MITIGATION OF SALT STRESS BY FOLIAR APPLICATION OF SALICYLIC ACID ON TOMATO PLANT

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CERTIFICATE

*This is to certify that the thesis entitled, "**MITIGATION OF SALT STRESS BY FOLIAR APPLICATION OF SALICYLIC ACID ON TOMATO PLANT**" submitted to the 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 **MD. SAHABUDDIN**, Registration No. 18-09030 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, 2020
Place: Dhaka, Bangladesh

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Dedicated to
my beloved parents

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ABSTRACT

A pot experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh from October, 2018 to March, 2019 to determine the mitigation of salt stress (NaCl 0, 6, 9, 12 and 15 dSm^{-1}) through salicylic acid (SA: 0, 100 and 200 ppm) in BARI Tomato- 15. The experiment was laid out in Completely Randomized Design (CRD) with three replications. SA alleviate salt stress on growth and metabolic activities of tomato plants. The data which were collected during the experiment are plant height, number of leaves, number of branches per plant, leaf area, days required for transplanting to 1^{st} flowering, SPAD value, dry matter of plant, dry matter of fruit, number of flower cluster per plant, number of flowers per cluster, number of flowers per plant, number of fruit per plant, length of fruit, diameter of the fruit, weight of individual fruit, yield per plant etc. The results revealed that, salt treatment induced drastic reduction in growth characteristics of tomato plant through decreasing the plant height, number of leaves, number of branches per plant, leaf area, days required for transplanting to 1^{st} flowering, SPAD value, dry matter of plant, dry matter of fruit, number of flower cluster per plant, number of flowers per cluster, number of flowers per plant, number of fruit per plant, length of fruit, diameter of the fruit, weight of individual fruit, yield per plant etc. In the majority of cases with the application of 100 ppm of SA caused partial decrease in the deleterious effects of salinity in all parameters of this study. The highest yield (1411.0 g $plant^{-1}$) was recorded from the application of 100 ppm of SA while the lowest yield (687.00 g $plant^{-1}$) was found from 0 ppm of SA under saline condition. From this experiment, under saline and non-saline condition 100 ppm of SA gave the best result for all the growth and yield parameters.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

FIGURES (Continued)

LIST OF APPENDICES

LIST OF ABBREVIATION AND ACRONYMS

%	=	Percent
@	=	At the rate
^0C	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
AIS	=	Agriculture Information Service
ANOVA	=	Analysis of Variance
BADC	=	Bangladesh Agricultural Development Corporation
BARC	=	Bangladesh Agricultural Researcher Council
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
CRD	=	Completely Randomized Design
CV%	=	Percentage of Coefficient of Variance
DAT	=	Days after Transplanting
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
FAO	=	Food and Agricultural Organization of the United Nations
GA_3	=	Gibberellic acid
HI	=	Harvest Index
IAA	=	Indole- Acetic acid
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Not significant
RWC	=	Relative Water Content
SRDI	=	Soil Resources and Development Institute

TSP	=	Triple Super Phosphate
UNDP	=	United Nations Development Programme
WUC	=	Water uptake capacity
SA	=	Salicylic Acid

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is one of the most important vegetable crops grown throughout the world including Bangladesh under different conditions. Tomato is a nutritious vegetable crop generally grown in the winter season (December- April) in Bangladesh. The center of origin of the genus *Solanum* is the Andean zone particularly Peru-Ecuador-Bolivian areas but cultivated tomato originated in Mexico. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato is the rich source of vitamin A, Vitamin C and minerals and it keeps eye sight good. Night blindness occurs due to lack of Vitamin A. Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). A single tomato can provide 40% of the daily requirement of Vitamin C which is a natural anti-oxidant. Tomatoes are rich with Vitamin K which plays a major role in blood clotting.

Tomato ranks top of the list of canned vegetables and next to potato and sweet potato in the world vegetable production (FAO, 2012). The present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia (FAO, 2010). Now Bangladesh is producing a good amount of tomatoes. In Bangladesh it is mainly cultivated as winter vegetable, which occupies an area of 69,697 acres in 2018-2019 (BBS, 2019). But Various abiotic environmental stresses such as drought, high or low temperature, salinity, flooding, metal toxicity, etc., which pose serious threat to world agriculture. It has been reported that abiotic stresses reduced the crop growth and yield more than 50% among which salinity is one of the most brutal environmental factors which is increasing day by day due to anthropogenic activities and hamper the agricultural productivity including tomato (Tanji, 2002). Salinity is one of the major abiotic stress factors that limit the plant growth as well as fruit yield. It induces osmotic and toxic effects leading to physiological, morphological and biochemical modifications; it causes growth inhibition, crop yield reduction, lower rate of photosynthesis and respiration, nutritional deficiencies and inhibition of protein synthesis (Ashraf and Foolad, 2007).

Salinity is a major environmental constraint limiting yield of crop plants in many semi-arid and arid regions. The initial and primary effect of salinity, especially at low to moderate concentrations, is due to osmosis (Munns and Termaat, 1986). Most crops tolerate salinity up to a threshold level, above which yields decrease as salinity increases (Maas, 1986). Plant salt tolerance is generally thought of in terms of the inherent ability of the plant to withstand the effects of high salt concentration in the rhizosphere or in the leaves without significant adverse consequences. Maintenance of growth rate, preserving nutrients, avoiding ion toxicities, and inducing metabolite changes that improve water balance are probably the most common and universal characteristics of salt-tolerant plants. Tomato is one of the world's most important and widespread crops with adverse effects of salinity (Bradbury and Ahmad, 1990; Liang *et al*., 1996). Salinity reduced tomato yield (Sonnenveld and Welles, 1988), but improved fruit quality traits, such as total soluble solids and colour (Martinez *et al*., 1987). Large differences are apparent in tolerance of different varieties of tomatoes. A distinctive difference in salt tolerance was obtained with fresh market cultivated tomatoes (Alian *et al*., 2000). Whereas the salicylic acid (SA), an endogenous plant growth regulator has been found to generate a wide range of metabolic and physiological responses in plants thereby affecting their growth and development (Hayat *et al*., 2010). The roles of SA in defense mechanism to alleviate salt stress in plants (Afzal *et al*., 2006; Hussein *et al*., 2007) were observed. Considering the situation, the research was conducted with following objectives:

Objectives:

- To investigate the individual effects of salinity and salicylic acid on changes of morpho-physiology and yield of tomato;
- To investigate the interaction effects of salinity and salicylic acid on changes of morpho-physiology and yield of tomato;
- To find out the best levels of salicylic acid on alleviation of salt stress in tomato.

CHAPTER II
REVIEW OF LITERATURE

Tomato is one of the most important vegetable crops in Bangladesh and other countries of the world and it has drawn attention by the researchers for its various way of consumptions. Salinity is a great problem in the coastal region of Bangladesh, where a vast area remains fallow for long time. Tomato is an important crop plant which supply Vitamin C as well as used as a vegetable by the people of Bangladesh. It is a great source of Vitamin C for poor people of the coastal area. Very limited research works have been conducted to adapt tomato crop 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 saline stressed tomato plants. To facilitate the research works different literatures have been reviewed in this chapter under the following headings.

2.1 Effect of salinity on morphological characters of plant

Nawaz *et al.* (2010) reported that applications of salt in the growth medium caused reduction in shoot length of sorghum cultivars. Under saline conditions 50 mM proline was more effective to reduce the effect of NaCl than 100 mM proline in both cultivars. Proline level 50 mM showed 26.58% and 11.78% increased shoot length as compared to NaCl stresses plants. However, high concentration of proline (100 mM) was not so much effective as compared to low concentration i.e. 50 mM.

Mohammad *et al.* (1998) conducted a pot experiment of Tomato where Tomato seedlings (cv. riogrande) were grown in 500 ml glass jars containing Hoagland's solutions which were salinized by four levels of NaCl salt (0, 50, 100 and 150 mM NaCl) and/or enriched with three P levels (0.5, 1 and 2 mM P) making nine combination The results indicate that increasing salinity stress was accompanied by significant reductions in shoot weight, plant height, number of leaves per plant.

Memon *et al*. (2007) conducted a pot experiment on silty clay loam soil at Sindh Agriculture University, in Tando Jam, Pakistan. Sarokartuho variety of Sorghum (*Sorghum bicolor* L.) was continuously irrigated with fresh (control) and marginally to slightly saline EC 2, 3, 4 and 5 (dSm^{-1}) waters. Increasing water salinity progressively decreased plant height and fodder yield (fresh and dry weight) per plant. Javaid *et al*. (2002) investigated the salinity effect (0, 20, 50 and 75 mM NaCl) on plant height in four rice variety and reported that salinity affects the morphological characters of the studied plants and plant height decreased with increased salinity levels. Similar results were also reported by Uddin *et al.* (2005) in twenty-nine Ethiopian mustard (*Brassica carinata*) and in *B. campestris*.

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

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

Hasanuzzaman *et al.* (2009) observed a significant reduction in germination rate of 4 rice cultivars when exposed to various concentration of salt (30-150 mM). However, the sensitive cultivars were more prone to germination reduction under salt stress. In *Vigna radiata*, germination percentage decreased up to 55% when irrigated with 250 mM NaCl (Nahar and Hasanuzzaman, 2009). In a recent study, Kumar *et al*. (2012) observed drastic reduction in germination rate (32%), length of radicle (80%) and plumule (78%), seedling length (78%) and seed vigour (95%) when *Zea mays* seeds were exposed to 240 mM NaCl.

Soil salinity affects the growth of rice plant. But the degree of deleterious effect may vary on the growth stages of plant. During germination rice is tolerant, but it becomes very sensitive during the early seedling stage. Similar result was also reported by many workers in rice (Linghe *et al*., 2000; Burman *et al.,* 2002; Weon Young *et al*., 2003; Islam, 2004; Rashid, 2005; Karim, 2007).

Munns (2005); Munns and Tester (2008) reported that salt-induced osmotic stress is the major reason of growth reduction at initial stage of salt stress, while at later stages accumulation of Na^+ occurs in the leaves and reduces plant growth.

Angrish *et al*. (2001) conducted a pot experiment and observed that increasing levels of chloride (0-12 dSm^{-1}) and sulfate salinity decreased leaf number of wheat plants. Similarly, Khan *et al*. (1997) reported that leaf number and leaf area were seriously decreased by salinity in rice.

Babu and Thirumurugan (2001) conducted a pot experiment to study the effect of salt priming on growth and development of sesame under induced salinity condition. Salinity was induced by addition of 35, 70 and 140 mM NaCl solution to create three levels of salinity and observed that plant height decreased with the increased salinity level.

Two varieties were grown under salinity levels of 0, 5, 10 and 15dSm^{-1}. Salinity, irrigation frequency and variety significantly affected the number of ratoon tillers. The number of tillers declined with increase in salinity and with less frequent irrigation. Speed feed variety produced a higher number of tillers than KFS4. Parti *et al*. (2002) conducted an experiment where salinity levels of 4, 8 and 12 dSm^{-1} were obtained from adding chloride and sulphate salts of sodium, calcium and magnesium. Chakraborti and Basu (2001) conducted a pot experiment to study the effect of salinity (0, 6 and 9 dSm^{-1}) on growth and development of sesame under induced salinity condition and observed that number of leaves decreased with the increased salinity level.

Alaa El-Din Sayed Ewase (2013) conducted a pot experiment to observe the effect of salinity stress on plants growth of Coriander (Coriandrum sativum L.). He used four treatments of different concentrations of NaCl namely 0, 1000, 2000, 3000 and 4000 ppm. The Obtained results showed that plant length, number of leaves, roots number and length were reduced by increasing the NaCl concentration and Coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

Kandil *et al.* (2012) conducted a laboratory experiment to study the performance of mungbean to salinity stress with salinity tolerance of two mungbean varieties (Kawmy-1 and IV 2010) to eight salinity levels i.e. 0, 2, 4, 6, 8, 10, 12 and 14 dS/m of NaCl concen-trations. Mungbean (*Vigna radiate* L.) Wilczek varieties were compared for germination efficiency and seedling characters. The obtained results suggested that the two varieties registered a decrease in the percentage of germination and seedlings growth at higher NaCl concentrations. Results clearly indicated that mungbean Kawme-1 variety appeared to be more tolerant to salt stress than IV 2010 variety recording higher germination parameters and seedling characters. Increasing salinity concentrations significantly reduced germination percentage, seedling vigor index, coefficient of velocity, mean germination time, shoot and root length, shoot and root fresh and dry weight. It could be concluded that germination efficiency i.e. final germination percentage, germination index, energy of germination, mean germination time, abnormal seed percentage, root and shoot length, seedling total fresh and dry weight, dry weight reduction and shoot length reduction were gradually decreased significantly when salinity increased.

Crop performance may be adversely affected by salinity as a, result of nutritional disorders. These disorders may derive from the effect on nutrient availability, competitive uptake, transport or partitioning within the plant (Silva *et al.*, 2008).

Plant height is an important growth index of plant. In general, when salinity stress occurs, plants become stunted as a result of reduced rate of leaf surface expansion. The differences of plant height and number of leaves due to salt stress were found to be distinctively significant in mungbean (Raptan *et al.*, 2001).

Hajer *et al*. (2006) have also reported reduction in plant height, fresh and dry vegetative biomass in three tomato cultivars grown under sea water salinity. High salinity reduced plant height, primary and secondary branches number of leaves and leaf area, yield and yield attributes of the crop.

Jampeetong and Brix (2009) and Gorai *et al.* (2010) reported that, various plant growths and development processes viz. seed germination, seedling growth, flowering and fruiting are adversely affected by salinity, resulting in reduced yield and quality.

BINA (2008) studied the screening of wheat varieties for growth and yield attributes contributing to salinity tolerance and reported that wheat varieties of high yielding and tolerant group recorded a higher value of number of effective tillers plant$^{-1.}$

The salinity sensitivity of mungbean was studied by Amira and Abdul (2010) to determine the effect of salinity on vegetative growth (plant dry weight and plant height), yield components (plant height, pods number, pods weight, seeds number/pod, seeds weight/plant and biological yield/plant), nutritional value of produced seeds (N, P, K, Ca, Mg, Na, Cl, soluble carbohydrate, polysaccharides, total carbohydrate, proline, total amino acids and protein contents) and mineral contents in green shoot at harvest (N, P, K, and Na). Also, the role of arginine in alleviating the effect of salinity stress was studied. Munbean seeds were planted in soils of different salinity levels. The concentration of the irrigation water used in this experiment were (0, 15000, 3000, 4500 and 6000 ppm). All growth parameters were significantly reduced with high salinity levels (4500 and 6000 ppm) while 1500 and 3000 ppm induced slight increase. Salinity stress also, induced significant increases in Na, Cl, Ca and Mg and decreased significantly N, P, and K contents. Salinity stress reduced most yield components and nutritional value of produced seeds. However, spraying plants with arginine could alleviate the harmful effect of salinity at all studied parameters.

