ALLEVIATION OF ADVERSE EFFECTS OF SALT STRESS IN TOMATO BY FOLIAR APPLICATION OF SALICYLIC ACID

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CERTIFICATE

*This is to certify that the thesis entitled **"Alleviation of adverse effects of salt stress in tomato by foliar application of salicylic acid"** submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural chemistry**, embodies the result of a piece of bona fide research work carried out by **Md. Abdul Owhab Mridha,** Registration number: **12-04733** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
Place: Dhaka, Bangladesh

Dr. Sheikh Shawkat Zamil
Associate Professor
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

A pot experiment was conducted at the net house of Agro-Environmental Chemistry Laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2017 - August 2018 to find out the alleviation of adverse effects of salt stress in tomato by foliar application of salicylic acid. The experiment comprised of two factors: Factor-1. Salinity levels: 0, 3, 6 and 9 dSm^{-1} and Factor- 2. Rate of salicylic acid: 0 mM, 0.5 mM, 1 mM and 1.5 mM. BARI tomato -14 was used as the test crop. Data were taken from plant height, leaves $plant^{-1}$, number of branches $plant^{-1}$, days to 1^{st} flowering from transplanting, number of flower $cluster^{-1}$, number of flower cluster $plant^{-1}$,number of flower $plant^{-1}$, number of fruit $plant^{-1}$, length of fruit, diameter of fruit, fruit yield $plant^{-1}$, K, Na, Ca and P content in fruit. When single effect was considered, salinity adversely affected most of the growth and yield parameters and nutrient content except Na, but application of salicylic acid elevated all the mentioned parameters. When combined effect was considered, maximum plant height (70.33 cm), leaves $plant^{-1}$ (53.50) at final harvest, number of branches $plant^{-1}$ (6.67), flower $plant^{-1}$ (19.18), fruit $plant^{-1}$(11.78) and fruit yield $plant^{-1}$ (470.30 g) were found from $S_0SA_{1.5}$ treatment. Whereas the minimum plant height (23.00 cm), number of branches $plant^{-1}$(2.33), flower $plant^{-1}$ (6.10), fruit $plant^{-1}$ (4.88) and fruit yield $plant^{-1}$ (161.50 g) were found from $S_9SA_{0.0}$ treatment. In all the salinity levels, it was found that foliar application of salicylic acid reduce adverse effect of salt stress. Such as at S_9 salinity level showed minimum fruit yield $plant^{-1}$ (161.50 g) was found when no salicylic acid was applied but maximum fruit yield $plant^{-1}$ (186.70 g) was found when $SA_{1.5}$ salicylic acid was applied as foliar $S_9SA_{1.5.}$ Similar trend was observed for all the parameter except K, Ca and Na content.

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ABBREVIATIONS

%	Percent
&	And
/	Per
@	at the rate
˚C	Degree Centigrade / Degree Celsius
^{0}E	Degree East
^{0}N	Degree North
^{0}S	Degree South
^{0}W	Degree West
a.i.	Active ingredient
AA	Ascorbic acid
AAS	Atomic absorption spectrophotometer
ANOVA	Analysis of Variance
BS	Broad Sense
C.D	Critical Difference
Ca	Calcium
cm	Centimetres
CRD	Complete Randomized Design
CV	Coefficient of Variation
d.f.	Degree of Freedom
DAT	Date after transplanting
e.g.	Example Gratia (For example)
ECV	Environmental Coefficient of Variation
Ed.f	Error degree of freedom
EMS	Error mean Sum of Squares
ESP	Error Sum of Products
ESS	Error Sum of Squares
et al.	et alia (and other)
etc.	Etcetera (and all)
F- test	Fisher test
F. cal.	Calculated value of F
F. tab.	Tabulated value of F
FAO	Food of agriculture organization
Fig.	Figure

g	Gram
Hrs.	Hours
i.e.	id est. (That is)INAA International Neutron Activation Analysis
K	Potassium
kg	kilogram
LSD	Least significance difference
Max.	Maximum
mg	milligram
Min.	Minimum
ml	milliliter
mM	millimetre
MSS	Mean Sum of Squares
N.S.	Non – significant
Na	Sodium
P	Phosphorus
ppm	parts per million
RBD	Randomized Block Design
Rs.	Rupees
RSS	Replication Sum of Squares
S	Significant
S.D.	Standard deviation
S_0	Salinity
SA	Salicylic acid
SE(9±)	Standard error of mean
SEPA	State environmental protection administration.
Sig.	Significant
SR	Serial
SS	Sum of Squares
T	Treatment
TZ	Tetrazolium
Viz.	vide licet (namely)
WHO	World Health Organization

