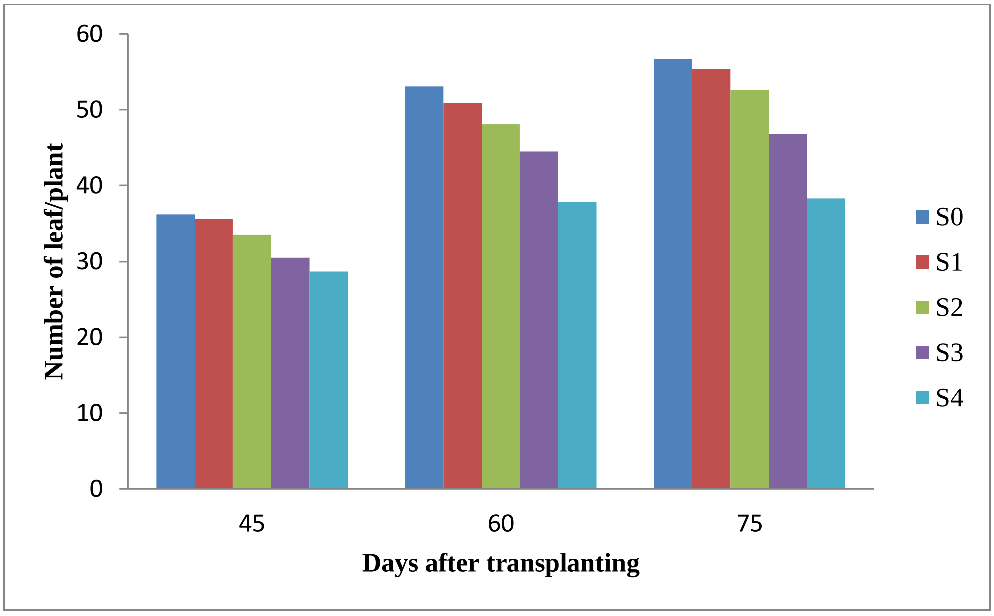

Figure 3. Effect of different levels of salinity on the number of leaf per plant of tomato

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m)

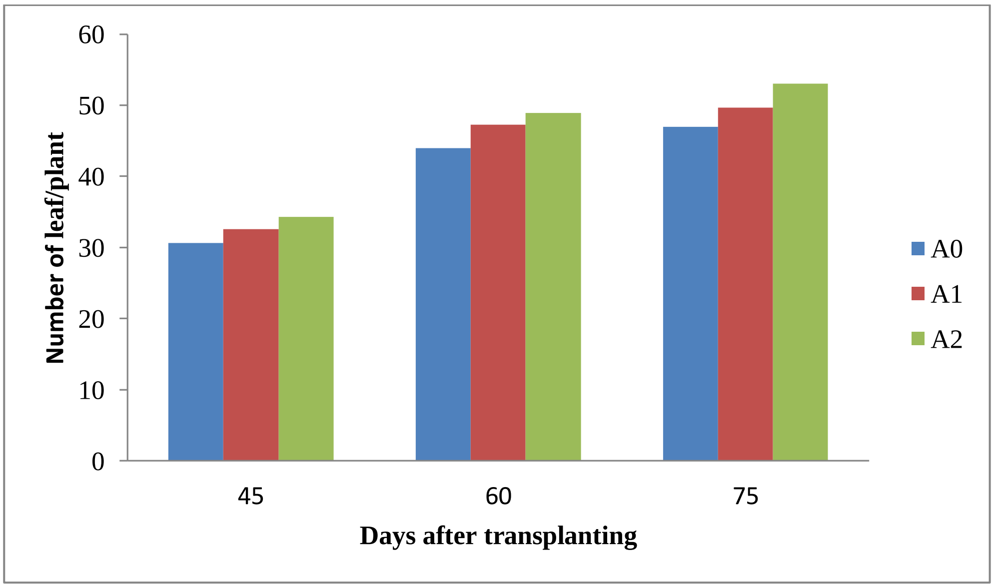

Figure 4. Effect of different levels of salicylic acid on the number of leaf per plant of tomato

(Here, A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 2. Combined effect of different levels of salinity and salicylic acid on the number of leaf per plant of tomato at different days after transplanting

Treatment combinations	No. of leaf per plant		
	45 DAT	**60 DAT**	**75 DAT**
S_0A_0	37.75 a	49.00 c-e	53.00 c
S_0A_1	34.00 c	54.00 b	55.50 b
S_0A_2	36.75 ab	56.50 a	61.50 a
S_1A_0	35.00 bc	47.50 d-f	51.50 cd
S_1A_1	35.75 a-c	51.25 c	55.25 b
S_1A_2	36.00 a-c	54.00 b	59.50 a
S_2A_0	30.00 de	47.25 d-f	50.25 de
S_2A_1	34.75 bc	47.50 d-f	52.00 cd
S_2A_2	35.75 a-c	49.50 cd	55.50 b
S_3A_0	26.00 f	42.00 g	45.00 g
S_3A_1	31.50 d	45.00 f	47.00 fg
S_3A_2	34.00 c	46.50 ef	48.50 ef
S_4A_0	26.25 f	37.00 h	37.00 i
S_4A_1	28.75 e	38.50 h	38.50 hi
S_4A_2	31.00 d	38.00 h	39.50 h
$LSD_{(0.05)}$	2.027	2.271	2.044
CV (%)	4.20	5.39	6.87

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

Number of branch per plant of tomato varied significantly due to different doses of salicylic acid at different days after transplanting DAT (Figure 6 and Appendix VI). At 40 DAT, the highest number of branch per plant (3.55) was recorded from A_1 treatments while the lowest number (3.25) from A_0. At 55 DAT, the highest number of branch per plant (7.55) was recorded from A_1 while the lowest number of branch per plant (5.25) from A_0. At 75 DAT, the highest number of branch (9.45) per plant was recorded from A_1 (0.50 mM SA) and the lowest number of branch (7.55) per plant from A_0 (no SA), both were statistically identical with A_2 (8.7). These results suggested that the salicylic acid application increased the number of branch by alleviating the effect of salt. Arzandi (2014) stated that SA increasing the number of branching in case of coriander.

A statistically significant variation in number of branch per plant at 40, 55 and 75 DAT was found due to combined effect of saline water and salicylic acid (Table 3 and Appendix VI). At 40 DAT, the highest number of branch per plant (4.50) was recorded from S_1A_1 treatment combination and the lowest number from (2.50) was recorded from S_3A_0 treatment combinations. At 55 DAT, the highest number of branch per plant (10.00) was found from S_1A_1 and the lowest value (4.00) was found from S_4A_0. At 75 DAT, the highest number of branch per plant (12.75) was found from S_1A_1 (4 dS/m salinity + 0.50 mM SA) which was statistically identical (12.00) to S_0A_1 and the lowest value (5.00) was found from S_4A_0 (16 dS/m salinity + no SA) which was statistically identical (6.50) to both S_4A_1 and S_4A_2.

4.4 Stem diameter

Different levels of salinity showed significant effect on stem diameter per plant of tomato at 25 and 65 DAT (Figure 7 and Appendix VI). At 65 DAT, the maximum stem diameter (0.88 cm) was observed from S_0 (control) treatment which is statistically similar to S_1 (0.82 cm) and S_2 (0.80 cm) treatment where the minimum stem diameter (0.65 cm) was found from S_4 (16 dS/m salinity)

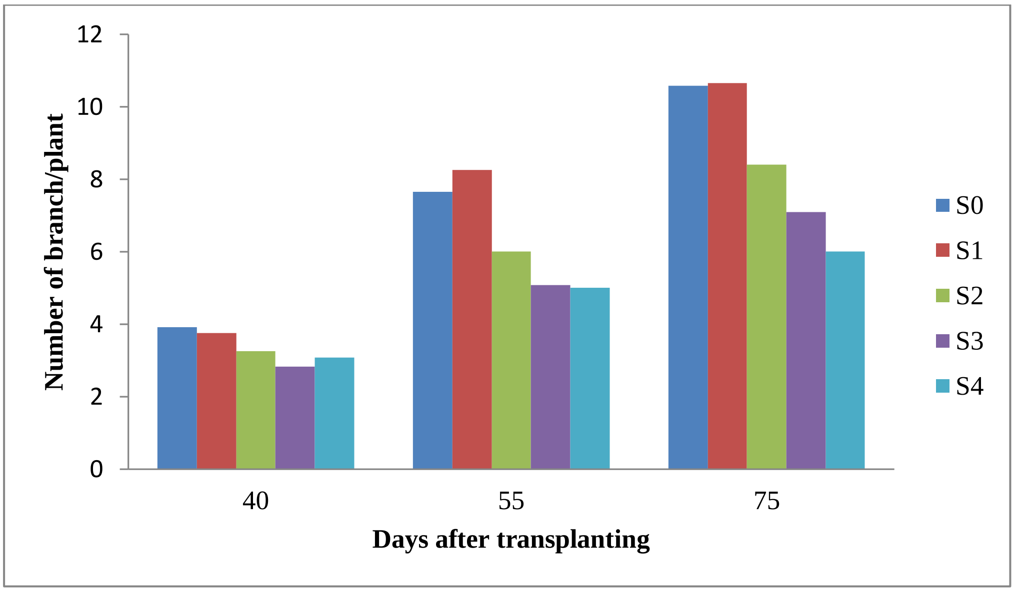

Figure 5. Effect of different levels of salinity on the number of branch per plant of tomato

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m)

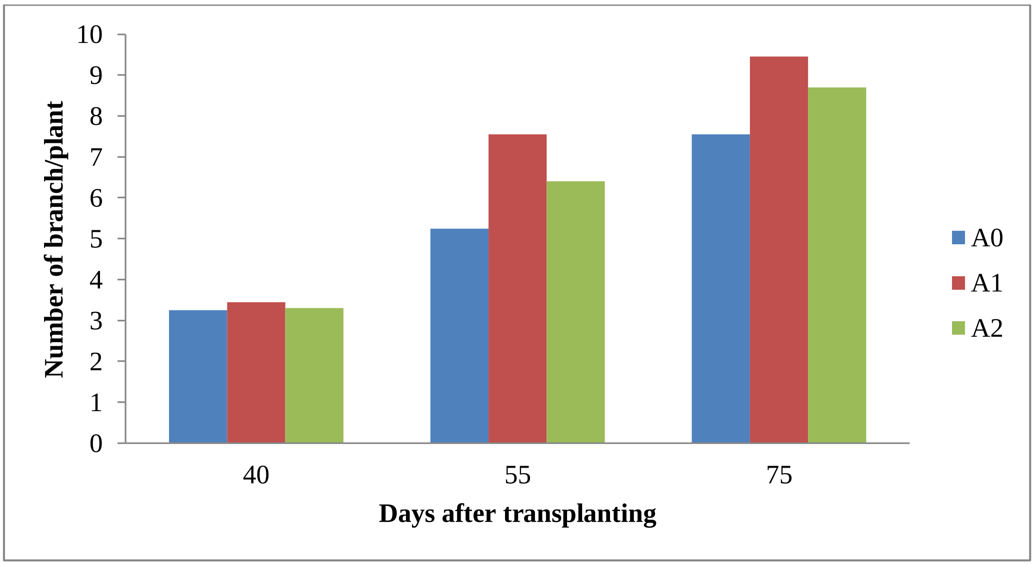

Figure 6. Effect of different levels of salicylic acid on the number of branch per plant of tomato

(Here, A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 3. Combined effect of different levels of salinity and salicylic acid on the number of branch per plant of tomato at different days after transplanting