Eisa (2012) conducted an experiment where *Chenopodium quinoa* plants were grown in a hydroponic quick check system with 0, 100, 200, 300, 400, and 500 mM NaCl (equivalent to 0, 20, 40, 60, 80 and 100% seawater salinity). Higher salinities considerably reduced plant growth, with maximum reduction of 82% observed at 500 mM NaCl. The plants were able to reduce the leaf water potential below the soil water potential. This was associated with substantial decrease in osmotic potential mainly by Na^+ and Cl^-. The net photosynthesis rates were greatly decreased by high salinity, being 28% of initial control values at 500 mM NaCl. Salt-induced photosynthesis inhibition was accompanied with a decrease in transpiration rates but also with improved water use efficiency. Salt-induced growth reduction is presumably due to low photosynthate supply as a consequence of impaired photosynthetic capacity. Hu and Schmidhalter (1997) showed that salinity significantly increased sodium and chloride concentration in leaves and stems of wheat, while the concentration of K^+, Ca^{2+}, Mg^{2+} and NO^{3-} decreased. Both K^+ and Ca^{2+} are required in the external growth medium to maintain the selectivity and integrity of the cell membrane. Soil salinity affects plant growth and development by way of osmotic stress, injurious effects of toxic Na^+ and Cl^- ions and to some extend Cl^- and SO_4^{2-} of Mg^{2+} and nutrient imbalance caused by excess Na^+ and Cl^- ions.

Effects of Salinity on physiological and biochemical parameters

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil. One of the initial effects of salt stress on plant is the reduction of growth rate. First, the presence of salt in the soil reduces the water uptake capacity of the plant, and this causes quick reduction in the growth rate. This first phase of the growth response is due to the osmotic effect of the soil solution containing salt, and produces a package of effects similar to water stress (Munns 2002; Nahar *et al*., 2009).

Singh and Sharma (2013) studied the response of antioxidant enzyme activities in seedlings of different sorghum cultivars under mannitol stress. Seven-day old seedlings were subjected to 100-500 mM mannitol stress which resulted in the decreases in shoot/root length and relative water content thus indicating the primary response to these tissues at phenotypic level. The level of lipid peroxidation as well as the specific activity of antioxidant enzymes such as peroxidase, catalase and superoxide dismutase increased at higher conc. except at 200 mM conditions. The level of catalase and peroxidase decreased at 500 mM concentration in the two different cultivars whereas the activity of superoxide dismutase consistently increased in response to the mannitol stress. They demonstrated that drought responsiveness tolerance in sorghum cultivars during germination is associated with enhanced activity of antioxidant enzymes.

The decrease in chlorophyll may be attributed to increased chlorophyllase activity. Decrease in chlorophyll content under salt stress could be due to the effect on membrane stability (Bidel *et al*., 2007). Similar results were reported for total leaf concentration of cucurbits species and lentil plant (Tester and Davenport, 2003).

Sairam *et al*. (2005) indicated that NaCl decreased relative water content, chlorophyll content and membrane stability index. Madan et al (2004) reported that salinity stress marginally decreased the rate of photosynthesis and chlorophyll content in the salt tolerant varieties however the sensitive ones showed greater reduction in cowpea. Under the influence of salinity, the photosynthetic pigments greatly decreased. Salt stress had toxic effects on plants and causing metabolic changes, like loss of chloroplast activity, decreased photosynthetic rate and increased photorespiration rate which then led to an increased reactive oxygen species (ROS) production (Parida and Das, 2005).

Effect of salinity on yield and yield contributing characters of plant:

Prakash and Chen (2010) observed that all the physiological properties and yield were negatively affected by increasing salinity levels due to less water use and radiation interception. Compared to the low salinity level, medium and high salinity levels reduced the above-ground dry weight of the crop at harvest by 40 and 41%, accumulated intercepted radiation by 23 and 37%, radiation use efficiency by 25 and 52%, water use by 18 and 35% and grain yield by 41 and 48%, respectively.

Rafat and Rafiq (2009) reported that, total chlorophyll content in tomato plant proportionally decreased with the increase in salinity levels up to 0.4% sea salt solution (EC 5.4 dSm^{-1}).

Karim (2007) conducted an experiment to investigate the effect of different salinity levels (0, 6, 9 and 12 dSm^{-1}) and reported that all parameters including panicle length decreased with increased salinity levels. Panicle length was adversely affected by soil salinity levels as reported by most of the researchers (Islam *et al.*, 1998; Hossain, 2002; Islam, 2004 and Rana, 2007).

Decrease in various yield contributing parameters viz., pods per plant, 100-grain weight and seed yield was recorded in blackgram and mungbean grown at different levels of salinity (Raptan *et al.*, 2001). Also, dry matter yield per plant decreased significantly with increase in salinity levels regardless of the stages of growth in mungbean (Hafeez *et al.*, 1988). The 100-seed weight also fell drastically with increased salinity indicating a significant difference among genotypes and salinity levels (Ahmad *et al.*, 2005).

The increasing salinity, decreased all the seed characteristics of economic yield that is number of pods per plant, number of seeds per pod, 100-seed weight, total seed yield per plant in all the genotypes of mungbean at maturity (Shakil, 2009). The harvest index value significantly decreased within increase of salinity over control. The highest (28.56) and lowest (23.60) harvest index were in control and 7.82 dS m^{-1} level of salinity. Mean number of pods and grains per plant. Mean grain weight and grain yields per plant of soybean cultivars under non-saline conditions were considerably higher than those under saline conditions. These traits decreased as salinity increased (Ghassemi-Golezani *et al.*, 2009).

2.2 Role of Salicylic Acid to mitigate the saline toxicity:

Exogenously sourced SA to stressed plants, either through seed soaking, adding to the nutrient solution, irrigating, or spraying was reported to induce major abiotic stress tolerance mechanisms (Horváth *et al.*, 2007; Khan *et al.*, 2012; Anwar *et al.*, 2013 and Palma *et al.*, 2013). SA influences plant functions in a dose dependent manner, where induced or inhibited plant functions can be possible with low and high SA concentrations, respectively. For example, in *Matricaria chamomilla,* 50 and 250 µM SA concentrations were reported to, respectively, promote and inhibit growth (Kováčik *et al.*, 2009). In another instance, 0.1 and 0.5 mM SA promoted photosynthesis and growth of *Vigna radiata* but an inhibited growth was evidenced with 1.0 mM SA (Nazar *et al.*, 2011). Besides the concentration of SA, the duration of the treatment, plant species, age, and treated plant organ can also influence the SA-effects in plants (Shi *et al.*, 2009; Miura and Tada, 2014).Two varieties (Deli Kabul and Kasuri) were grown in salt treated (100 mM NaCl) and untreated (0 mM NaCl) growth medium. Results showed that higher shoot fresh weight was recorded in Deli Kabul, while lower in Kasuri. Such reduction in growth biomass was mitigated by the foliar application of SA in both plants. Salinity caused net CO_2 assimilation rate, transpiration rate, stomatal conductance, and substomatal CO_2 concentration. Exogenous applied salicylic acid also overcomes the reduction in gas exchange attributes of the plants. The varieties "Deli Kabul" and "Kasuri" showed higher and lower net CO_2 assimilation rate, respectively. These results indicate that growth medium salinity induced reduction in biomass production, gas exchange attributes, and also chlorophyll contents whereas the application of SA through foliar method can be used to protect plant growth and improve these attributes under salt stress.

El-Tayeb, (2005) reported that SA application increased peroxidase contents, membrane permeability and lipid peroxidation in barley grains under salt stress. El-Tayeb (2005) reported that foliar application of 1.0 mM SA increased RWC, fresh and dry weights, water content, soluble protein, total free amino acids, proline content, photosynthetic pigments, and phosphorus and peroxidase activity of barley seedlings under varying salt treatments.

The harmful effects of oxidative stress may not be ameliorated by indigenous antioxidant system under stressful conditions (Ding *et al.,* 2002). The application of 500 μM SA on barley plants improved antioxidant system (Popova *et al*., 2003).

Coronado *et al*. (1998) a reported a significant increase in biomass of shoots and roots of soybean by SA application. Significant increase in water-use-efficiency (WUE) and carboxylation efficiency occurred due to foliar spray of SA (Kumar *et al*., 2000).

Afzal *et al*. (2006) recorded an increase in wheat seed germination and seedling vigour by priming of seed with 50 mg kg^{-1} SA under saline conditions ($15 dSm^{-1}$). Similarly, Stevens and Senaratna (2006) reported a 4-fold increase in growth rate, higher photosynthetic and transpiration rates than those in untreated check by drenching tomato roots with 0.1 mM SA under 200 mM NaCl conditions. SA increased the number of flowers, pods/plant and seed yield of soybean (Gutierrez-Coronado *et al*., 1998), and enhanced growth of wheat (Shakirova *et al*., 2003) and maize (Abdel-Wahed *et al*., 2006; El-Mergawi and Abdel-Wahed, 2007). Electrolytic leakage from plant tissues is one of the most prominent effects of the salinity on plants. However, application of SA reduced electrolyte leakage in tomato (Stevens and Senaratna, 2006) in seedlings of wheat (Afzal *et al.*, 2006) and barley (El-Tayeb, 2005) under salt stress.

It is obvious that higher concentration of SA enhanced the stress tolerance by altering morpho-physiology to salt stress in many crops including tomato.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted during the period from October 2018 to March 2019 to study the mitigation of salt stress in tomato by using exogenous salicylic acid. The details of the materials and methods of this research work were described in this chapter as well as on experimental materials, site, climate and weather, experimental design, layout, materials used for experiment, raising of seedling, treatments, land preparation, manuring and fertilizing, transplantation of seedlings, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

3.1 Experimental site

This study was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is 23°74′N latitude and 90°35′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004), which have been shown in the Appendix III.

3.2 Experimental period

The experiment was carried out during the Rabi season from October 2018 to March 2019. Seedlings were sown on 23 October 2018 and were harvested up to 25 March 2019.

3.3 Characteristics of soil that used in pot

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

3.4 Climate of the experimental field

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix II.

3.5 Planting materials

Seedlings of 30 days of BARI Tomato-15 were used. The seedlings of tomato were grown at the nursery of Horticulture Farm in Sher-e-Bangla Agricultural University. BARI Tomato-15, a high yielding variety of Tomato was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. Its total duration is about 95-100 days after transplanting.

3.6 Treatment of the experiment

The experiment consists of two factors

Factor A: Different levels of Salinity

- S_0 = 0 dS/m
- S_1 = 6 dS/m
- S_2 = 9 dS/m
- S_3 = 12 dS/m
- S_4 = 15 dS/m

Factor B: Different concentrations of Salicylic acid (SA):

- T_0 = 0 ppm
- T_1 = 100 ppm
- T_2 = 200 ppm

Total 12 treatment combinations were as follows:

T_0S_0: Without Salicylic Acid + Without Salt

T_1S_0: 100 ppm of Salicylic Acid + Without Salt

T_2S_0: 200 ppm Salicylic Acid + Without Salt

T_0S_1: Without Salicylic Acid + 6 dS/m of NaCl

T_1S_1: 100 ppm of Salicylic Acid+ 6 dS/m of NaCl

T_2S_1: 200 ppm Salicylic Acid + 6 dS/m of NaCl

T_0S_2: Without Salicylic Acid + 9 dS/m of NaCl

T_1S_2: 100 ppm of Salicylic Acid + 9 dS/m of NaCl

T_2S_2: 200 ppm Salicylic Acid + 9 dS/m of NaCl

T_0S_3: Without Salicylic Acid +12 dS/m of NaCl

T_1S_3: 100 ppm of Salicylic Acid +12 dS/m of NaCl

T_2S_3: 200 ppm Salicylic Acid +12 dS/m of NaCl

T_0S_4: Without Salicylic Acid + 15 dS/m of NaCl

T_1S_4: 100 ppm of Salicylic Acid + 15 dS/m of NaCl

T_2S_4: 200 ppm Salicylic Acid + 15 dS/m of NaCl

Preparation of different salinity and salicylic acid level:

Before the application of mentioned saline and salicylic acid treatment,0 dS/m, 6 dS/m, 9 dS/m, 12 dS/m and 15 dS/m salinity levels were converted into 0, 3.51, 5.27, 7, 8.77g of salt whereas 0 ppm, 100 ppm and 200 ppm salicylic acid concentration were converted into 0, 100 mg, 200 mg of salicylic acid per liter of water. Saline water with mentioned salinity level was applied to the tub and salicylic acid as foliar spray.

3.7 Design and layout of the experiment

The two factors experiment was laid out in Completely Randomized Design (CRD) with five levels of salinity and three levels of Salicylic acid. Three replications were maintained in this experiment. The total number of unit pots was 45 (15×3). Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height. The experiment was placed under Shed house which was made by bamboo with polythene roof and pots were kept on the bamboo made frame of 70 cm height.

3.8 Preparation of the pot

The experimental pots were first filled at 16 November, 2018. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soil. Cowdung was mixed with the soil as 1:3 ratio which was collected from farm house of the Horticulture farm. The final pot preparation was done on 18 November 2018. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final pot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.9 Application of manure and fertilizers

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

Manures and Fertilizers	**Dose/ha**	**Application (%)**			
		Basal (%)	**15 DAT**	**30 DAT**	**45 DAT**
Cowdung	14 tons	100	--	--	--
Nitrogen (as Urea)	250 kg		33.33	33.33	33.33
P_2O_5 (as TSP)	200 kg	100	--	--	--
K_2O (as MP)	175 kg	100	--	--	--

3.10 Raising of seedlings

Tomato seedlings were raised in 3 pots with 35 cm (14 inches) in diameter and 30 cm (12 inches) in height for BARI Tomato-15. The soil was well prepared and converted into loose friable and dried mass by spading. All weeds and stubbles were removed and 5 kg well rotten cow dung was mixed with the soil. Fifteen g of seeds were sown on these pots on 24 October. After sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg ha^{-1}, around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place with 5 to

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

3.11 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the pots and were transplanted in the experimental pots in the afternoon of 23 November 2018. This allowed an accommodation of 01 plant in each pot. The pots were watered before uprooting the seedling from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the hot sun and removed after seedling were established. They (transplants) were kept open at night to allow them receiving dew. Each pot allow two seedlings in the pot and one seedling is removed from pot after healthy establishment of seedlings.

3.12 Preparation and application of treatment

As per the treatment the required amount of saline solution was applied in the pot during application of water. The tray was used in the bottom of each pot to collect the water. Salicylic acid was foliar sprayed according to treatment combination. 1st application of saline solution and salicylic acid applied in the pot soil at 20 days after transplanting, 2nd application was at 40 days after transplanting and final application of treatment was applied at 50 DAT.

3.13 Intercultural operation

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

3.13.1 Irrigation

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

3.13.2 Staking

When the plants were well established, staking was given to each plant by bamboo sticks for support to keep them erect.

3.13.3 Weeding

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

3.13.4 Earthing up

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

3.13.5 Plant protection measures

Melathion 57 EC was applied @2 mlL^{-1} of water against the insect pests like cutworm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and was stopped before second week of first harvest. Furadan 10G was also applied during pot preparation as soil insecticide. During foggy weather precautionary measure against disease attack of tomato was taken by spraying Diathane M-45 fortnightly @2 gmL^{-1} of water at the early vegetative stage. Ridomil gold was also applied @ 2 gmL-1 of water against blight disease of tomato.