CHAPTER I

INTRODUCTION

Salt stress is one of the most important environmental factors responsible for the reduced yield of cultivated plants. The problem of soil salinity observed both in coastal zone and inland is a pervasive threat to agricultural production and the environment in view of its adverse effects on sustainable use of land and water resources. While the immediate source of salts in saline soils can be the parent material, irrigation water, shallow groundwater, fertilizer and amendments applied to the soils also add to the problem. The effect of salinity on crop yield is a function of the threshold salinity above which yield decline, and the percentage of yield decrease $unit^{-1}$ of salinity increases above the threshold. The presence of salt could exert an adverse effect on plant growth. Salts make the nutrients less available because of osmotic pressure. Excess salt becomes toxic to plants. The long-term presence of excess salts can damage the soil irreversibly. The exposure of plant high salinity induces osmotic and ionic stress as well as the formation of reactive oxygen (Munro *et al.* 2002). Salinity disturbs the physiology of plants by changing the metabolism of plants (Garg *et al.* 2002). Salinity badly reduces leaf area, accumulation of dry matter content and also reduce net rate of CO_2 assimilation (Amador *et al.* 2002). Tomato (*Lycopersicon esculentum* Mill.) is a vegetable crop under the family Solanaceae and has been originated in tropical America (Salunkhe *et al*. 1987) which includes Peru, Ecuador, Bolivia areas of Andes (Kallo, 1986). Tomato is one of the most popular and important vegetable crop grown in Bangladesh (Mondal *et al*., 2011). Though it is a winter crop, nowadays, it is grown round the year and there has been a gradual increase in the area of land cropped to tomato and this led to marginal increases in tomato production. 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 (FAOSTAT, 2013). The total production of tomato was 339 lac tons in China, 137 lac tons in USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt (FAO, 2010). Due to increasing consumption of tomato products, the crop is becoming promising. At present Bangladesh is producing a good amount of tomatoes and it is using for the preparation of different delicious food.

In Bangladesh, it occupies an area of 26,316.2 hectares in the year of 2012-2013 with the total production of 251 thousand metric tons (BBS, 2013). The yield of tomato in our country is not satisfactory in comparison to other country and its requirement (Aditya *et al.* 1999*).* The low yield of tomato in Bangladesh, however, is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, poor crop management practices and lack of improved technologies. Use of high yielding variety and modern technology of cultivation is pre-requisite for increasing the production of tomato in Bangladesh. Crop plants encounter unavoidable abiotic stresses during their life cycles, including salinity, drought, extreme temperatures, metal toxicity, flooding, UV-B radiation, ozone, etc. which all pose serious challenges to plant growth, metabolism, and productivity (Hasanuzzaman *et al.* 2012). From the abiotic stresses, salt stress is a major environmental threat to agriculture, and its adverse impacts are getting more serious problems in regions where saline water is used for irrigation (Türkan and Demiral, 2009). Therefore, efforts to increase the salt tolerance of crop plants are very important to ensure global food security, as well as for water and land conservation. A high salt concentration in the soil or in irrigation water can have a devastating effect on plant metabolism; that is, it can result in the disruption of cellular homeostasis and uncoupling of major physiological and biochemical processes. Plants can respond and adapt to salt stress by altering their cellular metabolism and invoking various defence mechanisms (Ghosh *et al.* 2011).