Treatment combinations	No. of branch per plant at		
	40DAT	55 DAT	75 DAT
S_0A_0	4.00 ab	6.50 cd	9.50 c-e
S_0A_1	3.75 a-c	9.50 ab	12.00 ab
S_0A_2	4.00 ab	7.00 c	10.25 cd
S_1A_0	3.50 a-c	6.00 c-e	8.25 e-g
S_1A_1	4.50 a	10.0 a	12.75 a
S_1A_2	3.25 a-c	8.75 b	11.00 bc
S_2A_0	3.25 a-c	5.50 d-f	8.00 e-h
S_2A_1	3.50 a-c	6.50 cd	9.00 d-f
S_2A_2	3.00 bc	6.25 c-e	8.25 e-g
S_3A_0	2.50 c	4.25 fg	7.00 gh
S_3A_1	3.50 a-c	6.00 c-e	7.00 gh
S_3A_2	3.25 a-c	5.25 d-g	7.50 f-h
S_4A_0	3.00 bc	4.00 g	5.00 i
S_4A_1	2.50 c	5.00 e-g	6.50 hi
S_4A_2	3.00 bc	6.00 c-e	6.50 hi
$LSD_{(0.05)}$	1.161	1.175	1.440
CV (%)	6.32	8.78	11.77

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

treatment. Stem diameter gradually decreased with increasing salinity level. Bhatt *et al.* (2008) also stated that salinity decrease stem diameter in *Ziziphus mauritiana.*

There was significant effect of different doses of salicylic acid for stem diameter of tomato plant (Figure 8 and Appendix VI). At 65 DAT, maximum stem diameter was recorded from A_1 (0.84 cm) while minimum (0.74 cm) from A_0 (no SA) treatment.

Combined effect of salinity and salicylic acid showed statistically significant variation for stem diameter of tomato plant at different days after transplanting DAT (Table 4 and Appendix VI). At 65 DAT, maximum stem diameter (0.93 cm) was found from S_0A_1 (control + 0.50 mM SA) which was statistically identical with S_1A_1 (0.93 cm), S_2A_1 (0.93 cm) and followed by S_0A_0 (0.85 cm), S_0A_2 (0.88 cm), and S_1A_2 (0.80 cm) where the minimum (0.63 cm) from S_4A_0 (16 dS/m salinity + no SA) treatment combinations.

4.5 Leaf chlorophyll content

Leaf chlorophyll content of tomato plant showed significant variation due to different levels of salt stress at 50 and 75 DAT (Appendix VII). Leaf chlorophyll content (SPAD reading) of tomato decreased with increasing salinity levels. At 50 DAT, maximum chlorophyll content (46.44 SPAD units) was recorded from S_0 treatment and minimum (32.19 SPAD units) from S_4. At 75 DAT, maximum chlorophyll content (44.11 SPAD units) was recorded from S_0 (control) treatment and minimum (27.20 SPAD units) from S_4 (16 dS/m salinity) treatment (Figure 9). Islam *et al.* (2012) and Horchani *et al.* (2010) reported the similar findings in case of lentil genotype and stated that leaf chlorophyll content decreased with increasing salinity level.

Different levels of salicylic acid showed significant effect for the leaf chlorophyll content of tomato at different days after transplanting (Appendix VII). At 50 DAT, maximum chlorophyll content was recorded from

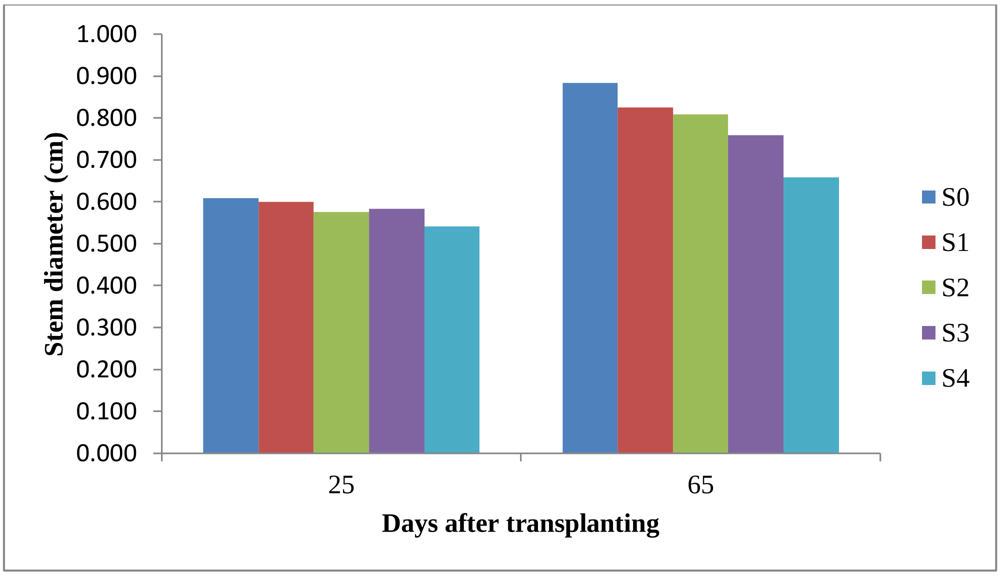

Figure 7. Effect of different levels of salinity on the stem diameter of tomato plant

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m)

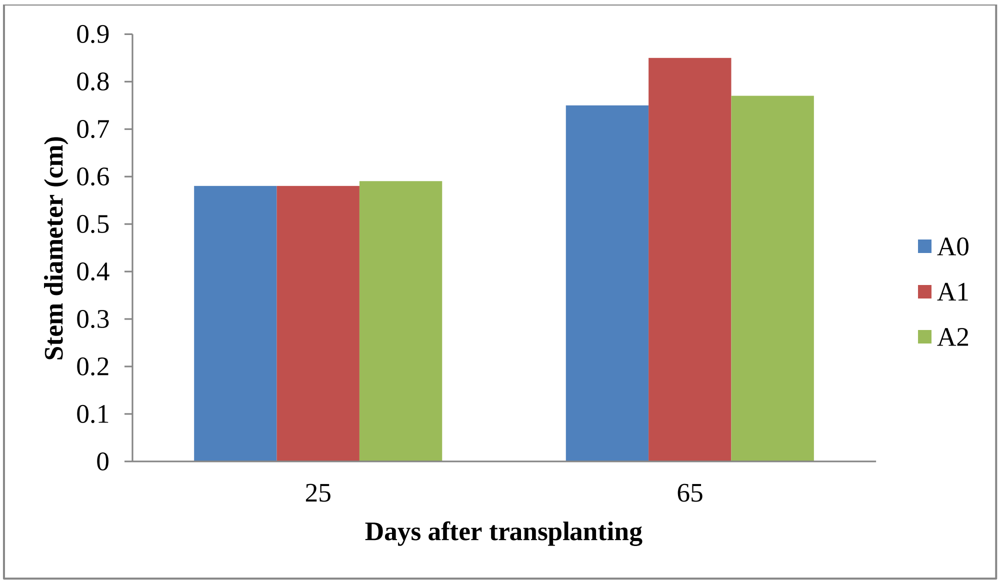

Figure 8. Effect of different levels of salicylic acid on the stem diameter of tomato plant

(Here, A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

A_1 (42.81) while minimum from A_0 (36.89) treatment. At 75 DAT, maximum chlorophyll content (36.43) was recorded from A_1 (0.50 mM SA) while minimum (33.37) from A_0 (no SA) treatment (Figure 10). The increase in chlorophyll content with SA was confirmed by the reports of Tayeb (2005) for barley and Yildrim *et al*. (2008) for cucumber.

The variation in leaf chlorophyll content of tomato due to combined effect of salinity and salicylic acid were found to be statistically significant at different days after transplanting (Appendix VII). At 50 DAT maximum chlorophyll content was recorded from S_1A_1 (48.60) which was statistically identical to both S_0A_1 (48.00) and S_0A_2 (47.33) treatment combinations and minimum from S_4A_0 (28.00). At 75 DAT, maximum chlorophyll content (43.21) was found from S_0A_1 (control +0.50 mM SA) which was statistically identical (40.81, 42.31and 40.74) to $S_0A_{0,}$ S_0A_2 and $S_1A_{2,}$ respectively while minimum (25.21) from S_4A_0 (16 dS/m salinity + no SA) which was statistically identical to S_4A_2 (26.50) treatment combination (Table 4).

4.6 Leaf area

Statistically significant variation was recorded for leaf area due to different levels of salt stress at flowering to fruiting stage (Appendix VII). The maximum leaf area (141.70 cm^2) was recorded from S_0 (control) treated plant where the minimum leaf area (114.40 cm^2) was found from S_4 (16 dS/m salinity) which was statistically similar (114.70 cm^2) to S_3 treatment (Table 5). Leaf area decreased with the increase in salinity level. Salt stress inhibited the cell division and cell expansion, consequently leaf expansion and as a result leaf area is reduced. The results are in agreement with that of Chakrabarti and Mukherji (2002) who reported decreased leaf area in mungbean under salinity. According to Agong *et al.* (2003) excessive accumulation of salts can lead to death of cell and reduction of leaf area. Leaf area/plant affected significantly due to different levels of salicylic acid (Appendix VII). The maximum leaf area (135.20 cm^2) was found from A_2

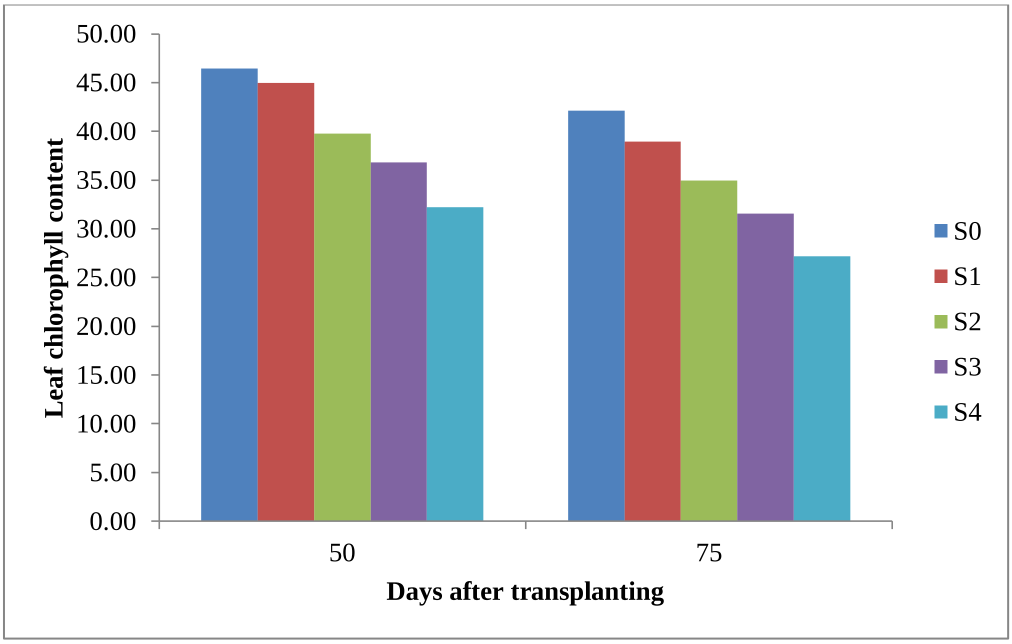

Figure 9. Effect of different levels of salinity on the leaf chlorophyll content of tomato

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m)