3.14 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they attained slightly red color. Harvesting was started from March 2019 and was continued up to April 2019.

3.15 Data collection

The following data was collected from plant of each unit plot.

1. **Physical parameter:**

- Plant height
- Number of branches per plant

- Number of leaves per plant
- Leaf area
- Days required for transplanting to 1st flowering

2. Physiological parameter

- SPAD value
- Dry matter of plant
- Dry matter of fruit

3. Yield contributing and yield parameter

- Number of flower cluster per plant
- Number of flowers per cluster
- Number of flowers per plant
- Number of fruits per plant
- Length of fruit (cm)
- Diameter of the fruit
- Weight of individual fruit
- Yield per plant

3.15.1 Plant height

Plant height was measured from plant of each unit pot from the ground level to the tip of the longest stem and mean value was taken. Plant height was calculated at 15 days interval started from the 30 days of planting up to 60 days to observe the growth rate of the plant.

3.15.2 Number of branches per plant

Total number of branches per plant was counted from the plant of each of unit pot. Data recorded at 20 days interval started from transplanting up to 60 days.

3.15.3 Number of leaves per plant

Total number of leaves per plant was counted from the plant of each of unit pot. Data was recorded at 20 days interval started from the 30 days of planting up to 60 days.

3.15.4 Leaf area plant^{-1}

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

3.15.5 Days required for transplanting to 1st flowering

Days required from transplanting to 1st initiation of flowering were measured from date of transplanting to 1st initiation of flowering and was calculated.

3.15.6 SPAD value

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

3.15.7 Dry matter content of plant

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

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

3.15.8 Dry matter content of fruit

After harvesting, randomly selected 100 g fruit sample previously sliced into very thin pieces were put into envelop and placed in oven for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of fruit were computed by simple calculation from the weight recorded by the following formula:

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

3.15.9 Number of flower cluster per plant

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

3.15.10 Number of flowers per cluster

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

3.15.11 Number of flowers per plant

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

$$\text{Number of flowers per cluster} = \frac{\text{Total number of flowers in sample plant}}{\text{Total number of flowers clusters in sample plants}}$$

3.15.12 Number of fruits per plant

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

3.15.13 Length of fruit

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

3.15.14 Diameter of fruit

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

3.15.15 Weight of individual fruit

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

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

3.15.16 Yield per plant

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

3.16 Analysis of data

The data in respect of growth, yield contributing characters and yield were statistically analyzed to find out the statistical significance. The means for all the treatments were calculated and the analysis of variance for all the characters was performed by MSTAT-C. The significance of the difference among the means was evaluated by Duncan's Multiple Range Test (DMRT) according to Gomez and Gomez, (1984) for interpretation of the results at 5% and 1% level of probability.

CHAPTER IV
RESULTS AND DISCUSSION

The present investigation was carried out to study the effect of salicylic acid (SA) to mitigate the salt stress in BARI Tomato-15. Various observations on morphological and Physiological changes were recorded at different growth stages. Salinity induced comparative changes in growth and yield contributing characteristics of tomato are discussed in this chapter. The results have been presented and discussed in the different tables and graphs and possible interpretations given under the following headings:

4.1 Effects of salicylic acid (SA) on the morphological traits of tomato under salt stress

4.1.1. Plant Height

Salicylic acid (SA) also has a significant effect on the plant height (Appendix III) At 30, 45 and 60 DAT the maximum plant height (37.67, 51.67 and 47.67 cm, respectively) was obtained from T_2 (200 ppm SA), while the minimum (33.20, 42.39 and 33.89 cm, respectively) was recorded from T_0 (0 ppm GA_3) (Figure 1) This result agreed with Qados (2015) who reported that SA treatment improved the plant height at all levels of salt stress and also control plants, it is therefore acting as growth stimulants The increase in plant height with different levels of SA might be due to the fact that cell enlargement was accelerated with the application of Salicylic acid(SA). Under low and high salt condition 200 ppm of SA gave the best result in the terms of plant height.

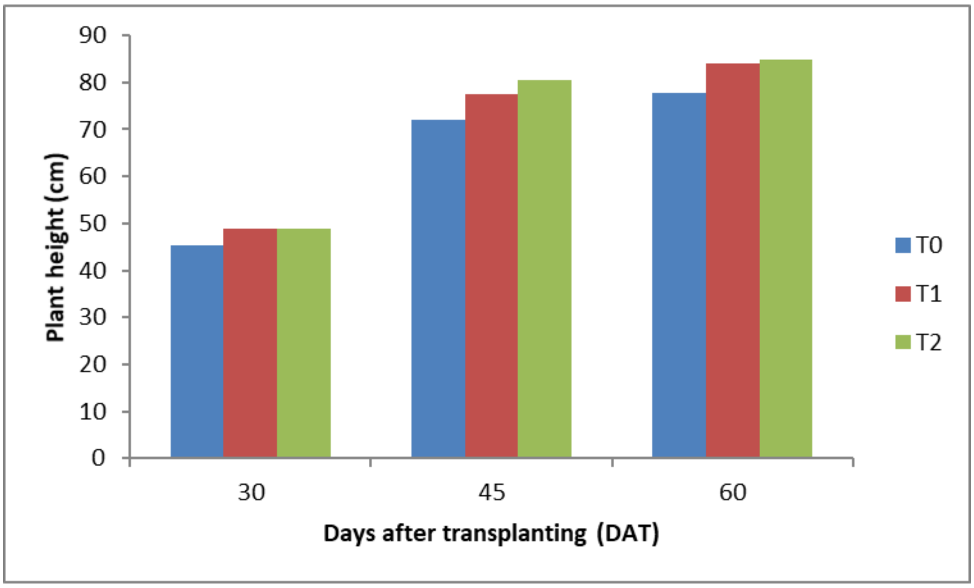

Figure 1. Plant height of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

The plant height (cm) varied significantly due to the effect of salinity stresses observed at 30, 45, 60 days after planting (DAT) with statistically significant variation (Figure 2 and Appendix III). At 30, 45 and 60 DAT, the highest plant height 50.87 cm, 85.73 cm and 90.12 cm, respectively was found from S_0 or control whereas the lowest value 42.07 cm, 67.67 cm and 73.60 cm, respectively was observed with S_4 salinity level or addition of NaCl 15 dS/m of NaCl with soil. The results of this study showed that salinity significantly reduced the plant height of tomato at different DAT and the reduction was quite incremental with the increase of NaCl concentrations. Salinity generally provides a slow growth and development of cells which is confirmed by Munns (2002) who reported salinity reduces plant growth through lessening or stopping the leaf expansion. This factor suppresses the turgor pressure and metabolic activities in the cells that are observed as low number and small size of leaves associated with short plant height. Memon *et al.* (2007) stated that increasing water salinity progressively decreased plant height and fodder yield (fresh and dry weight) per plant.

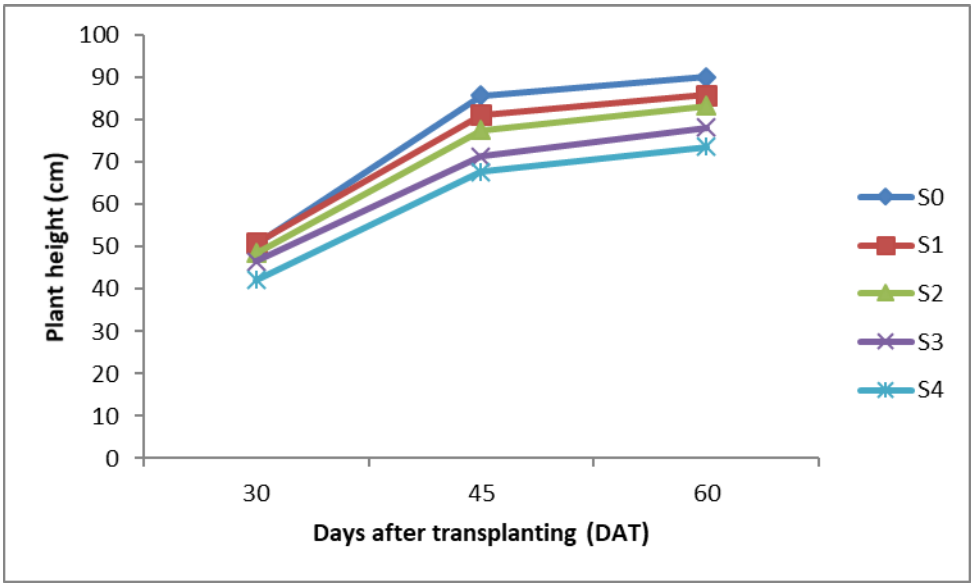

Figure 2. Plant height of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Combined effect of different levels of salt stress and salicylic acid showed significant differences on plant height of tomato at 30, 40, and 60 DAT (Appendix III). At 30, 40, and 60 DAT, the tallest plant (16.76 cm, 41.71 cm, 63.1 cm, 84.0 cm and 94.0 cm) was found from T_1S_0 (100 ppm of SA+ 0 dS/m of salinity) treatment combination, while the shortest (11.7 cm, 32.0 cm, 52.6 cm, 64.0 cm and 74.4 cm) was found from T_0S_4 (control salt + control) treatment combination (Table 1).

Table 1. Plant height of tomato as influenced by salicylic acid under different salt stress

Treatment	Plant height (cm)		
	30 DAT	45 DAT	60 DAT
T_0S_0	50.67 ab	81.05 cd	86.32 b
T_0S_1	49.88 ab	77.63 ef	85.00 bc
T_0S_2	45.73 de	72.83 g	78.75 de
T_0S_3	43.76 e	64.50 h	70.87 g
T_0S_4	36.91 f	63.88 h	67.83 g
T_1S_0	51.91 a	85.76 b	91.60 a
T_1S_1	51.09 ab	82.15 c	86.38 b
T_1S_2	49.97 ab	78.95 de	85.55 b
T_1S_3	46.91 cd	74.02 g	81.65 cd
T_1S_4	44.60 de	66.53 h	75.09 f
T_2S_0	49.33 abc	90.39 a	92.43 a
T_2S_1	51.64 ab	83.64 bc	86.47 b
T_2S_2	49.99 ab	80.94 cd	85.59 b
T_2S_3	48.93 bc	75.54 fg	82.15 c
T_2S_4	44.69 de	72.59 g	77.88 ef
$LSD_{0.05}$	2.621	2.995	3.384
CV (%)	7.35	8.92	10.86

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.1.2 Number of branches plant^{-1}

Application of salicylic acid had showed significant effect on number of leaves plant^{-1} of tomato at different days after transplanting. (30, 45and 60 DAT) (Figure 3 and Appendix III). The maximum number of branches plant^{-1} 1.24, 2.60 and 7.67 at 30, 45 and 60 DAT were found from T_1 or 100 ppm of SA whereas the minimum number of leaves plant^{-1} 0.60, 1.80 and 6.27 at 30, 45 and 60 DAT was observed from T_0 or control. Farahbakhsh and Saiid (2011) who reported that high concentration of SA (200 ppm) caused an increase of 74.94% in leaf area and number of leaves.

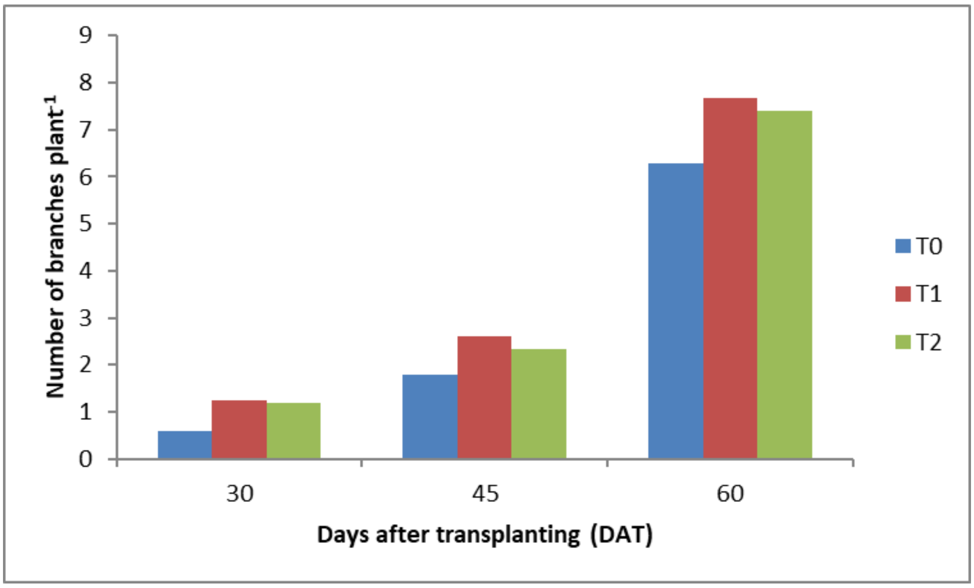

Figure 3. Number of branches/plant^{-1} of tomato as influenced by Salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Different levels of salt stress varied significantly in terms of number of branches per plant of tomato for at 30, 45 and 60 days after transplanting (DAT) under the present trial (Appendix III). At 30, 45 and 70 DAT the maximum number of branches per plant (2.00, 3.11 and 8.44) was recorded from S_0 which was closely followed (1.44, 2.78 and 8.11) by S_1. On the other hand, the minimum number (0.22, 1.22 and 5.22) was recorded from S_4 (Figure 4).

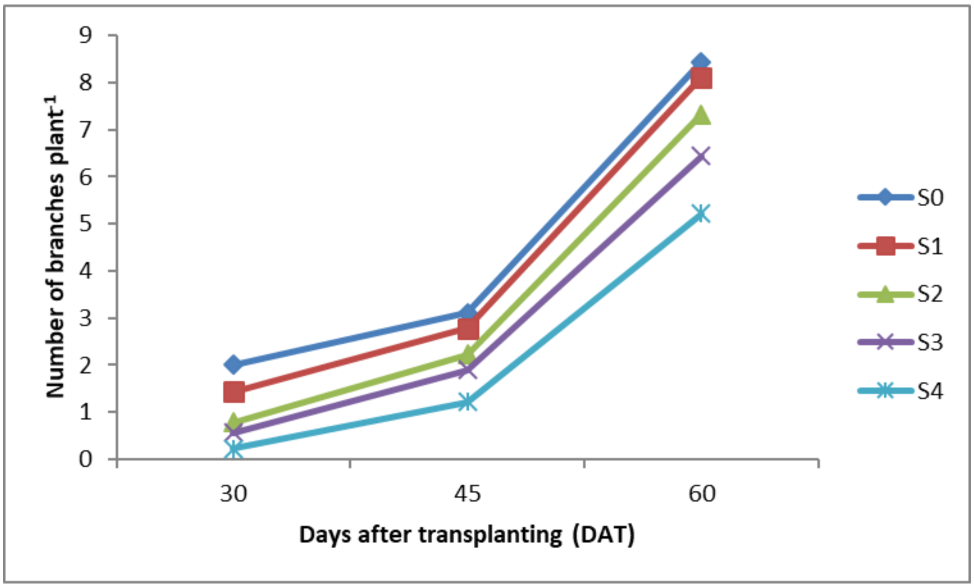

Figure 4. Number of branches plant^{-1}as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

The combined effect of salinity and calcium on number of branches plant^{-1} of tomato exhibited a significant effect at 30, 45 and 60 DAT (Table 2 and Appendix III). At 30, 45 and 60 DAT, the highest number of branches plant-1(8.67) was found from T_1S_0 which was statistically similar (8.67) to both T_2S_0. The lowest value (6.75) was found from T_0S_4. The lowest value (0.00, 0.67 and 3.67 was found from T_0S_4.