Tomato is one of the world most important and widespread crop with adverse effects of salinity (Bradbury and Ahmed, 1990). Salinity reduced tomato yield (Sonnenveld and Vander, 1991), but improved fruit quality traits, such as total soluble solid and color (Martinez *et al.*, 1987). A large differences are apparent in tolerance of different varieties of tomatoes. A distinctive differences in salt tolerance was obtained with fresh market cultivated tomatoes (Alia *et al. 2002*). Plant scientists are now searching for ways to make the plants adaptive under saline conditions. Researchers are trying to understand the effects of salt stress on plants so that they can modify the plant‘s external growing condition as well as change the plant from within by applying different exogenous protectants including trace elements and phyto hormones by molecular mechanisms against abiotic stresses, Salicylic acid (SA) is regarded as one of the most effective growth regulator. SA not only acts as an antioxidant but the cellular levels of SA are correlated with the activation of complex biological defense mechanisms. It has also been used to counteract the adverse effects of salt stress in many crop plants (Beltagi *et al*. 2008). It has proposed functions in whole plant metabolism. Furthermore, experimental studies on different plants have shown that exogenous application of Ascorbic acid may reduce salt induced adverse effects and results in a significant increment of growth and yield. Also ascorbate influences many enzyme activities, minimizing the oxidative damage through synergic function with other antioxidant (Foyer *et al.* 2005). Treatment with exogenous salicylic acid has been shown to decrease the harmful effect of abotic stresss, such as high salinity (Tari *et al.* 2002). The effect of salicylic acid not only depend on not only concentration but also plant species, developmental stage or mode of application (Horvath *et al*. 2007).

Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al*. 2010). Endogenous salicylic acid is said to act like a growth regulator and functions as an indirect signal stimulating many physiological, biochemical and molecular processes and therefore it affects the plant growth and development (Klessig and Malamy, 1994). Numerous studies have documented the influence of endo and exogenous salicylic acid on the content of photosynthetic pigments in leaves (Yildirim *et al*. 2008), on plant photosynthesis (Fariduddin *et al*. 2003) and on nitrogen metabolism owing to salicylic acid producing a positive impact on the activity of nitrate reductase (Fariduddin *et al*. 2003; Miguel *et al*. 2002), synthesis of secondary plant metabolites (Eraslan *et al*. 2007). Salicylic acid increased fruit number and yield also facilitate transferring sugar to the fruit from leaves (Elvwan and Hamahyomy, 2009). Thus, application of salicylic acid affected yield and quality characters of tomato (Javaheri *et al.* 2012). In most of the cases, hardening with SA to a subsequent abiotic stress was investigate in short term experiments (Wang *et al*. 2005). However, our knowledge about oxidative stress and antioxidant response during salt stress after a long term SA pre-treatment is incomplete.

Several studies have supported the major role of salicylic acid (SA) in mediating the Response of plants to abiotic and biotic stress by the induction of antioxidant defense.

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objectives:

1. To investigate the effect of salinity on morphological characters, yield and nutrient contents of BARI Tomato -14,
2. To evaluate the different concentration of salicylic acid for attaining optimum yield and quality of tomato,
3. To identify the best combinations of salinity and salicylic acid for better yield attributes, yield and quality of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetable crop in Bangladesh and other countries of the world and it has drawn attention by the searchers for its various consumptions. It is adapted to a wide range of climate ranging from tropics within a few degree of the Arctic Circle. But very few research works available related to alleviation of adverse effects of salt stress in tomato by salicylic acid. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to salt stress and also mitigating to the salt stress in vegetable crops as well as tomato, so far been done at home and abroad, have been reviewed in this chapter under the following heads:

2.1 Salt stress

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. A considerable amount of land in the world is affected by salinity which is increasing day by day. More than 45 million hectares of irrigated land which account to 20% of total land have been damaged by salt worldwide and 1.5 million ha are taken out of production each year due to high salinity levels in the soil (Lauchli, 2002). On the other hand, increased salinity of agricultural land is expected to have destructive global effects, resulting in up to 50% loss of cultivable lands by the middle of the twenty- first century (Mahajan and Tuteja, 2005).