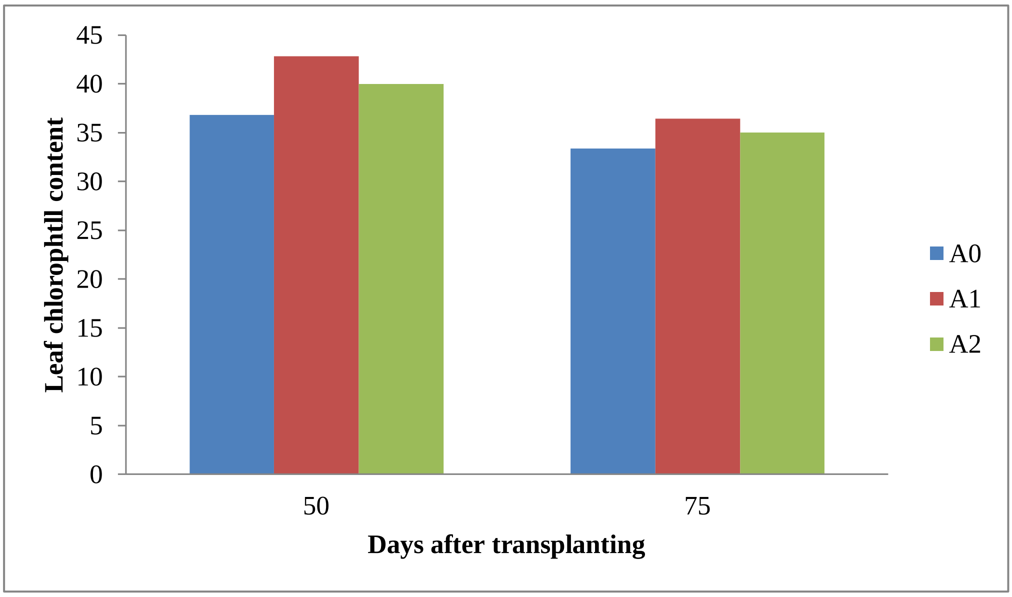

Figure 10. Effect of different levels of salicylic acid on the leaf chlorophyll content of tomato

(Here, A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 4. Combined effect of different levels of salinity and salicylic acid on the stem diameter and leaf chlorophyll content per plant of tomato at different days after transplanting

Treatment combinations	Stem diameter (cm)		Leaf chlorophyll content (SPAD unit)	
	25 DAT	65 DAT	50 DAT	75 DAT
S_0A_0	0.63 ab	0.85 ab	44.00 bc	40.81 ab
S_0A_1	0.55 ab	0.93 a	48.00 a	43.21 a
S_0A_2	0.65 a	0.88 ab	47.33 a	42.31 ab
S_1A_0	0.63 ab	0.75 b-d	41.90 cd	36.03 c
S_1A_1	0.60 ab	0.93 a	48.60 a	40.00 b
S_1A_2	0.58 ab	0.80 a-c	44.43 b	40.74 ab
S_2A_0	0.50 b	0.75 b-d	38.00 f	34.13 cd
S_2A_1	0.55 ab	0.93 a	42.26 b-d	36.50 c
S_2A_2	0.58 ab	0.75 b-d	39.00 ef	34.16 cd
S_3A_0	0.55 ab	0.75 b-d	32.57 g	30.74 e
S_3A_1	0.63 ab	0.78 bc	40.62 de	32.55 de
S_3A_2	0.58 ab	0.75 b-d	37.25 f	31.32 e
S_4A_0	0.58 ab	0.63 d	28.00 h	25.21 f
S_4A_1	0.58 ab	0.68 cd	34.57 g	29.90 e
S_4A_2	0.58 ab	0.68 cd	34.00 g	26.50 f
$LSD_{(0.05)}$	0.123	0.134	2.301	2.475
CV (%)	8.56	11.16	4.02	4.96

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

(1 mM SA) where the minimum leaf area (118.10 cm^2) was recorded from A_0 (no SA) treatment (Table 5). Exogenous SA increase leaf area which is also confirmed by Eraslan *et al.* (2007).

The combined effect of salt and salicylic acid was a significant effect on the leaf area/plant (appendix VII). The maximum leaf area (154.50 cm^2) was recorded from S_0A_2 (control + 1 mM SA) and the minimum (105.70 cm^2) from S_4A_0 (16 dS/m salinity + no SA) which was statistically similar (108.30 cm^2) to S_3A_0 treatment combinations (Table 6).

4.7 Days to first flowering

Days to 1st flowering varied significantly due to different levels of salinity application (Appendix VII). The earliest flowering (29.25 days) was found from S_1 (4 dS/m salinity) which was statistically similar to S_0 (29.75 days) treatment and late flowering (38.17 days) was found in S_4 (16 dS/m salinity) treatment (Table 5). Higher levels of salinity delays flowering which was also confirmed by Islam *et al*. (2011).

Although days to 1st flowering has no significant effect at different levels of salicylic acid (Appendix VII), the earliest flowering (31.25 days) occurred in A_1 (0.50 mM SA) which was statistically similar with (33.80 and 32.30) A_0 and A_2 treatment (Table 5) respectively.

There was significant combination effect among the different doses of salinity and salicylic acid on days to first flowering (Appendix VII). The days to first flowering ranged from 28.50 to 38.50 days. The treatment combination of S_1A_1 (4 dS/m salinity + 0.50 mM SA) produced early flowering (27.50 days) which was statistically identical to S_0A_1 (29.25) and S_1A_2 (28.50) treatment combination while S_4A_0 (16 dS/m salinity + no SA) produced delayed flowering (38.50 days) which was statistically identical to both S_4A_1 (38.00 days) and S_4A_2 (38.00 days) treatment combinations (Table 6).

4.8 Number of flower cluster per plant

There was a significant difference in number of flower cluster per plant at different levels of salinity (Appendix VIII). The highest number of flower cluster per plant (13.25) was found in control plants (S_0) and the lowest number of flower cluster (8.75) was recorded from S_4 (16 dS/m salinity) treatment (Table 5).

Significant variation was observed for number of flower cluster per plant of tomato for different levels of salicylic acid (Appendix VIII). The highest flower cluster/plant (12.00) was found in A_1 (0.50 mM SA) treated plants and control treated plants showed the lowest flower cluster/plant (10.35), both A_0 and A_1 were statistically identical with A_2 (11.55) (Table 5).

Number of flower cluster/plant varied significantly due to the combined effect of salinity and salicylic acid levels (Appendix VIII). The highest number of flower cluster/plant (14.50) was found from S_0A_1 (control + 0.50 mM SA), while the lowest number (8.25) was obtained from S_4A_0 (16 dS/m salinity + no SA) treatment combinations (Table 6).

4.9 Number of flower per cluster

Number of flower per cluster of tomato showed significant variation for different salinity levels (Appendix VIII). The highest number of flower per cluster (6.03) was observed from S_0 (control) treatment which was statistically similar to S_1 (5.89) and S_2 (5.92), respectively where the lowest number (4.56) was found from S_4 (16 dS/m salinity) treatment which was statistically similar to S_3 (5.44). Salinity reduced the number of flower per cluster (Table 5).

Different levels of salicylic acid have no significant effect for the number of flower/cluster of tomato (Appendix VIII). The highest number of flower/cluster (5.73) was found from A_1 (0.50 mM SA) treatment which was statistically similar with A_0 (5.59) and A_2 (5.37) treatment, respectively (Table 5).

The variations in number of flower/cluster showed significant differences due to combined effect of salinity and salicylic acid (Appendix VIII). The highest number of flowers/cluster (6.45) was recorded from S_0A_0 (control + no SA) where, the lowest number (4.47) was obtained from S_4A_0 (16 dS/m salinity + no SA) which was statistically similar to S_4A_2 (4.52) treatment combination (Table 6).

4.10 Dry matter content in shoot (%)

Percent of dry matter content in shoot statistically varied due to different level of saline water (Appendix VIII). The highest dry matter content in plants (14.87%) was recorded from S_0 (No saline) treatment and the lowest dry matter content in plants (9.23%) was recorded from S_4 (16 dS/m salinity) which was statistically identical with S_3 (10.12%) treatment (Table 7). Shoot dry weight production of tomato decreased by salinity (Abdelrahman *et al.*, 2005 and Shibli *et al.,* 2007).

A statistically significant difference was recorded due to different levels of salicylic acid for dry matter percent in shoot (Appendix VIII). The highest dry matter content in shoot (12.85%) was recorded from A_1 (0.50 mM SA) treatment while the lowest dry matter content in shoot (11.63%) was recorded from A_0 (No SA) treatment which was statistically similar with A_2 (12.12%) treatment (Table 7).

Combined effect of saline water and salicylic acid showed statistically significant variation for dry matter percent in shoot (Appendix VIII). The highest dry matter content in plants (15.24%) was recorded from S_0A_1 (No saline + 0.50 mM SA) which was statistically identical with S_0A_2 (15.00%) and followed by S_0A_0 (14.38%) treatment combination, while the lowest dry matter content in shoot (9.00%) was recorded from S_4A_0 (16 dS/m salinity + no SA) treatment combination which was statistically identical with S_3A_0 (9.23%), S_4A_1 (9.20%) and S_4A_2 (9.50%), respectively (Table 8).

Table 5. Effect of different levels of salinity and salicylic acid on leaf area, days to first flowering, number of flower cluster/plant and number of flower/cluster

Treatments	Leaf area (cm^2)	Days to first flowering	Number of flower/cluster plant	Number of flower/ cluster
Effect of different levels of salinity				
S_0	141.70 a	29.75 c	13.25 a	6.03 a
S_1	130.80 b	29.25 c	12.50 a	5.89 a
S_2	122.80 c	32.33 b	12.00 a	5.92 a
S_3	114.70 d	32.75 b	9.75 b	5.44 b
S_4	114.40 d	38.17 a	8.75 b	4.56 b
$LSD_{(0.05)}$	6.530	2.061	1.664	0.788
CV (%)	5.36	8.77	7.52	11.02
Effect of different levels of salicylic acid				
A_0	118.10 c	33.80 a	10.35 b	5.59 a
A_1	127.30 b	31.25 a	12.00 a	5.73 a
A_2	135.20 a	32.30 a	11.55 ab	5.37 a
$LSD_{(0.05)}$	9.645	3.329	1.398	2.271
CV (%)	5.36	8.77	7.52	11.02

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 6. Combined effect of different levels of salinity and salicylic acid on leaf area, days to first flowering, number of flower cluster/plant and number of flower/cluster

Treatment combinations	Leaf area/ plant (cm^2)	First flowering DAT	Number of flower cluster/ plant	Number of flower/ cluster
S_0A_0	134.30 b	29.50 ef	11.00 d	6.45 a
S_0A_1	136.40 bc	29.25 e-g	14.50 a	6.34 ab
S_0A_2	154.50 a	30.50 de	14.25 ab	5.31 b-e
S_1A_0	128.20 b-d	31.75 cd	11.00 d	6.21 ab
S_1A_1	128.80 cd	27.50 g	13.50 a-c	5.97 a-c
S_1A_2	135.40 bc	28.50 fg	13.00 bc	5.50 a-d
S_2A_0	115.20 ef	34.50 b	12.50 c	5.84 a-c
S_2A_1	125.80 de	31.00 de	12.50 c	5.94 a-c
S_2A_2	124.40 ef	31.50 cd	11.00 d	5.97 a-c
S_3A_0	108.30 g	34.75 b	9.00 ef	5.00 c-e
S_3A_1	117.70 f	30.50 de	10.00 de	5.75 a-c
S_3A_2	112.20 f	33.00 bc	10.25 de	5.57 a-d
S_4A_0	105.70 g	38.50 a	8.25 f	4.47 e
S_4A_1	119.90 ef	38.00 a	9.00 ef	4.69 de
S_4A_2	117.70 f	38.00 a	9.00 ef	4.52 e
$LSD_{(0.05)}$	5.931	1.753	1.215	0.882
CV (%)	5.36	8.77	7.52	11.02

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

4.11 Dry matter content in fruit (%)

Percent dry matter content in fruit varied significantly due to different level of saline water (Appendix VIII). The highest dry matter content in fruits (3.26%) was recorded from S_0 (Control) which was followed by S_1 (3.11%) treatment. On the other hand, the lowest dry matter content in fruits (1.90%) was recorded from S_4 (60 dS/m salinity) which was followed by S_3 (2.36%) treatment (Table 7). 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.