Table 2. Number of branches plant^{-1} of tomato as influenced by salicylic acid under different salt stress

Treatment	Number of branches plant^{-1}		
	30 DAT	**45 DAT**	**60 DAT**
T_0S_0	1.33 bc	2.67 bc	8.00 bc
T_0S_1	1.00 cd	2.33 cd	7.67 cd
T_0S_2	0.33 ef	2.00 de	6.67 fg
T_0S_3	0.33 ef	1.33 f	5.33 h
T_0S_4	0.00 f	0.67 g	3.67 i
T_1S_0	2.33 a	3.67 a	8.67 a
T_1S_1	1.67 b	3.00 b	8.33 ab
T_1S_2	1.00 cd	2.33 cd	8.00 bc
T_1S_3	0.67 de	2.33 cd	7.00 ef
T_1S_4	0.33 ef	1.67 ef	6.33 g
T_2S_0	2.33 a	3.00 b	8.67 a
T_2S_1	1.67 b	3.00 b	8.33 ab
T_2S_2	1.00 cd	2.33 cd	7.33 de
T_2S_3	0.67 de	2.00 de	7.00 ef
T_2S_4	0.33 ef	1.33 f	5.67 h
$LSD_{0.05}$	0.338	0.498	0.548
CV (%)	4.93	5.37	8.67

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.1.3 Number of leaves plant^{-1}

Different level of Salicylic acid (SA) exert impact insignificantly on number of leaves per plant of tomato at 30, 45, and 60 DAT (Appendix III). Data revealed that at 30, 45, and 60, the maximum number of leaves per plant (10.00, 12.93 and 17.78) was obtained from T_1 whereas the minimum number (9.00, 11.33 and 15.33) was found from T0 for same DAT (Figure 5).

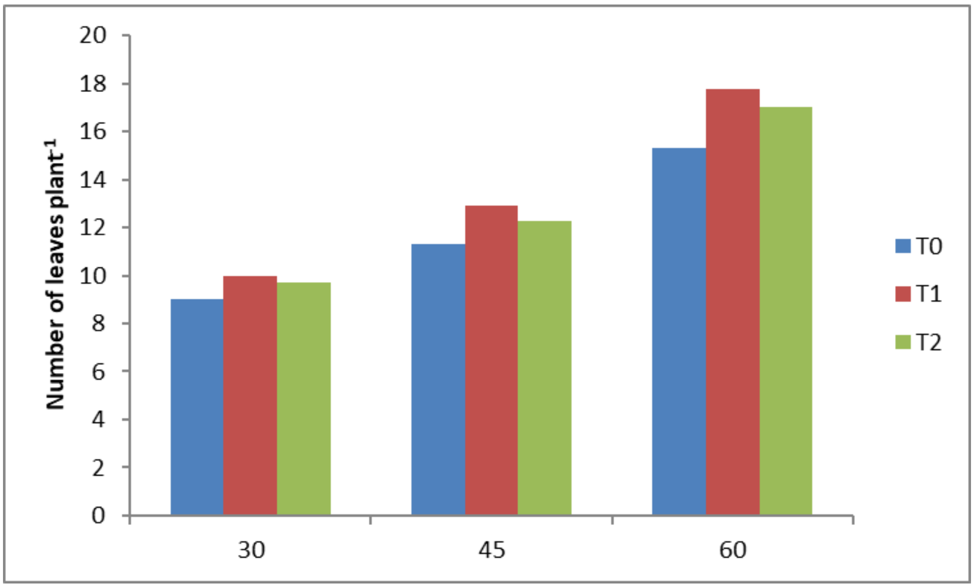

Figure 5. Number of leaves plant^{-1}of tomato as influenced by Salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Statistically significant variation was recorded for number of leaves per plant of tomato due to different levels of salt stress at 30, 45 and 60 DAT under the present trial (Appendix III). At 30, 45 and 60 DAT the maximum number of leaves per plant (10.56, 14.33 and 20.01) was observed from S_0 which was closely followed (18.97) by S_1 at 60 DAT, while the minimum number (8.67, 10.22 and 13.11) was found from S_4 (Figure 6)

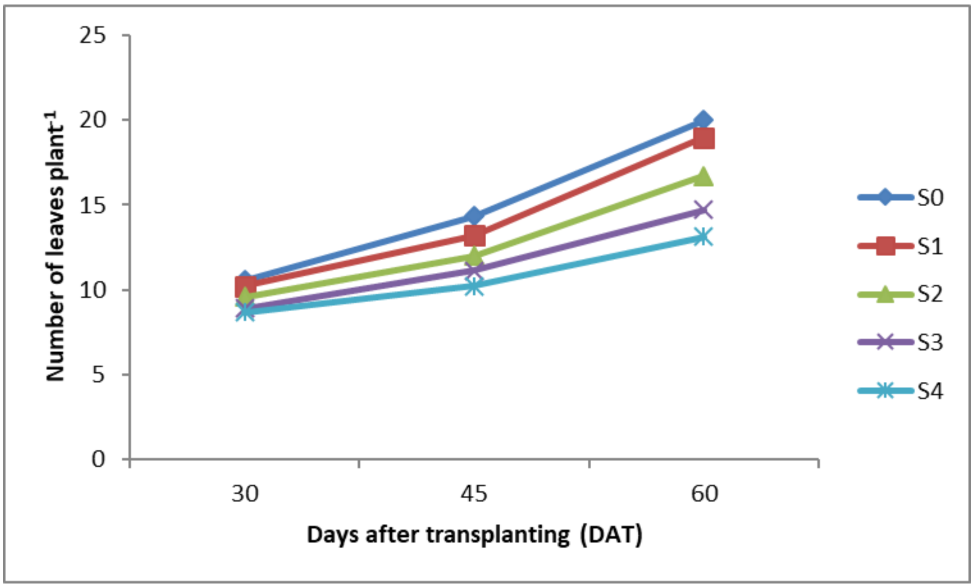

Figure 6. Number of leaves plant^{-1} of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

The combined effect of salinity and salicylic acid showed significant variation on number of leaves plant^{-1} of wheat at 30, 45 and 60 DAT (Table 3 and Appendix III). The combination of T_1S_0 gave the maximum number of leaves plant-1 (11.00, 15.67 and 20.93). The minimum number of leaves plant^{-1} (9.00, 10.33 and 13.43) was recorded from. Farahbakhsh and Saiid (2011) also stated that salinity had a negative effect on the number of leaves (25.6% reduction).

Table 3. Number of leaves plant^{-1} of tomato as influenced by salicylic acid under different salt stress

Treatment	Number of leaves plant^{-1}		
	30 DAT	45 DAT	60 DAT
T_0S_0	10.00	13.00 c	18.77 cd
T_0S_1	9.67	12.67 cd	18.07 d
T_0S_2	9.00	11.33 ef	14.97 f
T_0S_3	8.33	10.00 g	12.80 gh
T_0S_4	8.00	9.667 g	12.07 h
T_1S_0	11.00	15.67 a	20.93 a
T_1S_1	10.67	13.67 bc	19.77 bc
T_1S_2	10.00	13.00 c	18.43 d
T_1S_3	9.33	11.67 de	15.93 ef
T_1S_4	9.00	10.67 efg	13.83 g
T_2S_0	10.67	14.33 b	20.33 ab
T_2S_1	10.33	13.33 bc	19.07 cd
T_2S_2	9.67	11.67 de	16.73 e
T_2S_3	9.00	11.67 de	15.47 f
T_2S_4	9.00	10.33 fg	13.43 g
$LSD_{0.05}$	NS	1.306	1.044
CV (%)	7.30	6.67	6.10

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.2.1 Leaf area plant^{-1}

Leaf area plant^{-1} of tomato varied significantly due to different levels of salicylic acid at different days after transplanting (DAT) (Figure 7 and Appendix III). At 30, 45 and 60 days, the highest leaf area per plant was recorded from T_1 (889.90, 956.70 and 1036.00) treatment, while the leaf area per plant (758.50, 850.40 and 930.80) from T_0 (Figure 4). Farahbakhsh and Saiid (2011) who reported that high concentration of SA (200 ppm) caused an increase of 74.94% in leaf area and number of leaf.

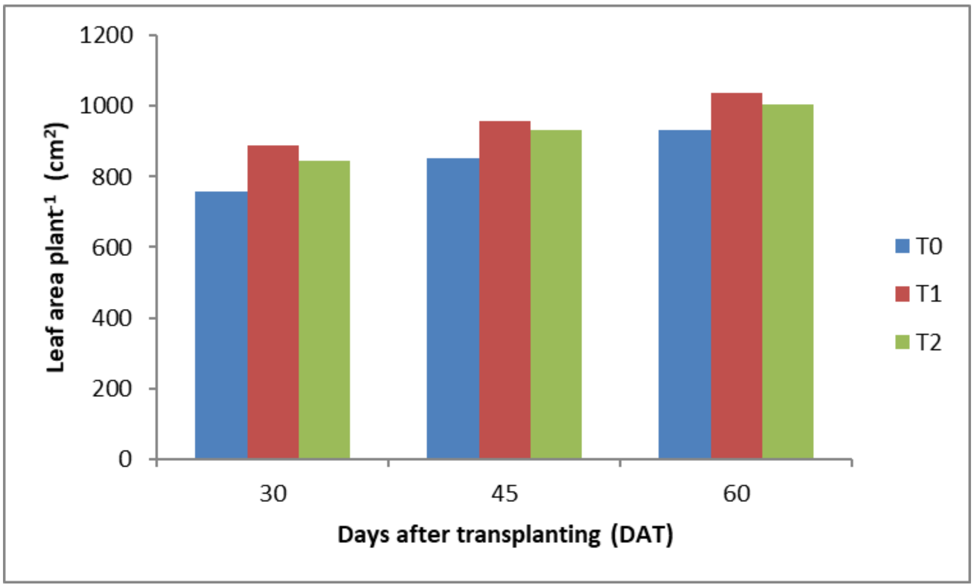

Figure 7. Leaf area plant^{-1} of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Leaf area plant^{-1} of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Appendix III). At 30, 45 and 60 days after transplanting, the highest leaf area per plant (984.80, 1047.00 and 1135.00) was recorded from S_0 treatment. In saline condition best result gives S_1 treatment at 30, 45 and 60 DAT. (Figure 8) and the lowest leaf area per plant (705.60, 808.30 and 861.90) from S_4 at different DAT, respectively.

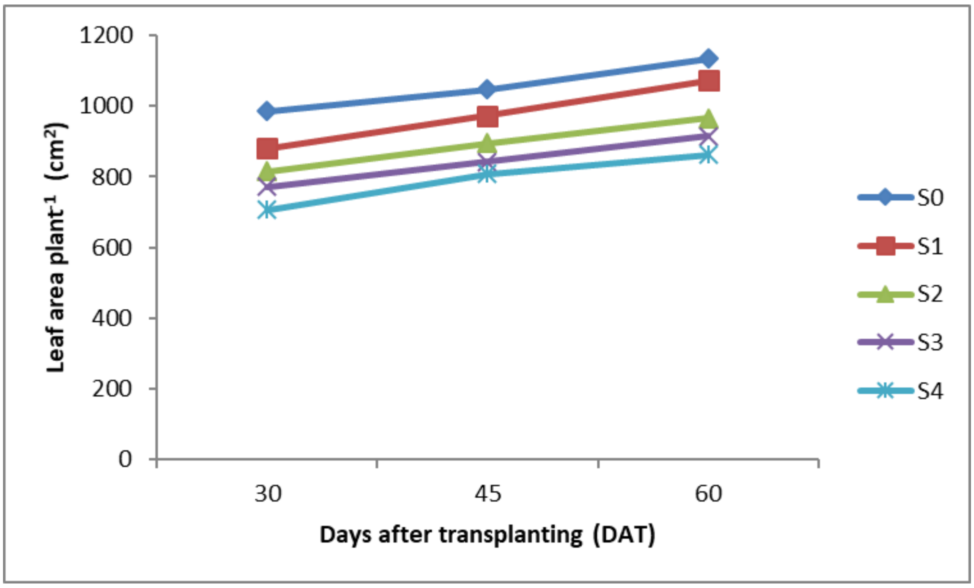

Figure 8. Leaf area plant^{-1} of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Combined effect of saline water and salicylic acid showed statistically significant variation for leaf area per plant at 30, 45 and 60 DAT (Table 4 and appendix III). At 30, 45 and 60 DAT the highest leaf area per plant was recorded from T_1S_0 (1107.00, 1144.00 and 1177.00) treatment combination which was statistically similar with T_2S_0 (1175.00) at 60 DAT. On the other hand, the lowest number of leaf area per plant (2.33) was recorded from T_0S_4 (15 ds/m salinity + No salicylic acid) treatment combination at 30, 45 and 60 DAT.

Table 4. Leaf area plant^{-1} of tomato as influenced by salicylic acid under different salt stress

Treatment	Leaf area plant^{-1} (cm^2)		
	30 DAT	45 DAT	60 DAT
T_0S_0	846.00 e	965.70 d	1054.00 c
T_0S_1	833.70 ef	914.00 e	1014.00 d
T_0S_2	775.30 gh	855.30 gh	913.70 fg
T_0S_3	701.00 j	778.30 i	860.70 i
T_0S_4	636.70 k	738.70 j	811.30 j
T_1S_0	1107.00 a	1144.00 a	1177.00 a
T_1S_1	915.70 c	1006.00 c	1136.00 b
T_1S_2	841.30 ef	915.30 e	1017.00 d
T_1S_3	825.70 f	875.30 f	952.00 e
T_1S_4	759.70 h	843.30 h	896.00 gh
T_2S_0	1001.00 b	1032.00 b	1175.00 a
T_2S_1	891.70 d	998.00 c	1066.00 c
T_2S_2	826.30 f	912.70 e	967.00 e
T_2S_3	790.30 g	874.00 fg	931.30 f
T_2S_4	720.30 i	843.00 h	878.30 hi
$LSD_{0.05}$	18.48	18.93	19.86
CV (%)	7.87	9.02	8.33

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.2.2 SPAD Value

SPAD values of tomato at 60 days after transplanting varied significantly due to different levels of salicylic acid (Appendix III). At flowering stage, the highest SPAD value (50.14) was found from T_1 which was statistically similar (48.31) with T_2, while the lowest SPAD value (43.85) was recorded from T_0 (Figure 9).