Most of Bangladesh's coastal region lies on the southwest coastal region of the country. Approximately 30% of the crops land of Bangladesh is located in this region (Mondal *et al*. 2001) and continuous to support crops productivity and GDP growth. But in the recent past, the contribution of crops to GDP has decreased because of salinity. In total, 52.8% of the cultivable land in the coastal region of Bangladesh was affected by salinity in 1990 and the salt affected area has increased by 14600 ha per year (SRDI, 2001). SRDI had made a comparative study of the salt affected area between 1973 to 2009 and showed that about 0.223 million ha (26.7%) of new land has been affected by varying degrees of salinity during the last four decades and that has badly hampered the agro-biodiversity (SRDI, 2001). Farmers mostly cultivate low yielding, traditional rice varieties. Most of the land kept fallow in the summer or pre-monsoon hot season (March-early June) and autumn or post- monsoon season (October- February) because of soil salinity, lack of god quality irrigation water and late draining condition. In the recent past, with the changing degree of salinity of southwest coastal region of Bangladesh, crop production becomes very risky and crop yields, cropping intensity, production levels of crop and people‘s quality of livelihood are much lower than that in the other parts of the country. Cropping intensity in saline area of Bangladesh is relatively low, mostly 170% ranging from 62% in Chittagong coastal region to 114% in Patuakhali coastal region (FAO, 2010).

In most of the cases, the negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions produce many physiological disorders in plant, Cl^- is the most dangerous (Tavakkoli *et al*. 2010). Salinity at higher levels causes both hyper ionic and hyperosmotic stress and can lead to plant demise. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leading to plant death (Mahajan and Tuteja, 2005; Hasanuzzaman *et al*. 2012). One of the most initial effects of salt stress on plant is the reduction of growth rate. Salinity can affect growth of plant in various ways. First, the presence of salt in the soil reduces the water uptaking capacity of the plant, and this quickly causes 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, *et al*. 2002).

2.2 Salt stress on tomato plant

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

A field study was conducted by (Siddiky *et al*. 2012) to screen out a number of Bangladeshi tomatoes (*Lycopersicon esculentum* L.) varieties for salinity tolerance. Three levels of salinity were 2.0-4.0 dSm^{-1}, 4.1-8.0 dSm^{-1} and 8.1-12.0 dSm^{-1}. Significant varietal and salinity treatment effects were registered on plant height, leaf area, plant growth, yield, dry matter $plant^{-1}$, Na^+ and Cl^{-1} accumulation in tomato tissues. Variety BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 consistently showed superior biological activity at moderate salinity (4.1-8.0 dSm^{-1}), based on dry matter biomass production thus displaying relatively greater adaptation to salinity. Under saline condition, all plant parameters of tomato varieties were reduced compared to the control except number of fruits of BARI Tomato14, BARI Hybrid Tomato 5 and BARI Tomato 2. Thus, BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 can be regarded as a breeding material for development of new tomato varieties for tolerance to salinity in saline areas of Bangladesh. Bahar and Tuzel, (2011) was conducted an study in a greenhouse to determine the response of 4 commercial tomato rootstocks, 21 cultivars and 8 candidate varieties to salinity stress. Seeds were germinated in peat and when the plants were at the fifth-true leaf stage, salt treatment was initiated except control treatment. NaCl was added to nutrient solution daily with 25 mM concentration and had been reached to 200 mM final concentration. On harvest day, genotypes were classified based on the severity of leaf symptoms caused by NaCl treatment. After symptom scoring, the plants were harvested and leaf number, root length, stem length and diameter per plant were measured. The plants were separated into shoots and roots for dry matter production. Our results showed that, on average, NaCl stress decreased all parameters and the root stocks gave the highest performance than genotypes. Among all rootstocks, three varieties (819, 2211 and 2275) and ten genotypes (Astona, Astona RN, Caracas, Deniz, Durinta, Export, Gökçe, Target, YeniTalya and 144 HY) were selected as tolerant with slight chlorosis whereas the genotype Malike was selected as sensitive with severe chlorosis. Candidate varieties 2316 and 1482 were the most sensitive ones. Plant growth and dry matter production differed among the tested genotypes. However no correlation was found between plant growth and dry matter production. Rootstock Beaufort gave the highest shoot dry matter although He man had highest root dry matter. Newton showed more shoot and root dry matter than of her genotypes. It is concluded that screening of genotypes based on severity of symptoms at early stage of development and their dry matter production could be used as a tool to indicate genotypic variation to salt stress.