No significant difference was recorded due to different levels of salicylic acid for dry matter content in fruits (Appendix VIII). The highest dry matter content in fruits (2.77%) was recorded from A_1 (0.50 mM SA) which was statistically similar with A_0 (2.54%) and A_2 (2.62%) treatment, respectively (Table 7).

A statistically significant variation for the percent of dry matter content in fruits was recorded in case of combined effect of saline water and salicylic acid (Appendix VIII and Table 8). The highest dry matter content in fruits (3.35%) was recorded from S_0A_1 (No saline + 0.50 mM SA) treatment combination which was statistically identical with S_0A_0 (3.10%), S_0A_2 (3.34%), S_1A_0 (3.15%) and S_1A_1 (3.28%), respectively while the lowest dry matter content in fruits per plant (1.81%) was recorded from S_4A_0 (16 dS/m salinity + no SA) treatment combination which was statistically identical with S_4A_1 (1.93%) and S_4A_2 (1.96%).

4.12 Number of flower per plant

Number of flower/plant of tomato showed significant differences with different levels of salinity (Appendix VIII). The highest number of flower/plant (78.17) was observed from S_0 (control), where the lowest number (41.58) was recorded from S_4 (16 dS/m salinity) (Table 7). Number of flower/plant gradually reduced with the increased levels of salinity (Rameeh and Mahyar, 2015).

Significant variation was recorded for the number of flower/plant of tomato for different doses of salicylic acid (Appendix VIII). The maximum number of flower/plant (67.75) was found from A_1 (0.50 mM SA) followed by A_2 (63.30) treatment. Again lowest number (57.10) was obtained from A_0 (no SA) treatment (Table 7). Application of salicylic acid increased the number of flower/plant.

Combined effect of salinity level with salicylic acid showed significant variation in terms of number of flower/plant (Appendix VIII). The highest number of flower/plant (88.75) was observed in S_0A_1 (control + 0.50 mM SA) and the lowest number (38.50) was recorded from S_4A_0 (16 dS/m salinity + no SA) treatment combination (Table 8).

4.13 Number of fruit per plant

Number of fruit/plant of tomato showed significant differences in response to different levels of salinity (Appendix IX). The highest number of fruits/plant (41.75) was recorded from S_0 (control) which was statistically similar to S_1 (39.83) and the lowest number (16.92) was observed from S_4 (16 dS/m salinity) (Table 7). 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). Salinity adversely affects reproductive development by inhibiting microosporogenesis, stamen filament, ovule abortion and senescence of fertilized embryo.

Statistically significant variation was recorded for number of fruit/plant of tomato after the application of different levels of salicylic acid (Appendix IX). Highest number of fruit/plant (34.90) was observed from A_1 (0.50 mM SA) treatment which was statistically similar (32.85) to A_2 (1 mM SA) and the lowest value (30.85) from A_0 (control) treatment which was statistically similar to A_2 (32.85) treatment (Table 7). These results were also confirmed by Stevens *et al.* (2006) and Tari *et al.* (2002) in case of tomato that SA increases total number of fruit per plant.

Number of fruit per plant showed statistically significant variation for the combined effect of saline water and salicylic acid (Appendix IX). The maximum number of fruit per plant (42.50) was recorded from S_0A_1 (No saline + 0.50 mM SA) treatment combination which was followed by S_0A_0 (40.50), S_0A_2 (42.25) and S_1A_1 (41.50) while the minimum number of fruit per plant (15.50) was recorded from S_4A_0 (16 dS/m salinity + no SA) which was statistically similar with S_4A_2 (16.50) (Table 8).

4.14 Fruit length

Length of fruits showed statistically significant variation due to different level of saline water (Appendix IX). The maximum length of fruit (4.57 cm) was recorded from S_0 (Control) treatment followed by S_1 (4.30 cm) and S_2 (4.03 cm), while the minimum length of fruit per plant (3.60 cm) was recorded from S_4 (16 dS/m salinity) which was followed by S_3 (3.83 cm) (Table 9).

Different levels of salicylic acid showed a statistically significant difference for the length of tomato fruit/plant (Appendix IX). The maximum length of fruit (4.42 cm) was recorded from A_1 (0.50 mM SA) treatment while the minimum length of fruits (3.98 cm) was recorded from A_0 (No SA) which is statistically identical with A_2 treatment (Table 9).

Combined effect of saline water and salicylic acid showed statistically significant variation for length of fruit (Appendix IX). The maximum length of fruit (4.80 cm) was recorded from S_0A_1 (No saline + 0.50 mM SA) treatment combination, followed by S_0A_0 (4.40), S_0A_2 (4.50) and S_1A_1 (4.60) while the minimum length of fruit per plant (3.40 cm) was recorded from S_4A_0 (16 dS/m salinity + no SA) which was statistically identical with S_3A_2 (3.70 cm), S_4A_1 (3.70cm), S_4A_2 (3.70 cm) and S_3A_0 (3.80 cm) treatment combinations (Table 10).

4.15 Fruit diameter

Diameter of fruits varied significantly due to different levels of saline water (Appendix IX). The maximum diameter of fruit (5.30 cm) was recorded from

Table 7. Effect of different levels of salinity and salicylic acid on dry matter content of shoot, dry matter content of fruit, total number of flower/ plant and total number of fruit/plant

Treatments	Dry matter content of shoot (%)	Dry matter content of fruit (%)	Number of flower/plant	Number of fruit/plant
Effect of different levels of salinity				
S_0	14.87 a	3.26 a	78.17 a	41.75 a
S_1	13.60 b	3.11 ab	74.17 b	39.83 a
S_2	12.85 b	2.60 bc	66.42 c	35.33 b
S_3	10.12 c	2.36 cd	53.25 d	30.50 c
S_4	9.23 c	1.90 d	41.58 e	16.92 d
LSD(0.05)	1.005	0.577	2.563	2.502
CV(%)	6.99	11.14	8.11	4.73
Effect of different levels of salicylic acid				
A_0	11.63 b	2.54 a	57.10 c	30.85 b
A_1	12.85 a	2.77 a	67.75 a	34.90 a
A_2	12.12 b	2.62 a	63.30 b	32.85 ab
LSD(0.05)	1.206	0.827	2.544	3.622
CV(%)	6.99	11.14	8.11	4.73

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

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 8. Combined effect of different levels of salinity and salicylic acid on dry matter content of shoot, dry matter content of fruit, total number of flower/plant and total number of fruit/plant

Treatment combinations	Dry matter content in shoot(%)	Dry matter content in fruit(%)	Number of flower/ plant	Number of fruit/ plant
S_0A_0	14.38 ab	3.10 a	70.00 d	40.50 ab
S_0A_1	15.24 a	3.35 a	88.75 a	42.50 a
S_0A_2	15.00 a	3.34 a	75.75 bc	42.25 ab
S_1A_0	13.50 b-d	3.15 a	71.50 d	38.00 c
S_1A_1	14.00 a-c	3.28 a	78.00 b	41.50 ab
S_1A_2	13.30 b-d	2.91 ab	73.00 cd	40.00 bc
S_2A_0	12.53 d	2.43 c	60.50 f	33.00 d
S_2A_1	13.21b-d	2.91 ab	73.00 cd	37.75 c
S_2A_2	12.81cd	2.47 bc	65.75 e	35.25 d
S_3A_0	9.23 f	2.24 cd	45.00 h	27.25 f
S_3A_1	11.12 e	2.42 c	55.75 g	34.00 d
S_3A_2	10.00 ef	2.43 c	59.00 fg	30.25 e
S_4A_0	9.00 f	1.81 d	38.50 i	15.50 h
S_4A_1	9.20 f	1.93 d	43.25 h	18.75 g
S_4A_2	9.50 f	1.96 d	43.00 h	16.50 h
$LSD_{(0.05)}$	1.218	0.429	3.414	2.227
CV (%)	6.99	11.14	8.11	4.73

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

S_0 (No saline) treatment which was statistically identical with S_1 (4.93 cm) and followed by S_2 (4.57 cm), while the minimum diameter of fruit per plant (3.83 cm) was recorded from S_4 (16 dS/m salinity) followed by S_3 (4.17 cm) and S_2 (4.57 cm) treatment (Table 9).

A statistically significant difference was recorded due to different levels of salicylic acid for diameter of fruit (Appendix IX). The maximum diameter of fruit (4.86 cm) was recorded from A_1 (0.50 mM SA) treatment while the minimum diameter of fruit (4.46 cm) were recorded from both A_0 (No SA) and A_2 treatment (Table 9).

Combined effect of saline water and salicylic acid showed statistically significant variation for diameter of fruit (Appendix IX). The maximum diameter of fruit (5.60 cm) was recorded from S_0A_1 (No saline + 0.50 mM SA) treatment combination, while the minimum diameter of fruit per plant (3.80 cm) was recorded from S_4A_0 (16 dS/m salinity + no SA) which was statistically identical with S_4A_1 (3.90 cm), S_4A_2 (3.80 cm) and S_3A_0 (3.90 cm) treatment combinations (Table 10).

4.16 Individual fruit weight

Due to different levels of saline water statistically significant variation was recorded for weight of individual fruit (Appendix IX). The highest weight of individual fruit (72.92 g) was recorded from S_0 (Control) treatment which was statistically similar with S_1 (70.99 g), while the lowest weight of individual fruit (37.25 g) was recorded from S_4 (16 dS/m salinity) treatment (Table 9). Decreased fruit weight with increasing salinity were reported by Singh *et al*. (2015) and Cho and Chung (1997).

Individual fruit weight per plant showed statistically significant difference due to different levels of salicylic acid (Appendix IX). The highest weight of individual fruit (61.92 g) was recorded from A_1 (0.50 mM SA) treatment, while the minimum weight of individual fruit (56.94 g) was recorded from A_0 (No

SA) treatment (Table 9) and both A_0 and A_1 were statistically identical with A_2 (59.76 g).

A statistically significant variation was recorded in case of combination effect of saline water and salicylic acid for the weight of individual fruit/plant (Appendix IX). The maximum weight of individual fruit (77.79 g) was recorded from S_0A_1 (no saline + 0.50 mM SA) treatment combination, while the minimum weight of individual fruit (35.25 g) was recorded from S_4A_0 (16 dS/m salinity + no SA) which was statistically similar with S_4A_1 (37.00 g) treatment combination (Table 10).