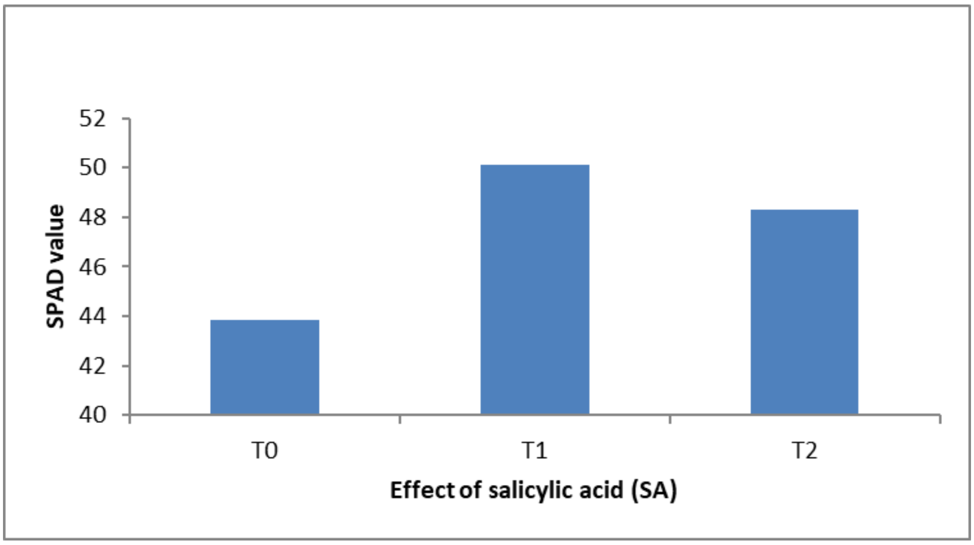

Figure 9. SPAD value of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Significant variation was observed for SPAD values of tomato plant due to different levels of salt stress at flowering stage and 30 days after flowering (Appendix III). At flowering stage, the highest SPAD values (55.01) was obtained from S_0, whereas the lowest SPAD values (31.8) was found from S_4 which was followed (39.24) (Figure 11)

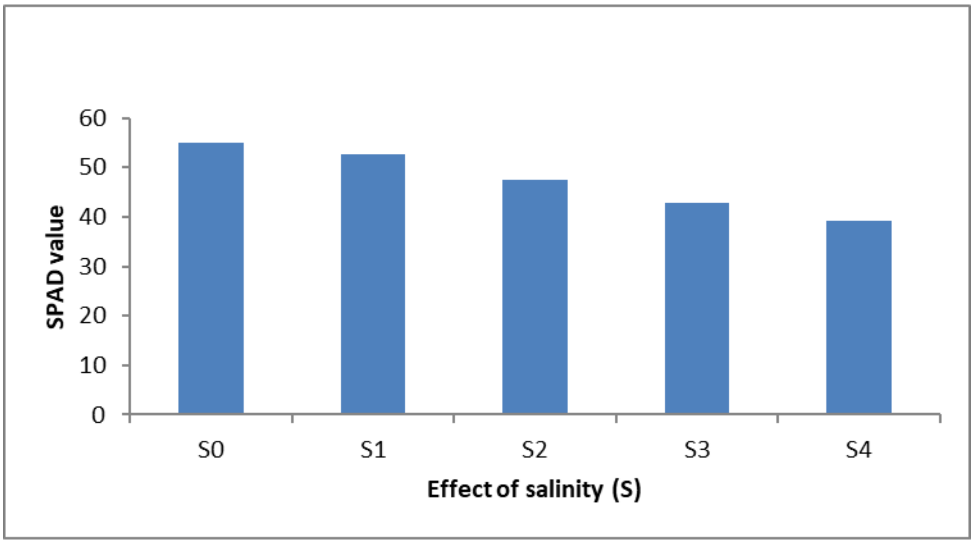

Figure 10. SPAD value of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Combined effect of different levels of salt stress and salicylic acid showed significant differences in terms of SPAD values of tomato at 60 days after transplanting (Appendix III). At flowering stage, the highest SPAD value (57.14) was observed from T_1S_0 treatment combination and the lowest SPAD values (35.68) from T_0S_4 treatment combination. (Table 5).

Table 5. SPAD value of tomato as influenced by salicylic acid under different salt stress

Treatment	SPAD value at 60 DAT
T_0S_0	52.31 cde
T_0S_1	50.43 e
T_0S_2	42.98 hi
T_0S_3	37.85 k
T_0S_4	35.68 k
T_1S_0	57.14 a
T_1S_1	54.38 bc
T_1S_2	51.75 de
T_1S_3	45.77 fg
T_1S_4	41.64 ij
T_2S_0	55.57 ab
T_2S_1	53.13 cd
T_2S_2	47.74 f
T_2S_3	44.74 gh
T_2S_4	40.39 j
$LSD_{0.05}$	2.419
CV (%)	5.10

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

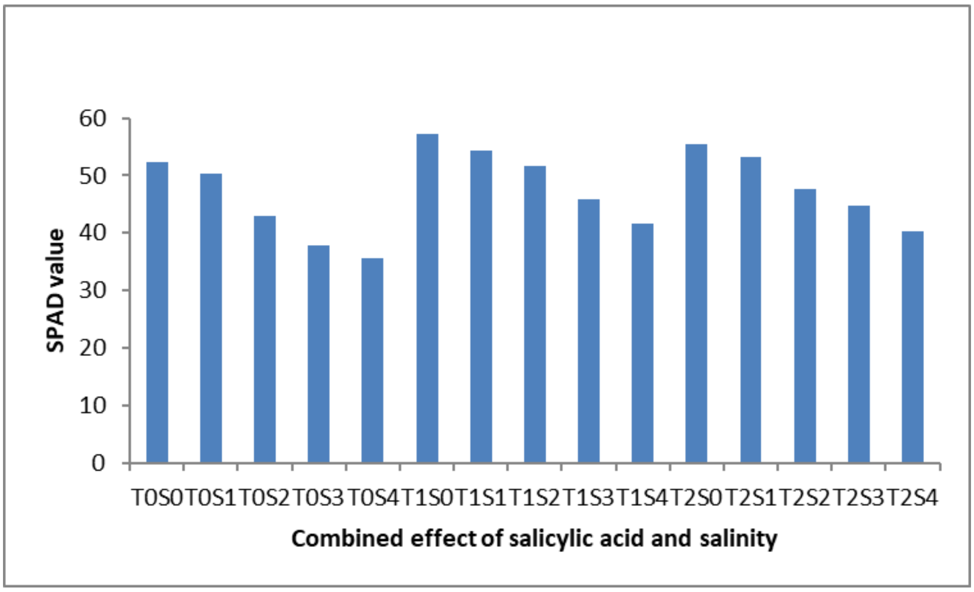

Figure 11. SPAD value of tomato as influenced by salicylic acid under different salt stress

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.3 Yield parameters

4.3.1 Number of flowers cluster^{-1}

Significance difference was recorded due to different levels of salicylic acid for number of flower cluster^{-1} (Appendix III). The maximum number of flower cluster^{-1} was recorded from T_1 (3.87, 9.47 and 14.33) treatment at 40, 50 and 60 DAT which was closely followed by T_2 (3.73, 9.00 and 13.73) (Figure 12), while the minimum number of flower cluster^{-1} (3.00, 7.33 and 10.87) was recorded from T_0 treatment.

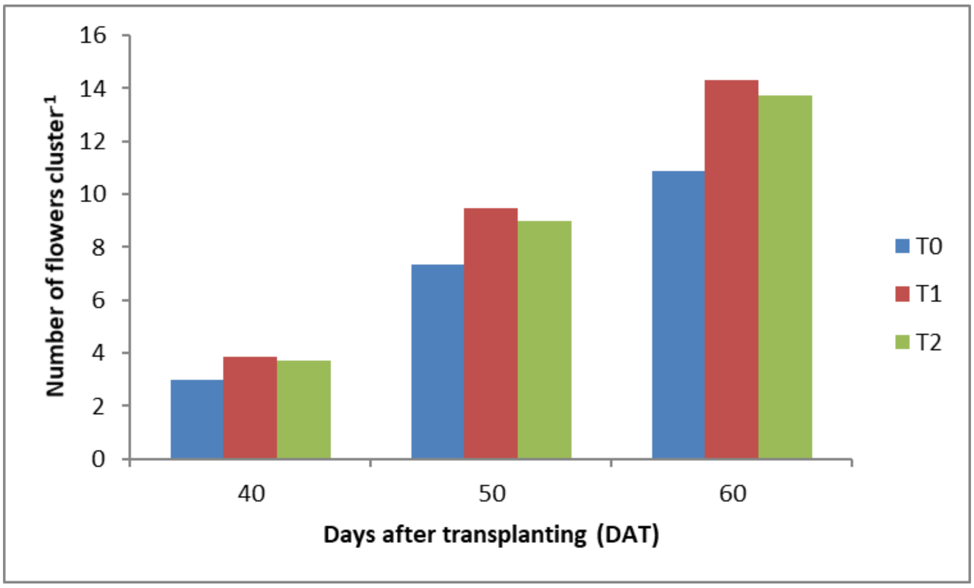

Figure 12. Number of flower cluster^{-1} of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Number of flower cluster showed statistically significant variation due to different level of saline water (Appendix III). The highest number of flower cluster per plant was recorded from S0 (4.33, 10.56 and 16.56) treatment which was statistically identical with S_1 (4.11, 10.11 and 14.78 b) treatment, while the lowest number of flower cluster per plant was recorded from S_4 (2.67, 6.44 and 9.556) at 40, 50 and 60 DAT (Figure 13).

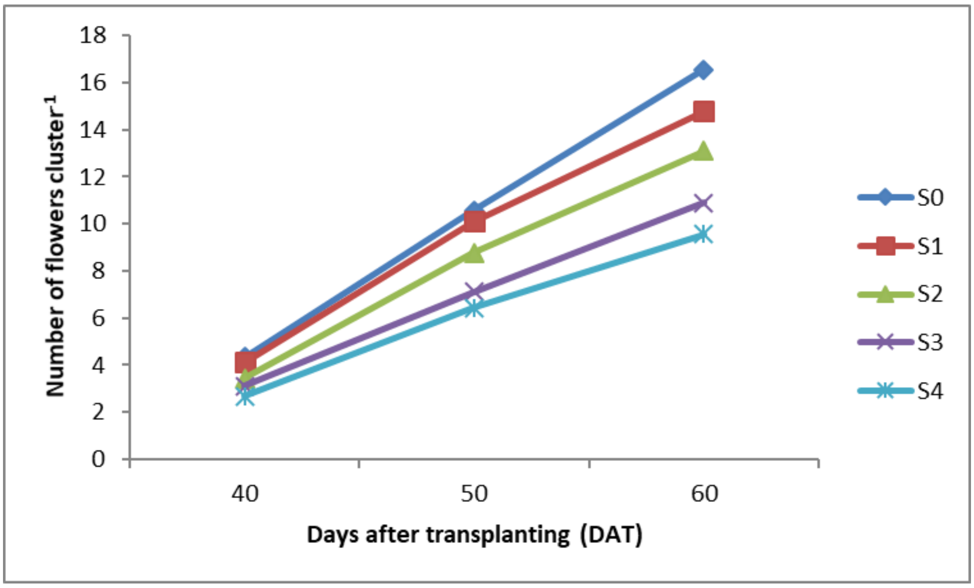

Figure 13. Number of flower cluster^{-1} of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Combined effect of saline water and salicylic acid showed statistically significant variation for number of flower cluster per plant (Appendix III). The maximum number of flowers per plant (5.00, 11.00 and 17.67 a) was recorded from T_1S_0 (No saline + 100 ppm of SA) at 40, 50 and 60 DAT, which was closely similar to T_1S_1 treatment combination at 50 and 60 DAT, while the minimum number of flowers per plant (2.00, 4.67 and 7.00) was recorded from T_0S_4 (15 dS/m salinityl + no SA) treatment combination at 40, 50 and 60 DAT (Table 6).

Table 6. Number of flower cluster^{-1} of tomato as influenced by salicylic acid under different salt stress

Treatment	Number of flowers cluster^{-1}		
	40 DAT	50 DAT	60 DAT
T_0S_0	3.67 c	9.67 b	14.67 c
T_0S_1	3.67 c	9.33 bc	13.67 de
T_0S_2	3.00 de	8.00 de	11.67 gh
T_0S_3	2.67 e	5.00 f	7.333 j
T_0S_4	2.00 f	4.67 f	7.000 j
T_1S_0	5.00 a	11.00 a	17.67 a
T_1S_1	4.33 b	10.90 ab	15.67 b
T_1S_2	3.67 c	9.67 b	14.33 cd
T_1S_3	3.33 cd	8.33 d	13.00 ef
T_1S_4	3.00 de	7.33 e	11.00 hi
T_2S_0	4.33 b	11.00 a	17.33 a
T_2S_1	4.33 b	10.00 b	15.00 bc
T_2S_2	3.67 c	8.67 cd	13.33 e
T_2S_3	3.33 cd	8.00 de	12.33 fg
T_2S_4	3.00 de	7.33 e	10.67 i
$LSD_{0.05}$	0.582	0.766	0.9299
CV (%)	5.75	6.71	6.56

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.3.2 Number flowers plant^{-1}

Significance difference was recorded due to different levels of salicylic acid for number of flowers per plant (Appendix III). The maximum number of flowers per plant (72.60 and 25.93) was recorded from T_1 (100 ppm of SA) at 60 and 90 DAT which was closely followed (25.40) by T_2 (200 ppm of SA) at 90 DAT, while the minimum number of flowers per plant (55.67 and 22.33) was recorded from T_0 (0 ppm of SA) (Figure 14).

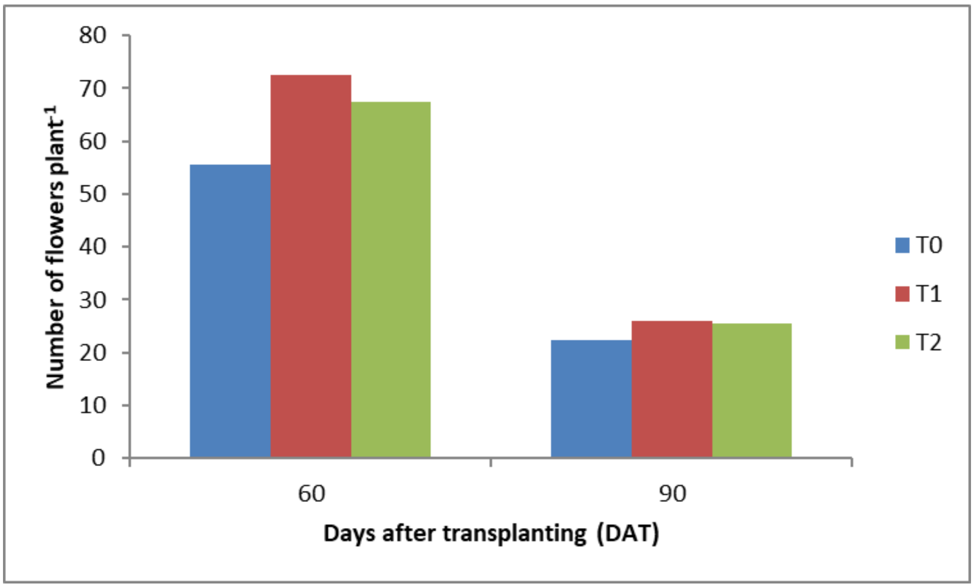

Figure 14. Number flowers plant^{-1} of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Number of flowers per plant showed statistically significant variation due to different level of saline water (Appendix III). The highest number of flowers per plant (82.89 and 28.78) was recorded from S_0 (0 dS/m salinity) at 60 and 90, while the lowest number of flowers per plant (48.11 and 20.56) was recorded from S_4 (15 dS/m salinity) (Figure 15).