A research was conducted by .(Boamah *et al*. 2011) to determine the salinity level of irrigation water from a dug well, pond and tap water as well as its effect on the yield of a tomato crop at the University of Cape Coast Teaching and Research Farm. Water samples were taken at fortnight intervals to determine the electrical conductivity (dSm^{-1}) using the TOA water quality checker 20A. The averages of the four batches were computed and used as the three sources fourth period of assessment. Flowering and yield of crop were the parameters used to assess the effect of salinity level on the tomato crop. Electrical conductivity as a measure of salinity was higher in the pond (0.25 dSm^{-1}) than the well and tap water (0.07dSm^{-1} and 0.02 dSm^{-1}, respectively). Flowering and yield of tomato was high with crops treated with well water (45.22%, 99.08$kgha^{-1}$) followed by the pond (27.70%; 43.76 $kgha^{-1}$) and tap water (27.08%; 27.25 $kgha^{-1}$) in that order. There was no significant difference in flowering and in yield of crops between the tap and pond treatments at both 0.05 and 0.01 levels but there was a significant difference in yield between the well treated crops and other sources.

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

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

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

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

(Parida *et al.* 2005) found in their study that salinity stress results in a clear stunting of plant growth, which results in a considerable decrease in fresh and dry weights of leaves, stems and roots of tomato. Increasing salinity is also accompanied by significant reductions in shoot weight, plant height and root length. They also found that exposure of plants to salt stress usually begins in the roots. This leads to changes in growth, morphology and physiology of the root that will in turn change water and ion uptake and the production of signals that sends information to shoot. The whole plant is then affected when roots are growing in a salty medium. Tomato cultivars varied significantly in their response to different salinity levels. Increasing NaCl concentrations in nutrient solution adversely affect tomato shoots and roots, plant height, K^+ concentration, and K^+/Na^+ ratio was investigated by Munns, (2005). They also found yield reductions induced by salinity may be due to both the osmotic stress that results from relatively high solute concentrations in the root growing medium, and specific toxicity due to the accumulation of high concentrations of Na^+ and Cl^- in the plant, which provokes a wide variety of physiological and biochemical alterations that inhibit plant growth and production.

Salt stress also affect fruit ripening on tomato. (Mirajhi *et al.* (1981) conducted an experiment on effect of salinity on fruit ripening. He showed that tomato (*Lycopersicon esculentum Mill*) plants from various cultivars growing on half-

Strength Hoagland solution were exposed at an thesis to 3 or 6 grams per liter NaCI. Salinity shortened the time of fruit development by 4 to 15%. Fruits of salt-treated plants were smaller and tasted better than did fruits of control plants. This result was obtained both for ripe fruits tested on the day of picking and for those picked at 100% development and allowed to ripen at room temperature for 9 days. Percentage of dry weight, total soluble solids, and titratable acidity; content of reducing sugars, Cl1, Na^+, and various pericarp pigments; and electrical conductivity of the juice were higher in fruits of saline-treated plants than they were in those of control plants, while the pH was lower. Ethylene and CO_2 evolution rates during ripening, as well as the activities of pectin methyl esterase, polymethyl galacturonase, and polygalacturonase; were also higher in fruits of the saline-treated plants.

2.3 Effect of salicylic acid on yield of tomato

In order to improve the germination of tomato seeds under high temperature stress conditions seed priming by salicylic acid was investigated by Singh and Singh (2016). The experiment was conducted to study the effect of salicylic acid on the tomato vegetative growth, yield and fruit quality of tomato. These factors included salicylic acid in three levels (0.25 mM, 0.5 mM and 0.75 mM) applied on tomato. Results indicated that germination and vegetative and reproductive growth of tomato severely reduced by high temperature. The TSS, TA, vitamin C and lycopene content of tomato fruit had significantly affected by application of salicylic acid. The exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in tomato fruit yield. Javaheri *et al*. (2014) carried out an experiment to study the effects of salicylic acid on some quality characters of tomato different concentration of salicylic acid (10^{-2} 10^{-4}, 10^{-6} and 10^{-8} molar and control) was done in seedling stage as foliar replication. Obtained results of this study show that salicylic acid significantly affected number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter. Among foliar application, the highest rate of tomato yield with mean of 3059.5 g obtained in SA_3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA (SA_1 at 10^{-2} M).

Highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA_1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control and the highest amount of fruit weight and also fruit diameter was measured in SA_1 (SA at 10^{-2} M) with mean of 61.50 g and 51.75 mm, respectively. (Lakzayi *et al*. 2014) reported that effect of drought is among the environmental constraints that affect crop growth and crop production worldwide. Drought or water deficit stress elicits many different physiological responses in plants. The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress and may be the result of pigment photo- oxidation and chlorophyll degradation. Relative water content (RWC), leaf water potential, stomatal resistance, the rate of transpiration, leaf temperature and canopy temperature are important characteristics that influence plant water relations. Salicylic acid (SA) as a potent signaling molecule in plants is involved in eliciting specific responses to biotic and abiotic stresses.

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

In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato.

(Guzman-Tellez *et al*. 2014) carried out a study to determine the change in the SA leaf concentration over time in response to the SA spraying in leaves of greenhouse grown tomato. In sprayed leaves the SA concentration showed changes over time similar to the reported responses to environmental stress. Two days after the first application, the SA foliar concentration reached the maximum of 8 $\mu g \cdot g^{-1}$, equivalent to twice the amount observed in the control plants. SA decreased until it reached the level of control plants eight days later. A second application showed actually the same response, but with a faster decline of SA in two days.

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

(Javaheri *et al*. 2012) carried out an experiment to study the effects of salicylic acid on yield quantity and quality of tomato, at research center of Shirvan Agricultural Faculty. Foliar application of five concentrations of salicylic acid (0, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} M) were used. Results showed that application of salicylic acid affected tomato yield and quality characters of tomato fruits so that tomato plants treated with salicylic acid 10^{-6} M significantly had higher fruit yield (3059.5 g per bush) compared to non-treated plants (2220 g bush^{-1}) due to an increase in the number of bunch per bush. Results also indicated that application of salicylic acid significantly improved the fruit quality of tomato. Application of salicylic acid increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits. Fruit of tomato plants treated with salicylic acid 10^{-2} M significantly had higher vitamin C (32.5 mg 100 g of fruit^{-1} fresh weight) compared to non-treated plants (24 mg 100 g fruit-1 fresh weight). Salicylic acid concentration 10^{-2} M also increased the diameter of fruit skin (0.54 mm) more than two fold compared to 10^{-2} M (0.26 mm). Fruit Brix index of tomato plants treated with salicylic acid significantly increased (9.3) compared to non-treated plants (5.9). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Consequently pot experiment was conducted by (Salehi *et al*. 2011) to evaluate the effect of SA on tomato growth under salt stress condition. The experiment was complete randomized block with 3 replications, 4 levels of irrigation water salinity (0, 4, 8 and 12 dSm^{-1}) and 4 levels of SA concentration (0, 10^{-6}, 10^{-4} and 10^{-2} M) which was foliar sprayed. There was highly significant reduction in shoot fresh and dry weights and number of flowers per plant with increasing salinity. There was no significant difference between shoot fresh and dry weighs and number of flowers per plant for SA treated plants and control. However, fresh weight of plants treated with 10^{-4} M SA was significantly higher than the other two concentrations. Within each salinity level, SA application did not have significant effects on the measured plants characteristics. Based on these results, under this experimental condition, SA acid did not improve the salt tolerance of tomato. However, lower concentrations of SA needs to be evaluated. (Zahra *et al*. 2010) planted tomato seeds in pots containing per lite were put in a growth chamber under controlled conditions of 27 ± 2^0C and 23 ± 2^0C temperature, 16 hour lightness and 8 hour darkness, 15 lux light intensity and 75% humidity; NaCl concentration of 0, 25, 50, 75 and 100 mM and salicylic acid concentration of 0, 0.5, 1 and 1.5 mM were used. Salinity increases the soluble sugar in leaf and root tissues, and salicylic acid decreases it. The leaf protein level decreased because of salinity effect, but salicylic acid could increase it. In the root, salinity increases protein, but salicylic acid with 1.5 mM concentration decreases it. Salinity increases the proline level in leaf and root, and salicylic acid did not significantly change in low salinity levels.