4.17 Yield per plant

Yield per plant of tomato showed statistically significant variation due to different levels of saline water (Appendix IX). The highest yield per plant (3.03 kg) was recorded from S_0 (Control) treatment which was statistically similar with S_1 (2.80 kg) while the lowest yield per pot (0.59 kg) was recorded from S_4 (16 dS/m salinity) treatment (Table 9). Ahmed *et al*. (2016) also stated that fruit yield per plant of tomato decreased with increasing salinity level and highest yield was found in case of control. Similar observations were also reported by Ali *et al.* (2007) in eggplant, Hakim *et al.* (2014) in rice.

A statistically significant difference was recorded due to different levels of salicylic acid for yield per plant (Appendix IX). The highest yield (2.27 kg) was recorded from A_1 (0.50 mM SA) treatment while the lowest yield (1.86 kg) was recorded from A_0 (No SA) and both A_0 and A_1 were statistically identical with A_2 (2.07 kg) treatment (Table 9). Fruit weight was increased with the supply of salicylic acid and highest result was recorded from 0.50 mM of SA. This result indicated that salicylic acid reduced the toxic effect of salinity and increased the fruit weight in tomato which agrees with the result of Agamy *et al.* (2013); Ahmed *et al.* (2011); Kazemi (2014) and Zahra *et al.* (2010) in tomato and Tayeb (2005) in barley and Hadi *et al.* (2014) in case of bean.

Combined effect of saline water and salicylic acid showed statistically significant variation for yield per plant of tomato (Appendix IX). The highest yield per plant (3.30 kg) was recorded from S_0A_1 (No saline + 0.50 mM SA) treatment combination while the lowest yield per plant (0.50 kg) was recorded from S_4A_0 (16 dS/m salinity + no SA) which was statistically similar with both S_4A_1 (0.62 kg) and S_4A_2 (0.65 kg) treatment combination (Table 10).

Table 9. Effect of different levels of salinity and salicylic acid on fruit length, fruit diameter, individual fruit weight and yield/plant of tomato

Treatments	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (gm)	Yield/plant (kg)
Effect of different levels of salinity				
S_0	4.57 a	5.30 a	72.92 a	3.03 a
S_1	4.30 ab	4.93 ab	70.99 a	2.80 a
S_2	4.03 a-c	4.57 a-c	62.71 b	2.24 b
S_3	3.83 bc	4.17 bc	52.84 c	1.60 c
S_4	3.60 c	3.83 c	37.25 d	0.59 d
LSD(0.05)	0.522	0.791	4.086	0.352
CV(%)	7.17	7.88	5.49	6.99
Effect of different levels of salicylic acid				
A_0	3.98 b	4.46 b	56.94 b	1.86 b
A_1	4.42 a	4.86 a	61.92 a	2.27 a
A_2	4.00 b	4.46 b	59.76 ab	2.07 ab
LSD(0.05)	0.865	0.461	3.493	0.319
CV(%)	7.17	7.88	5.49	6.99

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

(Here, S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

Table 10. Combined effect of different levels of salinity and salicylic acid on fruit length, fruit diameter, individual fruit weight and yield/plant of tomato

Treatment combinations	Fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (gm)	Yield/plant (kg)
S_0A_0	4.40 a-d	5.30 b	69.56 b	2.80 bc
S_0A_1	4.80 a	5.60 a	77.79 a	3.30 a
S_0A_2	4.50 a-c	5.00 c	71.42 b	3.00 b
S_1A_0	4.20 b-e	4.70 d	68.50 b	2.60 cd
S_1A_1	4.60 ab	5.40 b	71.28 b	3.00 b
S_1A_2	4.10 c-f	4.70 d	70.12 b	2.81 bc
S_2A_0	4.10 c-f	4.60 de	60.00 d	2.00 f
S_2A_1	4.40 d-f	4.60 de	64.00 c	2.41 de
S_2A_2	4.00 d-f	4.50 e	64.14 c	2.32 e
S_3A_0	3.80 e-g	3.90 g	51.41 e	1.40 g
S_3A_1	4.20 d-f	4.30 f	53.50 e	1.82 f
S_3A_2	3.70 fg	4.30 f	53.60 e	1.58 g
S_4A_0	3.40 g	3.80 g	35.25 g	0.50 h
S_4A_1	3.70 fg	3.90 g	37.00 fg	0.62 h
S_4A_2	3.70 fg	3.80 g	39.51 f	0.65 h
LSD $_{(0.05)}$	0.425	0.179	2.971	0.211
CV (%)	7.17	7.88	5.49	6.99

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

(S_0 = control, S_1 = 4 dS/m, S_2 = 8 dS/m, S_3 = 12 dS/m, S_4 = 16 dS/m
A_0 = No salicylic acid, A_1 = 0.50 mM salicylic acid, A_2 = 1 mM salicylic acid)

DAT = Days After Transplanting

CHAPTER V

SUMMARY AND CONCLUSION

The present work was done at the experimental field of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to March, 2017 to find out the alleviation of salt stress by exogenous application of salicylic acid on tomato. Seedlings of 25 days of BARI Hybrid Tomato-5 were used as test crop. The experiment consist of two factors: Factor A: Salinity concentrations (five levels) as S_0: control, S_1: 4 dS/m, S_2: 8 dS/m, S_3: 12 dS/m and S_4: 16 dS/m; Factor B: Salicylic acid (three levels) as A_0: 0 mM, A_1: 0.50 mM and A_2: 1 mM concentration. The experiment was laid out in a Complete Randomized Design with four replications. There were 15 treatment combinations and 60 pots in the experiment.

Significant variations were observed due to different levels of salinity in different growth and yield contributing parameters. At 45, 60 and 75 DAT, the tallest plant (61.46, 74.93 and 77.33 cm) was recorded from S_0, whereas the shortest plant (47.5, 54.33 and 54.43 cm) from S_4, respectively. At 45, 60 and 75 DAT, the maximum number of leaf per plant (36.16, 53.10 and 56.66) was recorded from S_0, and the minimum number of leaf per plant (28.66, 37.83 and 38.33) from S_4, respectively. At 40, 55 and 75 DAT, the maximum number of branch was recorded (3.91) from S_0, and (8.25 and 10.66) from $S_{1,}$ respectively where the minimum number of branch per plant (2.83, 5.00 and 6.00) from $S_{4,}$ respectively. At 65 DAT, the maximum diameter of stem (0.88 cm) was recorded from S_0 and the minimum (0.65 cm) from S_4 treatment. The maximum leaf chlorophyll content (46.44 and 44.11 SPAD unit) was found from S_0 at 50 and 75 DAT, respectively and minimum (32.19 and 27.20) from S_4 treatment, respectively. At flowering to fruiting stage the maximum leaf area (141.70 cm^2) was recorded from control treatment and minimum (114.40 cm^2) from S_4 treatment. The maximum days from transplanting to 1st flowering (38.17) was recorded from S_4 and minimum days (29.25) from S_0. The highest number of flower cluster per plant (13.25) and number of flower/cluster (6.03) was found from S_0 and the lowest (8.75 and 4.56) from S_4, respectively. The maximum dry matter content of shoot (14.87%) and fruit (3.26%), the highest number of flower (78.17) and fruit (41.66) was found from S_0 and minimum dry matter content of shoot (9.23%) and fruit (1.90%), the lowest number of flower (41.58) and fruit (16.92) was found from S_4 treatment, respectively. The maximum length (4.57 cm) and diameter of fruit (5.30 cm) was found from control treatment again while the lowest (3.60 cm and 3.83 cm) from S_4, respectively. The highest weight of individual fruit (72.92 g) and yield per plant (3.03 kg) was found from S_0 and the lowest weight of individual fruit (37.25 g) and yield per plant (0.59 kg) from S_4.

At 45, 60 and 75 DAT, the tallest plant (55.78, 67.40 and 69.71 cm) was recorded from A_1, whereas the shortest plant (50.80, 60.32 and 62.5 cm) from A_0, respectively. At 45, 60 and 75 DAT, the maximum number of leaf per plant was recorded (34.30, 48.90 and 53.00) from A_2, and the minimum number of leaf per plant (30.60, 44.55 and 47.35) from A_0, respectively. At 40, 55 and 75 DAT, the maximum number of branch per plant (3.55, 7.55 and 9.45) was recorded from A_1, and the minimum number of branch per plant (3.25, 5.25 and 7.55) from A_0 treatment, respectively. At 65 DAT, the maximum diameter of stem (0.84 cm) was recorded from A_1 and the minimum (0.74 cm) from A_0 treatment. The maximum leaf chlorophyll content (42.81 and 36.43) SPAD unit was found from A_1 at 50 and 75 DAT, respectively and the minimum (36.89 and 33.37) from A_0 treatment, respectively. At flowering to fruiting stage the maximum leaf area 135.20 cm^2 was recorded from A_2 treatment and minimum (118.10 cm^2) from A_0 treatment. The minimum days from transplanting to 1st flowering (31.25) was recorded from A_1 and the maximum days (33.80) from A_0. The highest number of flower cluster per plant (12.00) and number of flower/cluster (5.73) was found from A_1 and the lowest (10.35 and 5.37) from A_0 and A_2, respectively. The maximum dry matter content of shoot (12.85%) and fruit (2.77%), the highest number of flower (67.75) and fruit (34.90) was found from A_1 and minimum dry matter content of shoot (11.63%) and fruit (2.54%), the lowest number of flower (57.10) and fruit (30.85) was found from A_0 treatment, respectively. The maximum length (4.42 cm) and diameter of fruit (4.86 cm) was found from A_1 again while the lowest (3.98 and 4.46 cm) from $A_{0,}$ respectively. The highest weight of individual fruit (61.92 g) and yield per plant (2.27 kg) was found from A_1 and the lowest weight of individual fruit (56.94 g) and yield per plant (1.86 kg) from A_0 treatment

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In combined effect of salt stress and salicylic acid at 45, 60 and 75 DAT, the tallest plant (63.00, 78.75 and 82.50 cm) was recorded from S_0A_1 whereas the shortest plant (41.90 cm) from S_3A_0 and (52.00 and 52.00 cm) from S_4A_0 treatment combination, respectively. At 45, 60 and 75 DAT, the maximum number of leaf per plant was recorded (37.75) from S_0A_0 and (56.50 and 61.50) from S_0A_2, respectively and the minimum number of leaf per plant (26.00) from S_3A_0 and (37 and 37) from S_4A_0, respectively. At 40, 55 and 75 DAT, the maximum number of branch per plant (4.50, 10.00 and 12.75) was recorded from S_1A_1, respectively while the minimum number of branch per plant (2.50) from S_3A_0 and (4.00 and 5.00) from S_4A_0, respectively. At 65 DAT, the maximum diameter of stem (0.93 cm) was recorded from S_0A_1 and the minimum (0.63 cm) from S_4A_0 treatment combination. The maximum leaf chlorophyll content (48.00 and 43.21 SPAD unit) was found from S_0A_1 at 50 and 70 DAT, respectively and the minimum (28.00 and 25.21) from S_4A_0 treatment combination, respectively. At flowering to fruiting stage the maximum leaf area (154.50 cm^2) was recorded from S_0A_2 treatment combination and the minimum (105.70 cm^2) from S_4A_0 treatment combination. The maximum days from transplanting to 1st flowering (38.50) was recorded from S_4A_0 and the minimum days (27.50) from S_1A_1 treatment combination. The highest number of flower cluster per plant (14.50) and number of flower/cluster (6.45) was found from S_0A_1 and $S_0A_{0,}$ respectively while the lowest (8.25 and 4.47) from $S_4A_{0,}$ respectively. The maximum dry matter content of shoot (15.24%) and fruit (3.35%), the highest number of flower

(88.75) and fruit (42.50) was found from S_0A_1 and minimum dry matter content of shoot (9.00%) and fruit (1.81%), the lowest number of flower (38.50) and fruit (15.50) was found from S_4A_0 treatment combination, respectively. The maximum length (4.80 cm) and diameter of fruit (5.60 cm) was found from S_0A_1 treatment combination while the lowest (3.40 cm and 3.80 cm) from S_4A_0 treatment combination, respectively. The highest weight of individual fruit (77.79 g) and yield per plant (3.30 kg) was found from S_0A_1 and the lowest weight of individual fruit (35.25 g) and yield per plant (0.50 kg) from S_4A_0 treatment combination, respectively.