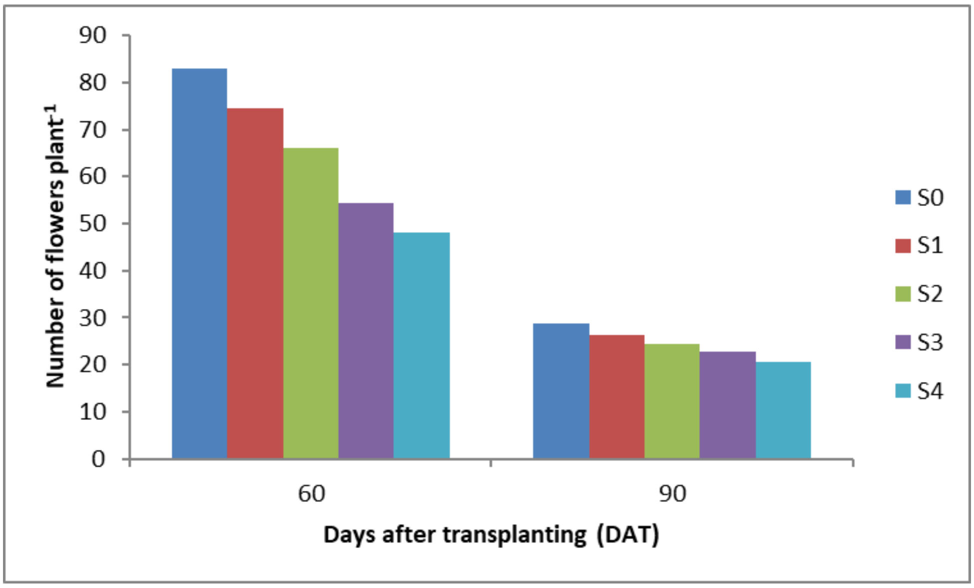

Figure 15. Number flowers plant^{-1} of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Interaction effect of saline water and salicylic acid showed statistically significant variation for number of flowers per plant (Appendix III). The maximum number of flowers per plant (87.67 and 30.33) was recorded from T_1S_0 (0 dS/m salinity + 100 ppm of SA), while the minimum number of flowers per plant (37.00 and 16.67) was recorded from T_0S_4 (15 dS/m salinity + control) (Table 7).

Table 7. Number flowers plant^{-1} of tomato as influenced by salicylic acid under different salt stress

Treatment	Number flowers plant^{-1}	
	60 DAT	90 DAT
T_0S_0	75.67 c	26.67 bc
T_0S_1	66.33 d	25.00 cd
T_0S_2	61.00 ef	23.33 d
T_0S_3	38.33 h	20.00 e
T_0S_4	37.00 h	16.67 f
T_1S_0	87.67 a	30.33 a
T_1S_1	79.00 b	27.00 bc
T_1S_2	74.33 c	25.33 cd
T_1S_3	62.33 e	24.33 cd
T_1S_4	59.67 f	22.67 de
T_2S_0	85.33 a	29.33 ab
T_2S_1	78.33 b	26.67 bc
T_2S_2	63.00 e	24.67 cd
T_2S_3	62.33 e	24.00 cd
T_2S_4	47.67 g	22.33 de
$LSD_{0.05}$	2.607	3.048
CV (%)	6.63	8.10

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0 = No salicylic acid, T_1 = 100 ppm salicylic acid, T_2 = 200 ppm salicylic acid S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

4.3.3 Number fruits plant^{-1}

Significance difference was recorded due to different levels of salicylic acid for number of fruits per plant. The maximum number of fruits per plant (27.60) was recorded from T_1 (100 ppm of SA) treatment (Figure 16), while the minimum number of fruits per plant (3.83) was recorded from T_0 (No salicylic acid) (Figure 16).

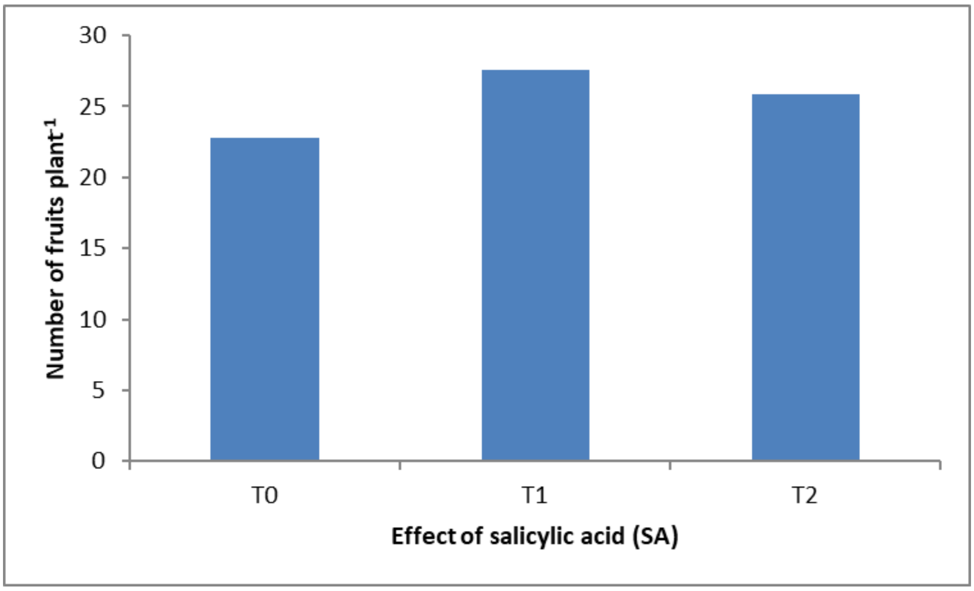

Figure 16. Number of fruits plant^{-1} of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Number of fruits per plant showed statistically significant variation due to different level of saline water. The highest number of fruits per plant (29.33) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (28.56), while the lowest number of fruits per cluster (20.11) was recorded from S_4 (15 dS/m salinity) treatment (Figure 17).

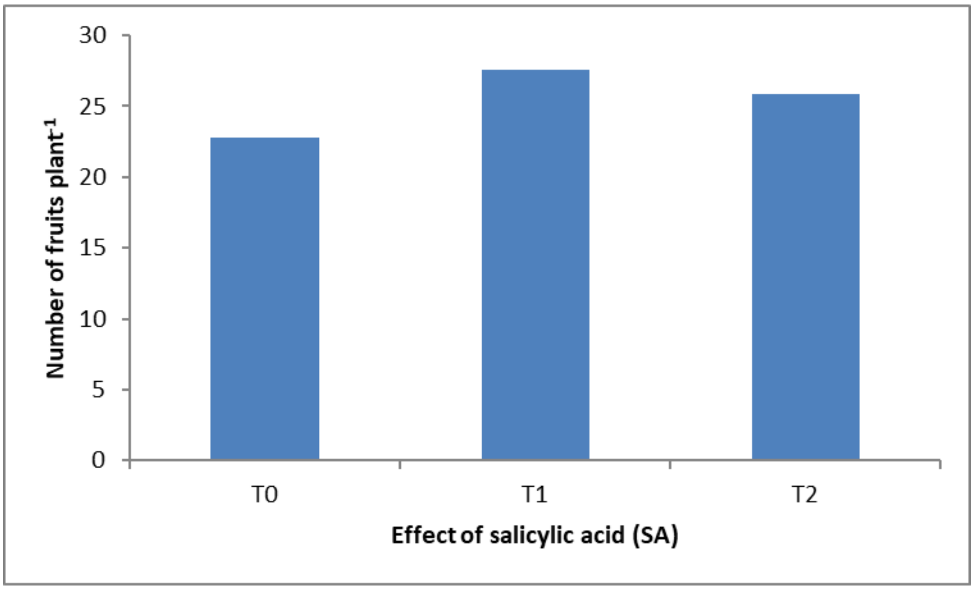

Figure 17. Number of fruits plant^{-1} of tomato as influenced by different salt stress

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of fruits per plant. The maximum number of fruits per plant (30.00) was recorded from T_1S_0 (No saline + 100 ppm of SA), while the minimum number of fruits per cluster (16.67) was recorded from T_0S_4 (0 ppm of SA+ 15 ds/m) (Figure 18).

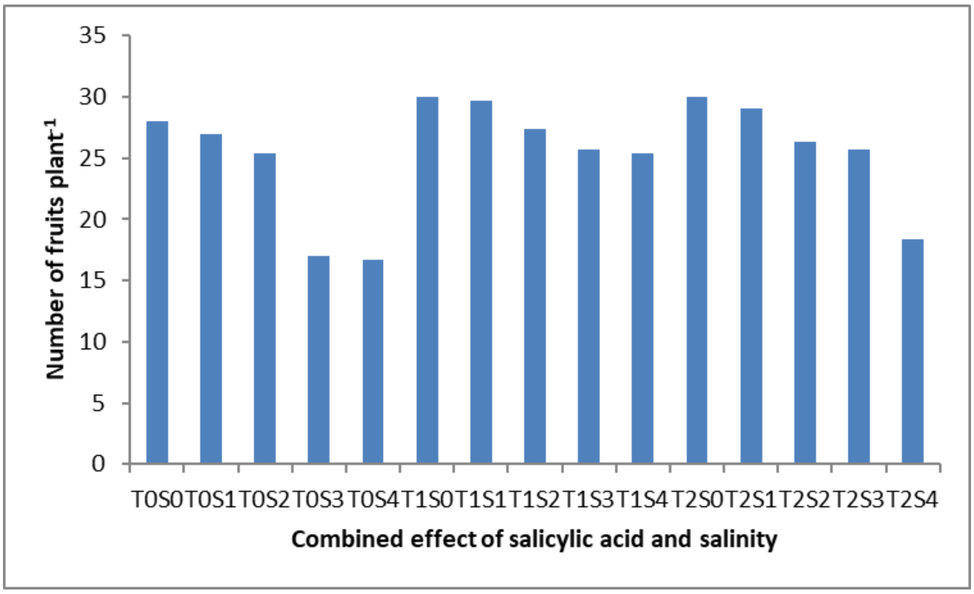

Figure 18. Number of fruits plant^{-1} of tomato as influenced by salicylic acid under different salt stress

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.3.4 Number of fruit drop

The number of fruit drop varied significantly due to application of different concentrations of SA. The maximum fruit drop (3.400) was obtained from T_0 (no SA) and minimum fruit drop (1.733) obtained from T_1 (100 ppm of SA)

Increasing salinity levels significantly increased the fruit drop of tomato plant. The highest fruit drop (4.33) was recorded from S_4 (15 dSm^{-1} of saline water), while the lowest (0.44) was recorded from S_0 (0 dSm^{-1} of saline water).

The variation was found due to combined effect of salicylic acid application and salinity on fruit drop. The maximum fruit drop of petiole (8.00) was recorded from the treatment combination of T_0S_4 (0 ppm of SA+ 15 ds/m of salinity), while the treatment combination of T_1S_0 (control) gave the minimum (0.00) (Table 8). From the results it was found that salicylic acid application under saline condition favored plant growth which ensured minimum fruit drop of tomato.

4.3.5 Length of fruit

Different levels of salicylic acid showed significant differences on length of fruit of tomato. The highest length of fruit (5.24 cm) was attained from T1 which was closely followed (5.14 cm) by T2. On the other hand, the lowest length of fruit (4.88 cm) was obtained from T_0 treatment.

Length of fruit of tomato varied significantly for different levels of salt stress under the present trial. The highest length of fruit (5.46 cm) was recorded from S_0. On the other hand, the lowest length (6.06 cm) was recorded from L_4 which was followed (4.69 cm) by S_4 (Table 10). Hao and Papadopoulos (2004) reported that at 300 mgL–1 Ca, total fruit length increased linearly.

The combined effect or different levels of salicylic acid and salinity on the fruit length was found to be statistically significant. The maximum fruit length (5.57 cm) was found from the treatment combination of 100 ppm of SA and 0 ds/m of salinity and the minimum (4.44 cm) from the combination of 0 ppm of SA and 15 ds/m of salinity (Table 8).

Table 8. Yield contributing parameters of tomato regarding number of fruit drop, fruit length, fruit diameter and % fruit dry weight as influenced by salicylic acid under different salt stress

Treatment	Yield contributing parameters and yield			
	Number of fruit drop	Length of fruit (cm)	Diameter of fruit (cm)	% Fruit dry weight
Effect of salicylic acid (SA)				
T_0	3.400 a	4.88 b	4.37 b	4.04 c
T_1	1.267 b	5.24 a	4.77 a	5.68 a
T_2	1.733 b	5.14 a	4.71 a	5.07 b
$LSD_{0.05}$	0.6140	0.094	0.078	0.261
CV (%)	5.31	5.95	5.02	6.78
Effect of salinity				
S_0	0.44 d	5.46 a	4.97 a	6.80 a
S_1	1.22 cd	5.28 ab	4.84 a	5.60 b
S_2	2.00 bc	5.11 ab	4.66 ab	4.62 c
S_3	2.67 b	4.90 bc	4.47 b	4.06 cd
S_4	4.33 a	4.69 c	4.15 c	3.57 d
$LSD_{0.05}$	1.395	0.3803	0.3090	0.6889
CV (%)	5.31	5.95	5.02	6.78
Combined effect of SA and salinity				
T_0S_0	1.00 de	5.27 bc	4.84 b	5.023 cd
T_0S_1	2.33 c	5.18 cd	4.73 c	4.680 cd
T_0S_2	2.33 c	4.94 e	4.55 de	4.347 d
T_0S_3	3.33 b	4.58 g	4.17 g	3.277 f
T_0S_4	8.00 a	4.44 h	3.57 h	2.853 f
T_1S_0	0.00 f	5.57 a	5.06 a	7.980 a
T_1S_1	0.33 ef	5.37 b	4.90 b	6.787 b
T_1S_2	1.33 d	5.21 cd	4.75 c	4.887 cd
T_1S_3	2.33 c	5.14 d	4.68 c	4.477 d
T_1S_4	2.33 c	4.87 e	4.48 ef	4.277 de
T_2S_0	0.33 ef	5.53 a	4.99 a	7.410 ab

T_2S_1	1.00 de	5.29 bc	4.89 b	5.330 c
T_2S_2	2.33 c	5.17 cd	4.69 c	4.620 cd
T_2S_3	2.33 c	4.98 e	4.58 d	4.423 d
T_2S_4	2.67 bc	4.75 f	4.39 f	3.573 ef
$LSD_{0.05}$	0.704	0.129	0.091	0.768
CV (%)	5.31	5.95	5.02	6.78

In a column, means followed by same letter(s) do not differ significantly at 5% level of significant by LSD.

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.3.6 Diameter of fruit (cm)

Very little significant difference was recorded due to different levels of salicylic acid for diameter of fruit. The maximum diameter of fruit (4.77 cm) was recorded from T_1 (100 ppm of SA) which was closely followed (4.71 cm) by T_2 (200 ppm of SA), while the minimum diameter of fruit (4.37 cm) was recorded from T_0 (0 ppm of SA) (Table 8).

Diameter of fruits varied significantly due to different level of saline water (Appendix VI). The maximum diameter of fruit (4.97) was recorded from S_0 (0 dS/m salinity) which was statistically identical (4.84) with S_1 (6 dS/m salinity), while the minimum diameter of fruit (4.15) was recorded from S_4 (15 dS/m salinity) (Table 8).

Interaction effect of saline water and salicylic acid showed statistically significant variation for diameter of fruits (Appendix III). The maximum diameter of fruit (5.06 cm) was recorded from T_1S_0 (100 ppm of SA+0 dS/m salinity), while the minimum diameter of fruit (4.44 cm) was recorded from T_0S_4 (15 dS/m salinity + 0 ppm of SA) (Table 8).

4.3.7 Dry matter content of fruit

A statistically significant difference was recorded due to different levels of salicylic acid for dry matter content in fruits. The highest dry matter content in fruits (5.68 %) was recorded from T_1 (100 ppm of SA) (Table 8), while the lowest dry matter content in fruits (4.04 %) was recorded from T_0 (No salicylic acid) treatment**.** It can be concluded that SA motivates the plant productivity and among the SA treatments, 200 ppm effectively increased shoot dry weight by 84%.

Dry matter content in fruits varied significantly due to different level of saline water. The highest dry matter content in fruits (8.35%) was recorded from S_0 (No saline) which was statistically identical with S_1 (6.80 %) treatment. On the other hand, the lowest dry matter content in fruits per plant (3.57 %) was recorded from S_3 (15 dS/m salinity) (Table 8).

Combined effect of saline water and salicylic acid showed statistically significant variation for dry matter content in fruits. The highest dry matter content in fruits (7.980%) was recorded from T_1S_0 (No saline + 1 Mm AA) treatment combination, while the lowest dry matter content in fruits per plant (2.853 %) was recorded from T_0S_4 (15 dS/m salinity + no AA) treatment combination which was closely followed by T_0S_3 (Table 8). Increases in dry matter and yield of salt stressed plant in response to SA may be related to induction of antioxidant response and protective role of membranes that increase the tolerance of plant to damage.

4.3.8 Single fruit weight (g)

Statistically significant variation was recorded for different levels of salicylic acid on weight of individual fruit of tomato. The highest weight of individual fruit (44.81 g) was recorded from T1, whereas the lowest weight (37.81 g) was attained from T_0 (Figure 19).

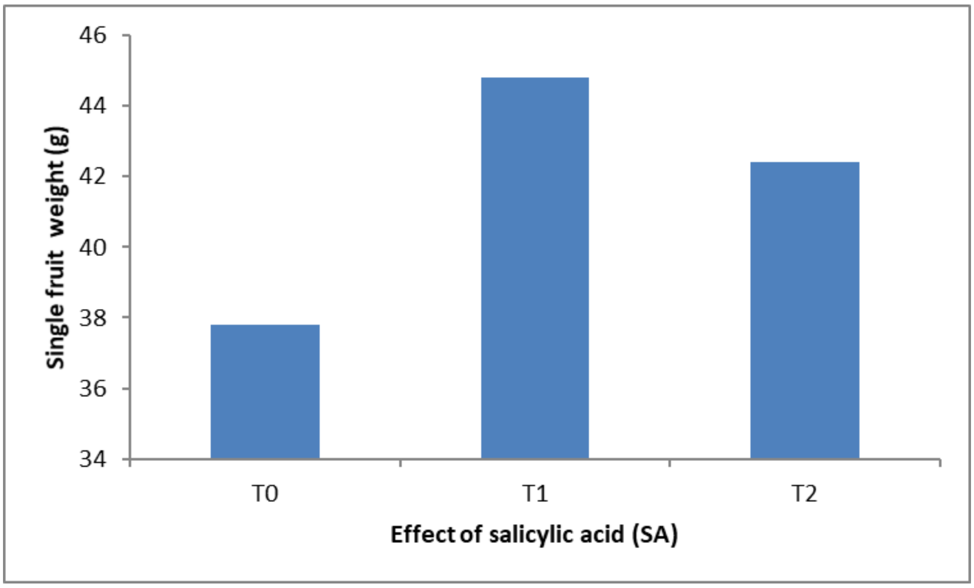

Figure 19. Single fruit weight of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Weight of individual fruit of tomato varied significantly due to effects of different levels of salt stress under the present trial. The highest weight of individual fruit (50.53 g) was found from S0 (no saline). On the other hand, the lowest (33.11 g) was observed from S4 (15 dS/m of salinity) treatment (Figure 20).

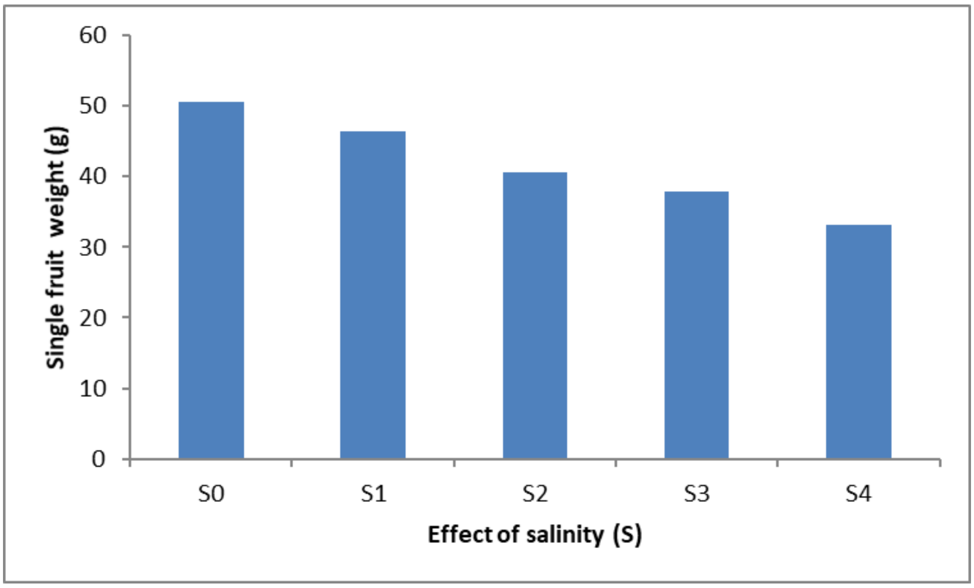

Figure 20. Single fruit weight of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

Combined effect of different levels of salt stress and salicylic acid showed significant differences on weight of individual fruit. The highest weight of individual fruit (55.12 g) was observed from T_1S_0 treatment combination, again the lowest (24.57 g) was recorded from T_0S_4 treatment combination (Figure 21).

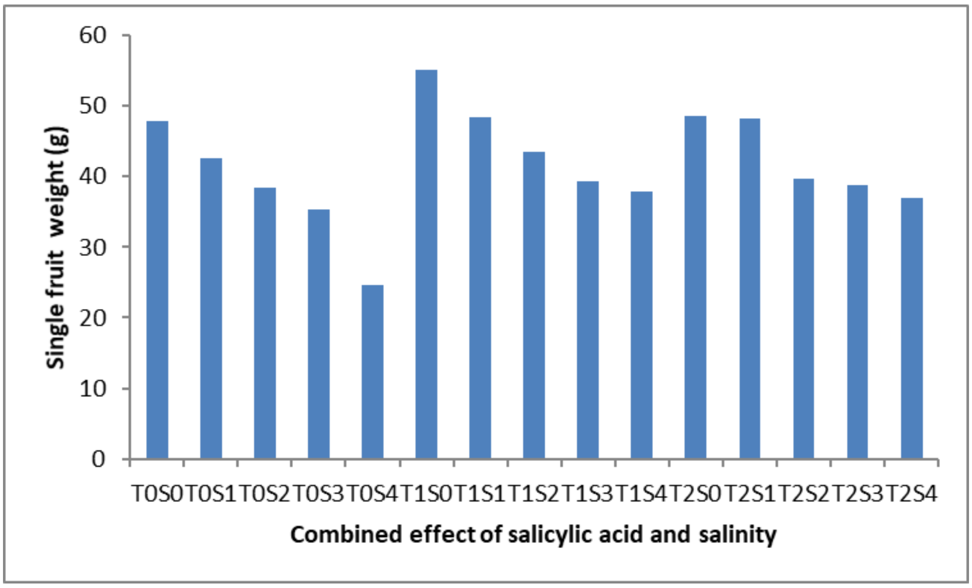

Figure 21. Single fruit weight of tomato as influenced by salicylic acid under different salt stress

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

4.3.9 Yield per plant

In this study the yield of fruit (g) of tomato was converted into gram plant^{-1} (Figure 22 and Appendix III). The different concentrations of salicylic acid had significant effect on the yield of tomato. The highest yield of tomato 1139.0 plant^{-1} was observed from T_1 or 100 ppm of SA whereas the lowest grain yield 920.30 g plant^{-1} was observed from T_0. The yield of tomato increased with increasing the application of salicylic acid. These results are consistent with the present morpho-physiological and yield contributing characters such as plant height, number of leaves no. of branches plant^{-1}, fruit weight (g), diameter of fruit, yield of tomato plant etc. The influence of the SA treatment was dependent on the concentration which was used. Maximum yield was obtained at 1.5mM. All together these results suggest that application of salicylic acid increased the yield of plant by changing the morpho-physiology in tomato plant.

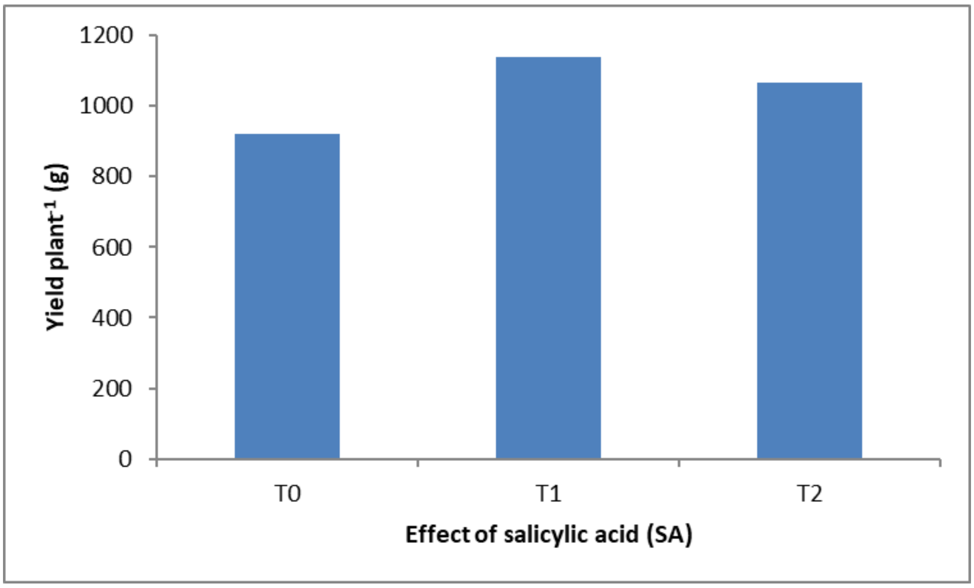

Figure 22. Yield plant^{-1} of tomato as influenced by salicylic acid

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid)

Different levels of salt stress varied significantly in terms of yield per plant of tomato under the present trial. The highest yield per plant (1264.0 g) was recorded from S_0, which was statistically similar, while the lowest yield (821.20 g) was found from S_4 (Figure 23) Most crops tolerate salinity up to a threshold level, above which yields decrease as salinity increases (Maas, 1986). Tomato yield were subjected to 75 and 150 mM NaCl stress in order to study the effect of salt stress on its antioxidant response and stress indicators by Slathia and Choudhary (2013).

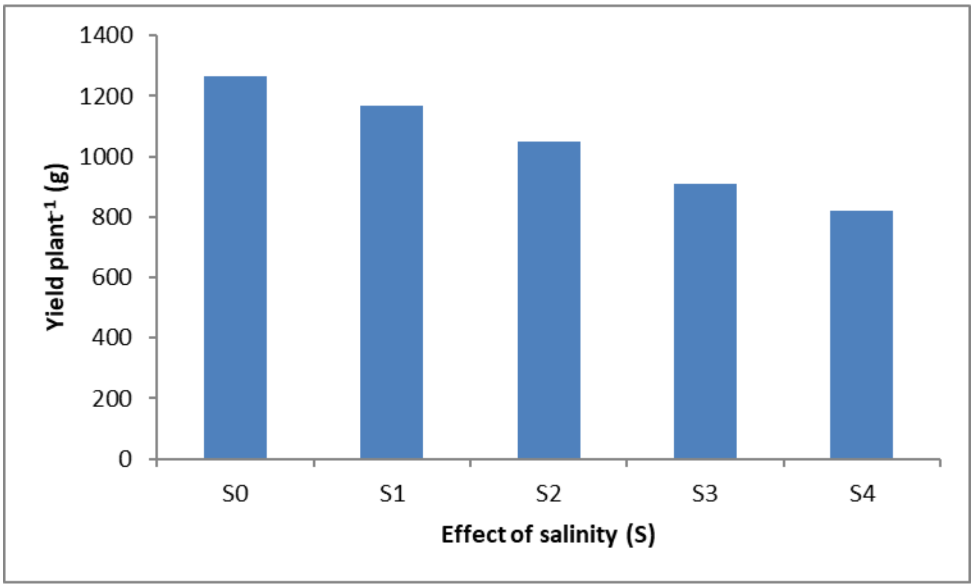

Figure 23. Yield plant^{-1} of tomato as influenced by different salt stress

(Here, S_0 = 0 dS/m (control), S_1 = 6 dS/m, S_2 = 9 dS/m, S_3 = 12 dS/m, S_4 = 15 dS/m)

There was a significant combined effect of different levels of salinity and salicylic acid concentrations and showed significant variation on the yield of tomato (Figure 24 and Appendix III). The maximum yield 1411.0 g plant^{-1} was observed from T_1S_0 while the lowest 687.00 g plant^{-1} was recorded from T_0S_4 treatment combination.