Conclusion

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 salicylic acid. Among the salicylic acid levels, 0.50 mM showed the highest result in growth, physiology and yield parameters as compared to control and 1 mM concentration. Hence, to increase the yield of tomato in saline area 0.50 mM salicylic acid application is suitable.

REFERENCES

Abdelrahman, N., Shibli, R., Ereifej, K. and Hindiyeh, M. 2005. Influence of salinity on growth and physiology of in vitro grown cucumber (*Cucumis sativus* L). *Jordan J. Agric. Sci*., **1**: 93-106.

Agamy, R. A., Sayed, E. L., Hafez, F. and Tarek, H. 2013. Acquired resistant motivated by Salicylic acid applications on salt stressed tomato (*Lycopersicon esculentum* Mill). *Am-Euras. J. Agric. & Environ. Sci*., **13** (1): 50-57.

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

Ahmed, H. B., Nizar, D. W., Salma, H. M., and Zid, E. 2011. Effects of Salicylic acid on the growth and some physiological characters in salt stressed tomato plants (*Solanum Lycopersicum*). *J. Life Sci*., **5**: 838-843.

Ahmed, A. M., Latifa, A. K., Hana, A. M. and Khan, M. 2010. Effect of salinity stress on growth of lettuce under closed recycle nutrient film technique. *Int. J. Agric. Biol*., **12**: 3

Ahmed, N. U., Nashir, U. M., Zannat, F. and Shyam, C. H. 2016. Effect of different salinity level on tomato (*Lycopersicon esculentum*) production under climate change condition in Bangladesh. *Annu. Rev. Plant Biol.,* **13**(3): 1-9.

Ahmed, P., Sharma, S. and Umar, S. 2008. Salt stress and phyto biochemical response of plants. *Plant Soil Environ*., **54**(3): 89-99.

Alam, A. K. M. S. 2013. Effects of different salinity level on growth and yield of five onion varieties. MS Thesis, Department of Horticulture, Bangladesh Agricultural University, Bangladesh. P. 95

Ali, Y., Aslam, Z., Ashraf, M. Y. and Tahir, G. R. 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *Int. J. Environ. Sci. Technol.*, **1**(3): 221-225.

Ali, U., Ahmet, K., Gulu, Z., Duygu, K., Engin Y. and Donald, L. S. 2007. Effects of salinity on eggplant growth and evapotranspiration. *Irrig. Drain.*, **59**(2): 203–214.

Aliu, Sali., Imer, R. Shukri, Fetah., Bekim, G., Emilija S., and Ludvik R. 2011. The effect of salt stress on the germination of maize (*Zea mays* L.) seeds and photosynthetic pigments. *Acta Agric. Slov.*, **10** (1): 85 – 94.

Ananieva, E. A., Christov, K. N. and Popova, L. P. 2004. Exogenous treatment with salicylic acid leads to increased antioxidant capacity in leaves of barley plants exposed toparaquat. *J. Plant Physiol.*, **161**: 319–328.

Anastasia, E. and Ilias, I. F. 2013. The effect of water stress and salinity on growth and physiology of tomato plant *(Lycopersicon esculentum* Mill*.)*. *Arch. Biol. Sci*., **65** (2): 611-620.

Apel, K. and Hirt, H. 2004. Reactive oxygen species: metabolism, oxidative stress and signal transduction. *Annu. Rev. Plant Biol*., **55**: 373-399.

Arfan, M., Athar, H. R. and Ashraf, M. 2007. Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress?. *J. Plant Physiol*., **164**(6): 685-694.

Arzandi, B. 2014. The effect of Salicylic acid different levels on two *Coriandrum sativum* varieties under deficit irrigation condition. *Euro. J. Zool. Res.,* **3** (1): 118-122.

Ashraf, M. 2009. Biotecnological approach of improving plant salt tolerance using antioxidants as markers. *Biotecnol. Adv*., **27**: 84-93.

Ashraf, M. and Mcneilly, T. 2004. Salinity tolerance in brassica oilseeds. *Crit. Rev. Plant Sci*., **23**(2): 157-174.

Azooz, M. M. 2009. Salt stress mitigation by seed priming with salicylic acid in two faba bean genotypes differing in salt tolerance. *Int. J. Agric. Biol*., **11**: 343-350.

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

BBS. 2016. Yearbook of Agricultural Statistics. Bangladesh Bureau of Statistics, Ministry of Planning, Government of People's Republic of Bangladesh. p. 41.

Bhatt, M. J., Ashish, D., Pran, M., and Pandey, A. N. 2008. Effect of soil salinity on growth , water status and nutrient accumulation in seedlings of *Ziziphus mauritiana*. *J. Fruit Ornam. Plant Res*., **16**: 383-401.

Biabani, A., Hamideh, H. and Mosarreza, V. 2013. Salinity effect of stress on germination of wheat cultivars. *Int. J. Agric. Food Sci. Technol.,* **4**(3): 263-268.

Botella, M. A., Amor, F. D. and Cerda, A. 2000. Salinity effect of the physico-chemical parameters in tomato. *Plant Physiol.,* **109**(4): 428-434.

Butt, M., Ayyub, C. M., Amjad, M. and Ahmad, R. 2016. Proline application enhances growth of chili by improving physiological and biochemical attributes under salt stress. *Pak. J. Agril. Sci*., **53**(1): 43-49.

Chakrabarti, N. and Mukherji, S. 2002. Growth regulator mediated changes in leaf area and metabolic activity in mungbean under salt stress condition. *Indian J. Plant Physiol.*, **7**(3): 256-263.

Cho, J. Y. and Chung, S. J. 1997. Effects of salinity in nutrient solution during seedling stage and transplanting on the growth and development of aeroponically grown tomato. *Korean J. Hort. Sci. Technol.*, **38**(6): 647-653.

Csiszar, J., Horvath, E., Vary, Z., Galle, A., Bela, K., Brunner, S. and Tari, I. 2014. Glutathione transferase supergene family in tomato: Salt stress-regulated expression of representative genes from distinct GST classes in plants primed with salicylic acid. *Plant Physiol. Biochem.*, **78**: 15–26.

Datta, J. K., Nag, S., Banergee, A. and Mondal, N. K. 2009. Impact of salt stress on five varieties of Wheat(*Triticum aestivum* L.) cultivars under laboratory condition. *J. Appl. Sci. Environ*., **13**(3): 93 – 97.

Eraslan, F., Inal, A., Gunes, A. and Alpaslan, M. 2007. Impact of exogenous salicylic acid on the growth, antioxidant activity and physiology of carrot plants subjected to combined salinity and boron toxicity. *Sci. Hortic*., **113**: 120-128.

Fariduddin, Q., Hayat, S. and Ahmad, A. 2003. Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity, and seed yield in *Brassica juncea*. *Int. J. Photosynthetic Res.*, **41**: 281-284.

Fathy, E. l., Rahman, A. B. D. and Khader, Z. M. A. 2003. Response of eggplant to foliar spray of salicylic acid to induce better internal K and sugars case towards better growth and productivity. *J. Agric. Sci.*, **28** (4): 2935-2954.

Gemes, K., Peter, P., Zita, S., Agnes, S., Margit, S., and Irma, T. 2008. Role of Salicylic acid pre-treatment on the photosynthetic performance of tomato plants (*Lycopersicon esculentum* Mill.) under salt stress. *Acta Biol. Szeged*., **52**(1):161-162.

Gharib, F. A. E. 2007. Effect of salicylic acid on the growth and metabolic activities and oil content of basil and marjoram. *Int. J. Agric. Biol*., **9** (2): 294-301.

Ghosh, P. K., Subhash, C., Koh-ichiro A., Akihito, K. and Masanori, T. 2001. Effect of salt stress on some chemical components and yield of potato. *J. Soil Sci. Plant Nutri.,* **47** (3): 467-475.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedure for agricultural research. Second edn. *Int. Rice Res. Inst*., John Wiley and Sons. New York. pp. 207-215.

Gunes, A., Inal, A., Alpaslam, M., Erslan, F., Bagsi, E. G. and Cicek, N. 2007. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. *J. Plant Physiol.*, **164**: 728-736.

Gutierrez, M. A., Trejo-Lopez, C. and Largue-Saavedra, A. 1998. Effects of salicylic acid on growth of roots and shoots in soybean. *Plant Physiol. Biochem*., **6**(1): 92-99.

Ghogdi, A. E., Izadi, D. A. and Borzouei, A. 2012. Effects of salinity on some physiological traits in wheat (*Triticum aestivum* L.) cultivars. *Indian J. Sci. Technol*., **5**: 1.

Hadi, H., Najafabadi, A. and Amirnia, R. 2014. Comparison of different treatment methods of salicylic acid on some physiological traits of white bean under salinity stress. *J. Plant Physiol*., **3**: 97- 105.

Hakim, M. A., Juraimi, A. S., Hanafi, M. M., Ismail, M. Y., Rafii, M. M., and Selamat, A. 2014. The effect of salinity on growth, ion accumulation and yield of rice varieties. *J. Anim. Plant Sci*., **24**: 3.

Hamada, A. M. and Al-Hakimi, A. M. A. 2005. Salicylic acid versus salinity-drought induced stress on wheat seedling. *Int. J. Agric. Sci. Technol*., **47**: 444-450.

Hasanuzzaman, M., Hossain, M. A., Silva, J. A. T. and Fujita, M. 2012. Plant responses and tolerance to abiotic oxidative stress: antioxidant defenses are key factors. **In**: Bandi, V., Shanker, A. K., Shanker, C. and Mandapaka, M. (eds.) Crop stress and its management: perspectives and strategies. Springer, Berlin. pp. 261–316.

Hassan, E R., Farshid, A., Mohammadreza K., Mojtaba, R., Ebrahim, A. and Ozra, Y. F. 2010. The effects of salinity at different growth stage on rice yield. *Irrig. Drain*., **56**: 3.

Hayat, Q., Hayat, S., Irfan, M. and Ahmad, A. 2010. Effect of exogenous salicylic acid under changing environment. *Environ. Exp. Bot.*, **68**: 14-25.

He, Y. and Zhu, Z. J. 2008. Exogenous salicylic acid alleviates NaCl toxicity and increases antioxidative enzyme activity in *Lycopersicon esculentum*. *J. Plant Biol*., **52**: 792-795.

Homma, S. 2016. Effect of salinity stress on growth parameters of potato genotypes. *Afr. J. Basic Appl. Sci*., **8** (4): 185-192.

Horchani, F., Hajri, R., Khayati, H. and Smiti, S. A. 2010. Physiological responses of tomato plants to the combined effect of root hypoxia and NaCl salinity. *J. Phytol*., **2**(11): 36–49.

Horvath, J. K., Guo, B., Liang, Y. and Zhu, Y. 2007. Does salicylic acid regulate antioxidant defense system, cell death, cadmium uptake and partitioning to acquire cadmium tolerance in rice? *J. Plant Physiol.*, **166**: 20-31.

Horvath, K., Erdei, L., Deer, A. K., Simon, M. L. and Tari, I. 2005. Role of salicylic acid pre-treatment on the acclimation of tomato plants to salt and osmotic stress. *Acta Biol*. *Szeged*, **49:**123-125.

Islam, M. T., Ara, M. I., Hossain, M. A., Sen, A. K. and Dutta, R. K. 2011. Identification of tomato genotypes for salt tolerance. *Int. J. Sustain. Crop Prod.*, **6**(1): 17-21.

Islam, M. T., Jahan, N. A., Sen, A. K. and Pramanik, M. H. R. 2012. Effects of salinity on morpho-physiological attributes and yield of lentil genotypes. *Int. J. Sustain. Crop Prod.*, **7**(1): 12-18.

Jamil, A., Riaz, S., Ashraf, M. and Foolad, M. R. 2011. Gene expression profiling of plants under salt stress. *Crit. Rev. Plant Sci*., **30**(5): 435–458.

Jayakannan, M., Bose, J., Babourina, O., Rengel, Z. and Shabala, S. 2013. Salicylic acid improves salinity tolerance in Arabidopsis by restoring membrane potential and preventing salt-induced K^+ loss via a GORK channel. *J. Exp. Bot*., **64**: 2255-2268.

Kalhoro, N. A., Rajpar, I., Kalhoro, S. A., Ali, A., Raza, S., Ahmed, M., Kalhoro, F. A., Ramzan, M. and Wahid, F. 2016. Effect of salts stress on the growth and yield of wheat (*Triticum aestivum* L.). *Am. J. Plant Sci*., **7**: 225-227.

Kang, G., Wang, C., Sun, G. and Wang, Z. 2003. Salicylic acid changes activities of H_2O_2-metabolizing enzymes and increases the chilling tolerance of banana seedlings. *Environ. Exp. Bot*., **50**(1): 9-15.

Kaplan, M., Kadiroglu, A., Dureceylan, M. E., Sener, H. R., Tuzel, Y., Burnage, S. W., Balicy, B. J. and Tuncay, O. 1999. Effects of salinity fertilization on tomato. *Acta Hort.,* **49:** 277-282.

Karen, W., Anthony, R. Y. and Timothy, J. F. 2002. Effects of salinity and ozone, individually and in combination on growth and ion contents of two chickpea (*Cicer aritinum* L.) varieties. *Environ. Pollut*., **120** (2): 397–403.

Karlidag, H., Yildirim, E. and Metin, T. 2009. Salicylic acid ameliorates the adverse effect of stress on strawberry. *J. Agric. Sci*., **4**: 180-187.

Katalin, G., Peter, P., Sulyok, Z. and Agnes, S. 2008. Role of salicylic acid pre-treatment on the photosynthetic performance of tomato plants (*Lycopersicon esculentum* Mill. L. cvar. Rio Fuego) under salt stress. *Acta Biol. Szeged.,* **52**(1): 161-164.

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

Kaydan, D., Yagmur, M. and Okut, N. 2007. Effects of salicylic acid on the growth and some physiological characters in salt stressed wheat (*Triticum aestivum* L.). *J. Agric. Sci*., **13**(2): 114-119.

Kazemi, M. 2014. Foliar application of salicylic acid and methyl jasmonate on yield, yield components and chemical properties of tomato. *Jordan J. Agric. Sci*., **10**(4): 771-778.

Khan, M. I. R., Asgher, M. and Khan, N. A. 2014. Alleviation of salt-induced photosynthesis and growth inhibition by salicylic acid involves glycinebetaine and ethylene in mungbean (*Vigna radiata* L.). *Plant Physiol. Biochem*., **80**: 67-74.

Khan, N. A, Syeed, S., Masood, A., Nazar, R. and Iqbal, N. 2010. Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. *Int. J. Plant Biol*., **1**: 1-8.

Khodarahmpour, Z., Mansour, I. and Motamedi, M. 2011. Effects of NaCl salinity on maize (*Zea mays* L.) at germination and early seedling stage. *Afr. J. Biotechnol*., **11**(2): pp. 298-304.

Khodary, S. E. A. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-Gstressed maize plants. *Int. J. Agric. Biol*., 6: 5-8.

Klessing, D. F. and Malamy, J. 1994. The salicylic acid signal in plants. *Plant Mol. Biol*., **26**: 1439-1458.

Kumar, D., Kumar, A., Sarkar, S., Mohodi, D., Thakuria, P. and Das, J. 2015. Optimal design of flow rate in drip irrigation system to enhance the tomato cultivation. *Int. J. Agril. Environ. Biotechnol.*, **8**(1): 11-19.

Larkindale, J. and Huang, B. 2005. Effects of abscisic acid, salicylic acid, ethylene and hydrogen peroxide in thermotolerance and recovery for creeping bentgrass. *Plant Growth Regul*., **47**: 17-28.

Lee, H. I., Leon, J. and Raskin, I. 1995. Biosynthesis and metabolism of salicylic acid. *Proc. Natl. Acad. Sci*., **92**: 4076-4079.

Lee, S., Kim, S. G. and Park, C. M. 2010. Salicylic acid promotes seed germination under high salinity by modulating antioxidant activity in *Arabidopsis*. *New Phytol*., **188**: 626-637.

Li, G., Peng, X., Wei, L. and Kang, G. 2013. Salicylic acid increases the contents of glutathione and ascorbate and temporally regulates the related gene expression in the salt stressed wheat seedlings. *J. Plant Physiol.,* **529**: 321–325.

Liu, H. T., Huang, W. D., Pan, Q. H., Weng, F. H., Zhan, J. C., Yan, L., Wan, S. B. and Liu, Y. Y. 2006. Contributions of PIP2-specific-phospholipase C and free salicylic acid to heat acclimation- induced thermo tolerance in pea leaves. *J. Plant Physiol*., **163**(4): 405-416.

Mady, M. A. 2009. Effect of foliar application with salicylic acid and vitamin E on growth and productivity of tomato (*Lycopersicon esculentum,* Mill.) plant. *J. Agric. Sci*., **34** (6): pp. 6735 – 6746.

Miguel, S., Gutierrez, R. M. and Larque, S. A. 2002. Low concentrations of salicylic acid increase nitrate accumulation in roots of *Pinus patula*. *Int. J. Exp. Bot*., **51**: 79-82.

Mohsina, H., Ashraf, M. Y., Rehman, K. U. and Arashad, M. 2008. Influence of salicylic acid seed priming on growth and Some biochemical attributes in wheat grown under saline conditions. *Pak. J. Bot.,* **40**(1): 361-367.

Munns, R. and Tester, M. 2008. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol,*. **59**: 651–681.

Noreen, S., Ashraf, M. H. and Jamil, A. 2009. Exogenous application of salicylic acid enhances antioxidative capacity in salt stressed sunflower (*Helianthus annuus* L.) plants. *Pak. J. Bot*., **41**: 473-479.

Olympios, C. M., Karapanos, I. C., Lionoudakis, K. and Apidianakis, I. 2003. Growth, yield and qualitiy of greenhouse tomatoesin relation to salinity applied at different stages of plant growth. *Acta Hort*., **609**: 313-320.

Patil, S. L., Hunshal, C. S., Nadagouda, B. T., Kori, R. N. and Salakinakop, S. R. 1996. Dry matter accumulation in lentil as influenced by saline water irrigation. *J. Adv. Agril. Res*., **6**: 78-87.

Pirlak, L. and Esitken, A. 2004. Salinity effects on growth, proline and ion accumulation in strawberry plants. *J. Plant Nutri. Soil Sci*., **54**: 189-192.

Rameeh, V. and Mahyar, G. 2015. The Soil salinity effects on phenological traits, plant height and seed yield in rapeseed genotypes. *Soil Sci. Annu*., **66**(1): 17-25.

Ramoliya, P. J. and Pandey, A. N. 2007. Soil salinity and water status effect on growth of seedlings of *Zizyphus mauritiana* (Rhamnaceae). *J. Fruit Ornam. Plant Res*., **16 :** 383-401.

Raul, L., Andres, O., Armado, L., Bernardo, M. and Enrique, T. 2003. Response to salinity of three grain legumes for potential cultivation in arid areas. *Soil Sci. Plant Nutri*., **49** (3): 329–336.

Saide, A. S., Keutgen, A. J. and Noga, G. 2005. The influence of NaCl salinity on growth, yield and fruit quality if strawberry CVS: Elsanta and Korona. *Sci. Hortic*., **103**: 289-303.

Sakhabutdinova, A. R., Fatkhutdinova, D. R., Bezrukova, M.V. and Shakirova, F. M. 2003. Salicylic acid prevents the damaging action of stress factors on wheat plants. *Bul. J. Plant. Physiol*., **29:** 314-319.

Sardoei, A. S. and Mohammadi, G. A. 2014. Study of the effect of salinity on germination of tomato (*Lycopersicon esculentum* L.) genotypes. *Eur. J. Exp. Biol.,* **4**(1): 283-287.

Sawada, H., Shim, I. S. and Usui, K. 2006. Induction of benzoic acid 2-hydroxylase and salicylic acid biosynthesis – Modulation by salt stress in rice seedlings. *Plant Sci*., **171**: 263-270.

Shakirova, F. M., Sakhabutdinova , A. R., Bezrukova , M. V., Fathudinova , R. A. and Fathudinova , D. R. 2003. Changes in hormonal status of wheat seedling induced by salicylic acid and salinity. *Plant Sci*., **164**: 317-322.

Sharma, S. K., Cheten, V. K. and Narayana, S. 2012. The effect of salt stress on biochemicals of chilli at seedling level. *Int. J. Pharm. Res*., **3**: 3.

Sharma, S. S. and Dietz, K. J. 2009. The relationship between metal toxicity and cellular redox imbalance. *Trends. plant Sci*., **14**: 43-50.

Shi, Q. H. and Zhu, Z. J. 2008. Effects of exogenous salicylic acid on manganese toxicity, element contents and antioxidative system in cucumber. *Environ. Exp. Bot*., **63**: 317-326.

Shi, Q. H., Bao, Z., Zhu, Z. J., Ying, Q. and Qian, Q. 2006. Effects of different treatments of salicylic acid on heat tolerance, chlorophyll fluorescence, and antioxidant enzyme activity in seedlings of *Cucumis sativa. J. Plant Growth Regul*., **48**: 127-135.

Shibli, R., Kushad, M., Yousef, G. and Lila, M. 2007. The Physiological and biochemical responses of tomato micro shoots to induced salinity stress with associated ethylene accumulation. *J. Plant Growth Regul*., **51**: 159-169.

Shimul, M. A. H., Ito Shin-ichi, S., Sadia, M. Z. K. and Jamal Uddin, A. F. M. 2014. Response of tomato (*Lycoperscon esculentum*) to salinity in hydroponic study. *Bangladesh Res. Pub. J*., **10**(3): 249-254.

Siddiky, M. A., Sardar, P. K., Hossain, M. M., Khan, M. S. and Uddin, K. M. 2012. Screnning of different tomato varities in saline areas of Bangladesh. *Int. J. Agric. Res. Innov. Technol*., **2** (1): 13-18.

Siddiky, M. D., Alamqir, A. M., Shahabuddin, K. D., and Uddin, K. 2014. Performance of tomato (*Lysopersicon esculentum*) germplasms grown in Bangladesh for salinity tolerance. *J. Agril. Sci.,* **36**: 2

Singh, P. K., Shahi, S. K. and Singh, A. P. 2015. Effects of salt stress on physio chemical changes in maize plants in response of salicylic acid. *Indian J. Plant Sci.,* **4** (1): 69-77.