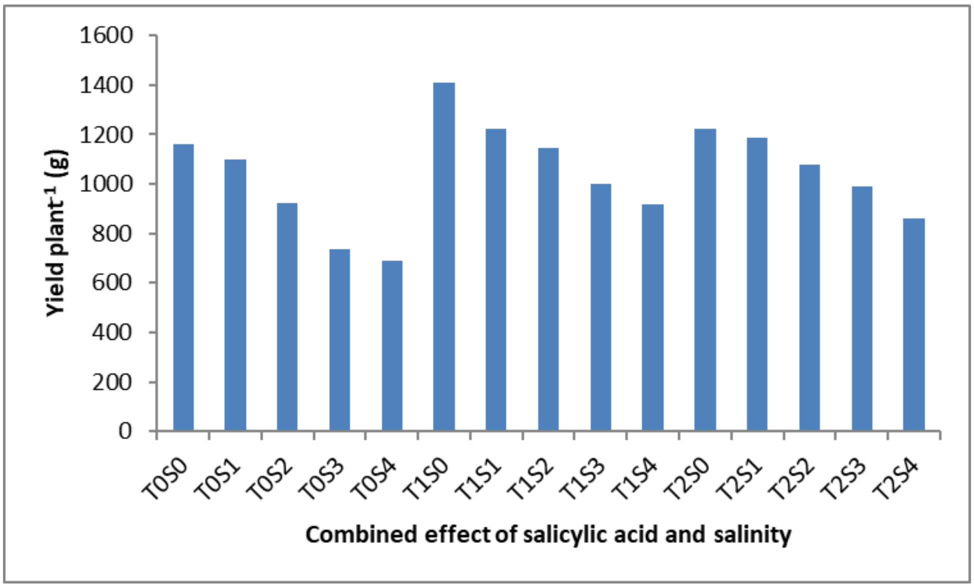

Figure 24. Yield plant^{-1} of tomato as influenced by salicylic acid under different salt stress

(Here, T_0= No salicylic acid, T_1= 100 ppm salicylic acid, T_2= 200 ppm salicylic acid, S_0= 0 dS/m (control), S_1= 6 dS/m, S_2= 9 dS/m, S_3= 12 dS/m, S_4= 15 dS/m)

However, SA induces a wide range of metabolic responses that are generally directed toward adjusting the redox balance in the photosynthetic machinery under conditions of environmental stress. In the case of stress induced by salinity, adjustments are primarily made in the levels of antioxidant compounds that alleviate oxidative stress and these adjustments do not always result in an increase in fruit yield. All together these results suggest that combination of without salt and application of 0.4 Mm salicylic acid increased the grain yield by changing the morphophysiology in tomato.

CHAPTER V
SUMMARY AND CONCLUSION

A pot experiment was conducted during Rabi season in 2018 in completely Randomized design (CRD) with three replications at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. This experiment was studied to know the alleviating the effect of salicylic acid on tomato under saline condition. In the present investigation, seeds of BARI tomato-15 was used. Plants were grown under saline and non-saline conditions. The experiment was two factorials. One Factor was A**:** Different levels of Salinity, S_0 = 0 dS/m**,** S_1 = 6dS/m**,** S_2 = 9dS/m**,** S_3= 12dS/m and S_4 = 15dS/m of salinity and Factor was B: Different concentrations of Salicylic acid (SA): T_0 = 0 ppm**,** T_1 = 100 ppm and T_2 = 200 ppm of salicylic acid. In all the treatments, single plant per pot was placed at 20 DAT. Salicylic Acid (SA) at 0, 100 and 200 ppm concentrations were sprayed at pre flowering, flowering and post-flowering stage. Results obtained from present investigation are as follows:

Significant variations were observed because of different level of salinity in different growth, physiological and yield contributing characters. At 30, 45 and 60 DAT, the highest plant height (50.87 cm, 85.73 cm and 90.12 cm) was found from $S_{0.}$ Whereas the lowest value 42.07 cm, 67.67 cm and 73.60 cm, respectively was observed with S_4 salinity. At 30, 45 and 70 DAT the maximum number of branches per plant (2.00, 3.11 and 8.44) was recorded from S_0. On the other hand, the minimum number (0.22, 1.22 and 5.22) was recorded from $S_{4.}$ At 30, 45 and 60 DAT the maximum number of leaves per plant (10.56, 14.33 and 20.01) was observed from $S_{0.}$ Whereas the minimum number (8.67, 10.22 and 13.11) was found from $S_{4.}$ At 30, 45 and 60 days after transplanting, the highest leaf area per plant (984.80, 1047.00 and 1135.00) was recorded from S_0 while lowest leaf area per plant from S_4 was (705.60, 808.30 and 861.90). At flowering stage, the highest SPAD values (55.01) was obtained from $S_{0.}$, whereas the lowest SPAD values (31.8) was found from S_4. The maximum number of flower cluster per plant was recorded from T_1 (3.87, 9.47 and 14.33) treatment at 40, 50, and 60 DAT. The highest number of flower cluster per plant (4.33, 10.56 and 16.56) was recorded from S_0 whereas the lowest number of flower cluster per plant was recorded from S_4 (2.67, 6.44 and 9.556) respectively. The highest number of flowers per plant (82.89 and 28.78) was recorded from S_0 (0 dS/m salinity) at 60 and 90 DAT, while the lowest number of flowers per plant (48.11 and 20.56) was recorded from S_4. The highest number of fruits per plant (29.33) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (28.56), while the lowest number of fruits per cluster (20.11) was recorded from S_4. The highest fruit drop (4.33) was recorded from S_4 (15 dSm^{-1} of saline water), while the lowest (0.44) was recorded from S_0 (0 dSm^{-1} of saline water). The highest length of fruit (5.46 cm) was recorded from S_0. On the other hand, the lowest length was recorded from S_4 which was followed by 4.69 cm. The maximum diameter of fruit (4.97) was recorded from S_0, while the minimum diameter of fruit (4.15) was recorded from S_4. The highest dry matter content in fruits (8.35%) was recorded from S_0. On the other hand, the lowest dry matter content in fruits per plant (3.57 %) was recorded from S_3. The highest weight of individual fruit (50.53 g) was found from S_0 (no saline). On the other hand, the lowest (33.11 g) individual fruit weight was observed from S_4. The highest yield per plant (1264.0 g) was recorded from S_0 while the lowest yield (821.20 g) was found from S_4.

The maximum plant height (37.67, 51.67 and 47.67 cm, respectively) was obtained from T_2 (200 ppm SA), while the minimum (33.20, 42.39 and 33.89 cm, respectively) was recorded from T_0 The maximum number of branches $plant^{-1}$ 1.24, 2.60 and 7.67 at 30, 45 and 60 DAT was found from T_1 or 100 ppm of SA whereas the minim at 30, 45, and 60 DAT, the maximum number of leaves per plant (10.00, 12.93 and 17.78) was obtained from T1 whereas the minimum number (9.00, 11.33 and 15.33) was found from T_0 for same DAT minimum number of branches $plant^{-1}$ 0.60, 1.80 and 6.27 at 30, 45 and 60 DAT was observed from T_0. At 30, 45 and 60 DAT, the highest number of leaf area per plant was recorded from T1 (889.90, 956.70 and 1036.00) treatment, while the lowest number of leaf area per plant from T_0 was recorded (758.50, 850.40 and 930.80). At flowering stage, the highest SPAD value (50.14) was found from T_1 which was statistically similar (48.31) with T_2, while the lowest SPAD value (43.85) was recorded from T_0. The maximum number of flower cluster per plant (3.87, 9.47 and 14.33) was recorded from T_1 treatment at 40, 50 and 60 DAT. while the minimum number of flower cluster per plant was recorded (3.00, 7.33 and 10.87) from T_0. The maximum number of flowers per plant (72.60 and 25.93) was recorded from T_1 (100 ppm of SA) at 60 and 90 DAT. while the minimum number of flowers per plant (55.67 and 22.33) was recorded from T_0. The maximum number of fruit per plant (27.60) was recorded from T_1, while the minimum number of fruit per plant (3.83) was recorded from T_0. The maximum fruit drop (3.400) was obtained from T_0 and minimum fruit drop (1.733) was obtained from T_1. The highest length of fruit (5.24 cm) was attained from T_1 which was closely followed (5.14 cm) by T2. On the other hand, the lowest length of fruit (4.88 cm) was obtained from T_0 treatment. The maximum diameter of fruit (4.77 cm) was recorded from T_1 while the minimum diameter of fruit (4.37 cm) was recorded from T_0. The highest dry matter content in fruits (5.68 %) was recorded from T_1, while the lowest dry matter content in fruits (4.04 %) was recorded from T_0. The highest weight of individual fruit (44.81 g) was recorded from T_1, whereas the lowest weight (37.81 g) was attained from T_0. The highest yield of tomato 1139.0 plant^{-1} was observed from T_1 or 100 ppm of SA whereas the lowest grain yield 687.00 g plant^{-1} was observed from T_0S_4.

In combined effect of salinity and salicylic acid levels at 30, 40, and 60 DAT, the tallest plant (16.76 cm, 41.71 cm, 63.1 cm, 84.0 cm and 94.0 cm) was found from T_2S_1 (200 ppm of SA+ 0 dS/m of salinity) treatment combination, while the shortest (11.7 cm, 32.0 cm, 52.6 cm, 64.0 cm and 74.4 cm) was found from T_0S_4 treatment combination. At 30, 45 and 60 DAT, the highest number of branches plant^{-1}(8.67) was found from T_1S_0. The lowest value (6.75) was found from T_0S_4 while the lowest value (0.00, 0.67 and 3.67 was found from T_0S_4. The combination of T_1S_0 gave the maximum number of leaves plant-1 (11.00, 15.67 and 20.93). The minimum number of leaves plant-1 (9.00, 10.33 and 13.43) was recorded from T_2S_4. At 30, 45 and 60 DAT the highest number of leaf area per plant was recorded (1107.00, 1144.00 and 1177.00) from T_1S_0 treatment combination while the lowest number of leaf area per plant (2.33) was recorded from T_0S_4 treatment combination. At flowering stage, the highest SPAD value (57.14) was observed from T_1S_0 treatment combination and the lowest SPAD values (35.68) from T_0S_4 treatment combination. The maximum number of flowers cluster^{-1} (5.00, 11.00 and 17.67 a) was recorded from at 40, 50 and 60 DAT, while the minimum number of flowers cluster^{-1} (2.00, 4.67 and 7.00) was recorded from T_0S_4 treatment combination respectively. The maximum number of flowers per plant (87.67 and 30.33) was recorded from T_1S_0 treatment combination while the minimum number of flowers per plant (37.00 and 16.67 f) was recorded from T_0S_4 treatment combination. The maximum number of fruit per plant (30.00) was recorded from T_1S_0 treatment combination, while the minimum number of fruit per cluster (16.67) was recorded from T_0S_4 treatment combination. The maximum fruit drop of petiole (8.00) was recorded from the treatment combination of T_0S_4, while the treatment combination of T_1S_0 (control) gave the minimum (0.00). The maximum fruit length (5.57 cm) was found from the treatment combination T_1S_0 and the minimum (4.44 cm) from the combination of T_0S_4. The maximum diameter of fruit (5.06 cm) was recorded from T_1S_0 treatment combination, while the minimum diameter of fruit (4.44 cm) was recorded from T_0S_4 treatment combination. The highest dry matter content in fruits (7.980%) was recorded from T_1S_0 treatment combination, while the lowest dry matter content in fruits per plant (2.853 %) was recorded from T_0S_4 treatment combination. The highest weight of individual fruit (55.12 g) was observed from T_1S_0 treatment combination, again the lowest (24.57 g) was recorded from T_0S_4 treatment combination. The maximum yield 1411.0 g plant^{-1} was observed from T_1S_0 treatment combination, while the lowest 687.00 g plant^{-1} was recorded from T_0S_4 treatment combination.

Conclusion

Considering the situation of the present experiment, it can be concluded that morphological, physiological and yield contributing characters and yield of tomato gradually reduced with the increase of salinity and this reduction rate decreased by foliar application of salicylic acid. Among the salicylic acid levels 100 ppm showed the best results as compared to 200 ppm.

CHAPTER VI

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APPENDICES

Appendix I.: Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207

Figure: The map of Bangladesh showing experimental site

Appendix II. (A) Records of meteorological information (monthly) during the period from October 2018 to March 2019.

Month	Air temperature (0C)		Relative Humidity (%)	Rainfall (mm)
	Maximum	minimum		
October, 2018	30.42	16.24	67.48	52.60
November, 2018	28.5	8.52	56.75	14.40
December, 2018	25.50	6.7	54.80	0
January, 2019	23.7	11.7	46.20	0
February, 2019	22.75	14.26	36.8	0
March, 2019	23.6	16.5	46.1	40

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

(B). Morphological characteristics of soil of the experimental plot

Morphological features	Characteristics
Location	Horticulture Garden, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained

(C). Physical and chemical properties of initial soil of the pot

Characteristics	Value
% Sand	25
% Silt	45
% Clay	30
Textural class	Silty-clay
P^H	6.15
Organic matter (%)	1.16
Total N (%)	0.05

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

Appendix-III: Analysis of variance of different character of tomato

Sources of variation	Degrees of freedom	Plant height (cm)		
		30 DAT	45 DAT	60 DAT
Replication				
Factor A (Salinity)	2	1.907**	2.110**	2.819**
Factor B (Salicylic acid)	4	118.11**	477.48**	377.23**
AB	8	10.970**	7.126**	13.800**
Error	30	2.407	3.225	4.119

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

Appendix-III: Continued

Treatment	Degree of freedom	Number of branches plant^{-1}		
		30 DAT	45 DAT	60 DAT
Replication				
Factor A	2	1.800**	2.489**	8.289**
Factor B	4	4.611**	4.967**	15.389**
AB	8	0.078**	0.100**	0.622**
Error	30	0.041	1.489	0.108

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAT	45 DAT	60 DAT
Factor A	2	NS	NS	NS
Factor B	4	NS	24.144**	73.91**
AB	8	NS	0.578**	0.661**
Error	30	3.622	0.613	0.392

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	Leaf area plant^{-1} (cm^2)		
		30 DAT	45 DAT	60 DAT
Factor A	2	7.867**	6.689**	8.756**
Factor B	4	1024.356**	3513.478**	3783.856**
AB	8	444.006**	231.994**	914.172**
Error	30	12.800	12.889	1 4.822

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	Dry matter content of plant after harvest (g)
Factor A	2	3.458**
Factor B	4	411.36**
AB	8	14.24**
Error	30	3.542

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	SPAD value
Factor A	2	6.920**
Factor B	4	390.009**
AB	8	4.160**
Error	30	0.994

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	Number of flower cluster^{-1}		
		40 DAT	50 DAT	60 DAT
Factor A	2	3.267**	1.867**	1.489**
Factor B	4	4.300**	29.256**	72.300**
AB	8	0.100**	1.089**	2.183**
Error	30	0.122	0.211	0.231

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

Appendix-III: Continued

Sources of variation	Degrees of freedom	Number flowers plant^{-1}	
		60 DAT	90 DAT
Factor A	2	6.467**	5.622**
Factor B	4	182.578**	89.500**
AB	8	66.078**	3.067**
Error	30	2.444**	3.444**

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