SRDI. 2010. Saline soils of Bangladesh. SRMAF project, Ministry of Agriculture, Govt. Peoples Republic of Bangladesh. p. 35.

Stevens, J., Senarantna, T. and Sivasithamparam, K. 2006. Salicylic acid induces salinity tolerance in tomato (*Lycopersicon esculentum* cv. Roma): associated changes in gas exchange, water relations and membrane stabilization. *J. Plant Growth Regul*., **49**: 77-83.

Tanji, K. K. 2002. Salinity in the soil environment. **In**: Lauchli, A. and Luttge, U. (eds.) Saline environment. Kluwer Academic Publishers, Dordrecht, Netherland. pp. 21-51.

Tari, I., Csiszir, J., Szalai, G., Horvath, F., Pecsvaradi, A., Kiss, G., Szepesi, A., Szabo, M. and Edrei, L. 2002. Acclimation of tomato plants to salinity stress after a salicylic acid pre-treatment. *Acta Biol. Szeged.*, **46**(3-4): 55-56.

Tayeb, M. A. 2005. Response of barley grains to the interactive effect of salinity and salicylic acid. *J. Plant Growth Regul*., **45**: 215-224.

Torabian, A. R. 2010. Effect of salicylic acid on germination and growth of alfalfa (*Medicago sativa* L.) seedlings under water potential loss at salinity stress. *J. Plant Ecophysiol*., **2**: 151-155.

Tufail, A., Arfan, M., Gurmani, A., Khan, A. and Bano, A. 2013. Salicylic acid induced salinity tolerance in maize. *Pak. J. Bot*., **45**: 75-82.

Volkamar, K. M., Hu, Y. and Steppuhn, H. 1998. Physiological responses of plants to salinity. *Can. J. Plant Sci*., **78**: 19–27.

Wilcox, J. K., Catignani, G. L. and Lazarus, C. 2003. Tomatoes and the cardiovascular health. *Food Sci. Nutri.,* **43**(1): 1-18.

Yildrim, E., Turan, M. and Guvenc, I. 2008. Effect of foliar salicylic acid applications on growth, chlorophyll, and mineral content of cucumber grown under salt stress. *J. Plant Nutri.,* **31**: 593-612.

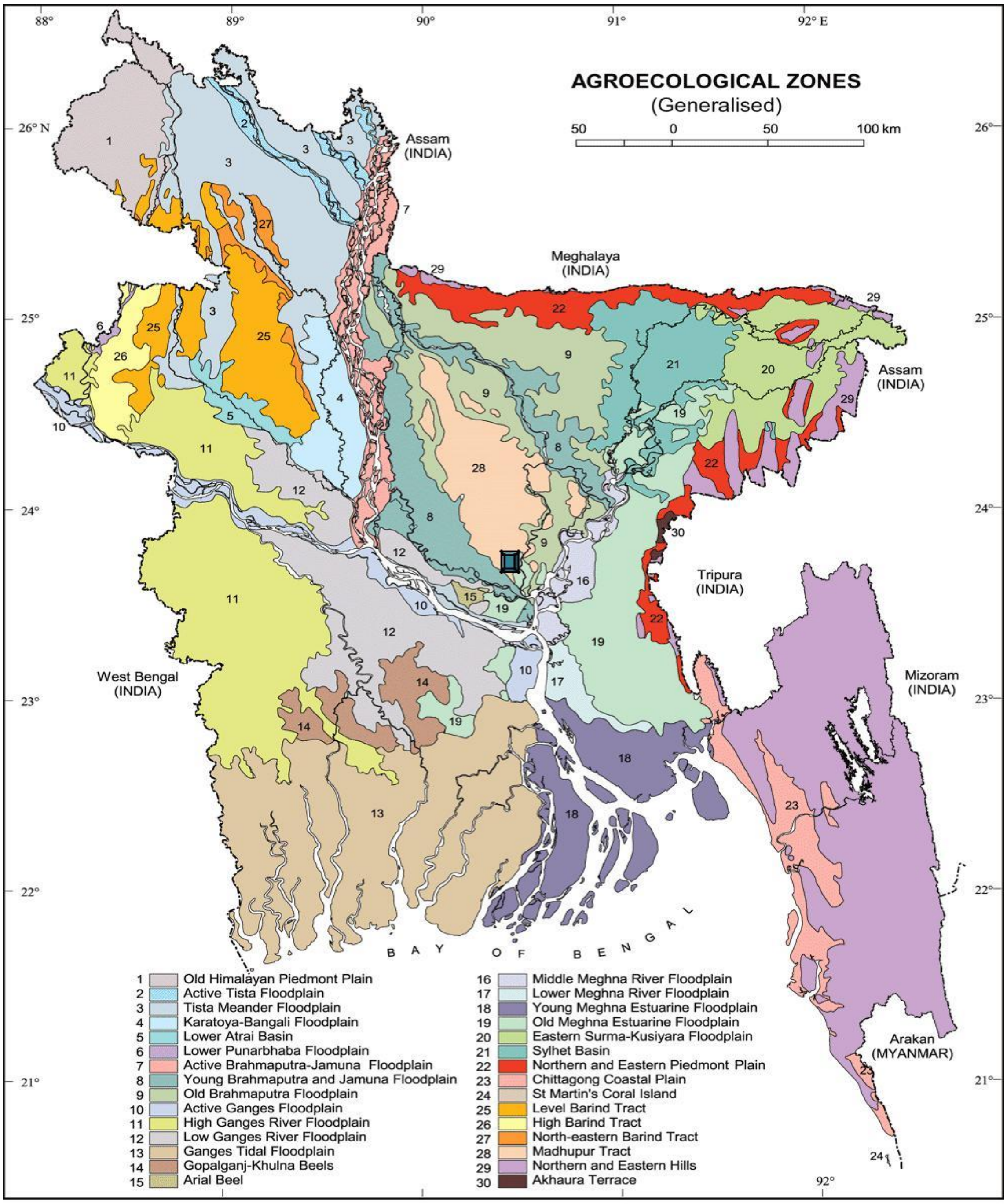
Zahra, S., Baghizadeh, A. and Ali, V. S. M. 2010. The salicylic acid effect on the tomato (*Lycopersicum esculentum* Mill.) sugar, protein and proline contents under salinity stress (NaCl). *J. Biophys. Struct. Biol*., **2**(3): 35-41.

Zeng, L. and Shannon, M. C. 2000. Salinity effects on seedling growth and yield components of rice. *Crop Sci*., **40**: 996–1003.

Zhani, K., Ben, F. M., and Cherif, H. 2012. Impact of salt stress (NaCl) on growth, chlorophyll content and fluorescence of Tunisian cultivars of chili pepper (*Capsicum frutescens* L.). *J. Stress Physiol. Biochem.,* **8** (4): 236-252.

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	6.20
Organic matter (%)	1.14
Total N (%)	0.05

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

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2016 to April 2017

Month	*Air temperature (ºc)		*Relative Humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2016	25.80	18.00	78	00	6.90
December, 2016	22.40	16.50	74	00	6.50
January, 2016	24.50	17.40	68	00	5.80
February, 2017	27.10	18.70	67	30	6.70
March, 2017	28.10	22.50	68	00	6.90
April, 2017	36.4	23.20	72	78	6.90

*Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka

Appendix IV. Analysis of variance of data on the plant height/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value		
		Plant height/plant (cm)		
		45 DAT	60 DAT	75 DAT
Replication	3	5.39	1.80	11.22
Salinity levels (A)	4	125.73*	434.31*	679.78*
Salicylic acid levels (B)	2	68.52*	96.45*	155.52*
Salinity levels (A) × Salicylic acid levels (B)	8	18.75*	8.47*	8.04*
Error	42	2.00	2.53	2.04

*= Significant at 0.05 % level of probability

Appendix V. Analysis of variance of data on the number of leaves/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value of		
		Number of leaf/plant		
		45 DAT	60 DAT	75 DAT
Replication	3	5.39	1.80	11.22
Salinity levels (A)	4	125.73*	434.31*	679.78*
Salicylic acid levels (B)	2	68.52*	96.45*	155.52*
Salinity levels (A) × Salicylic acid levels (B)	8	18.75*	8.47*	8.04*
Error	42	2.00	2.53	2.04

*= Significant at 0.05 % level of probability

Appendix VI. Analysis of variance of data on the number of branch and stem diameter/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value of				
		Branch number/plant			Stem diameter/plant (cm)	
		40 DAT	55 DAT	75 DAT	25 DAT	75 DAT
Replication	3	0.34	4.20	0.78	0.01	0.01
Salinity levels (A)	4	3.86*	25.77*	51.14*	0.01*	0.09*
Salicylic acid levels (B)	2	0.20*	23.82*	18.32*	0.01*	0.05*
Salinity levels (A) × Salicylic acid levels (B)	8	0.47*	2.88*	3.32*	0.01*	0.01*
Error	42	0.66	0.68	1.02	0.01	0.01

*= Significant at 0.05 % level of probability

Appendix VII. Analysis of variance of data on the leaf chlorophyll content, leaf area and days to first flowering/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value of			
		Leaf chlorophyll content/plant		Leaf area/plant (cm^2)	Days to first flowering/ plant
		50 DAT	75 DAT		
Replication	3	0.50	0.16	15.69	1.13
Salinity levels (A)	4	412.38*	416.23*	1608.40*	150.94*
Salicylic acid levels(B)	2	177.06*	46.53*	417.94*	32.85^{NS}
Salinity levels (A) × Salicylic acid levels (B)	8	6.34*	4.81*	121.72*	5.39*
Error	42	2.60	3.01	17.25	1.50

*= Significant at 0.05 % level of probability NS = Non Significant

Appendix VIII. Analysis of variance of data on the number of flower cluster, number of flower/cluster, dry matter content of shoot, dry matter content of fruit and flower number/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value of				
		Number of flower cluster/ plant	Number of Flower/ cluster	Dry matter content in shoot (%)	Dry matter content in fruit (%)	Flower number/ Plant
Replication	3	2.73	3.89	3.92	0.17	1.13
Salinity levels (A)	4	43.88*	4.43*	67.95*	3.71*	2759.1*
Salicylic acidlevels(B)	2	12.95^{*}	0.67^{NS}	3.41 *	0.28^{NS}	572.22*
Salinity levels (A) × Salicylic acid levels (B)	8	3.70*	0.53*	0.56*	0.07*	61.03*
Error	42	0.72	0.38	0.72	0.09	5.70

*= Significant at 0.05 % level of probability NS = Non Significant

Appendix IX. Analysis of variance of data on the fruit number, fruit length, fruit diameter, individual fruit weight, and yield/plant of tomato as influenced by combined effect of salinity levels and salicylic acid levels

Source of variation	df	Mean square value of				
		Fruit number/ Plant	Fruit length /plant (cm)	Fruit diameter /plant (cm)	Individual fruit weight/plant (gm)	Yield/ Plant (kg)
Replication	3	2.67	0.10	0.07	8.17	0.09
Salinity levels (A)	4	1180.60*	1.73*	4.11*	2657.06*	12.02*
Salicylic acid levels (B)	2	2.02*	0.36*	0.60*	124.75*	0.85*
Salinity levels (A) × Salicylic acid levels (B)	8	3.62*	0.08*	0.16*	21.21*	0.04*
Error	42	2.42	0.09	0.01	4.32	0.02

*= Significant at 0.05 % level of probability