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

Yildirim and Dursun (2009) conducted an experiment to determine the effect of foliar salicylic acid (SA) applications on fruit quality, growth and yield of tomato under greenhouse conditions. In the study, fruit diameter, fruit length, fruit weight, fruit number per plant, Vitamin C, pH, Total Soluble Solids (TSS), titratable acidity (TA), stem diameter, leaf dry matter ratio, chlorophyll content, early yield and total yield were determined. Tomato plants were treated with foliar SA applications at different concentrations (0.00, 0.25, 0.50 and 1.00 mM). SA was applied with spraying four times during the vegetation at 10-days interval two weeks after planting. In the study, it was determined that foliar applications of SA showed positive effect on some fruit characteristics, plant growth, chlorophyll content in leaves, early yield and total yield. SA treatments had no effect on pH, AA and TA of tomato. Total soluble solids (TSS) increased with foliar SA applications. The greatest stem diameter, leaf dry matter and chlorophyll content were obtained from 0.50 mM SA treatment. SA treatments increased the early yield of tomato compared to the control. The yield of tomato was significantly influenced by foliar SA applications. The highest yield occurred in 0.50 mM SA treatment. According to the results, applications of 0.50 mM SA should be recommended in order to improve yield.

Two field experiments were conducted by Mady (2009) to study the effect of foliar application with 50 and 100 ppm of salicylic acid (SA) and vitamin E and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phyto hormones, flowering, fruiting and fruit quality of tomato cv. Super strain B. Plants were sprayed two times at 30 and 45 days after transplanting. Results indicated that, different applied treatments significantly increased all studied growth parameters as well as number of branches and leaves per plant, leaf area per plant and leaves dry weight as well. In addition, chemical composition of minerals and some bio constituents such as carbohydrates, vitamin C, total soluble solids in tomato fruits were also increased at the same treatments. Therefore, the present study strongly admit the use of salicylic acid and vitamin E as foliar application not only increased early and total yields but also getting a good fruit quality as well. The above cited reviews revealed that variety and salicylic acid greatly affect the growth and as well as the yield of tomato. But the literature on the effects of salicylic acid on different variety of tomato have not been well defined and have no definite conclusion in this aspects under the agro climatic condition of Bangladesh.

CHAPTER III

MATERIALS AND METHODS

3.1. Location of the experimental field

The experiment was conducted at the net house of Agro-Environmental Laboratory of the department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, during the period from November 2017-August 2018. The experiment was carried out to evaluate the adverse effects of salt stress in tomato by foliar application of salicylic acid.

3.2. Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year (Source: NOAA).

3.3. Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, EC-25.28 (Haider, 1991). The analytical data of the soil sample collected from the experimental area which were determined from the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, dhaka and have been presented in Appendix II.

3.4. Plant materials collection

The tomato variety used in the experiment was "BARI Tomato-14" .This is a high yielding variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) Joydebpur, Gazipur.

3.5. Raising of seedlings

Tomato seedlings were raised in two seedbeds of 3 m x 1m size. 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. Five gram seeds were shown on each seedbed in 29 October 2017. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 6 to 7 days after sowing. Weeding, mulching and irrigation were done as and when required.

3.6. Treatments of the experiment

The experiment consists of two factors:

Factor A: Different levels of Salinity:

I. S_0: 0 dSm^{-1}
II. S_1: 3 dSm^{-1}
III. S_2: 6 dSm^{-1}
IV. S_3: 9 dSm^{-1}

Factor B: Different levels of Salicylic Acid: 0 mM, 0.5 mM, 1 mM and 1.5 mM

Treatment combination: (4×4) = 16, Replication: 3

3.7. Design and layout of the experiment

The experiment was laid out in CRD **(**Completely Randomized Design) having two factors with three replications. There were 48 pots for this experiment. Each pot consist of 1 plant where 8 treatments were allotted randomly. Each plant consists of different salinity level and different levels of salicylic acid.

3.8. Cultivation procedure

3.8.1. Soil preparation

The soil was well prepared and good tilt was ensured for commercial crop production. The soil of the experiment was ploughed with a power tiller on 02 November, 2017. Later on the land was ploughed three times followed by laddering to obtain desirable tilt. The corners of the land were spaded and larger clods were broken into smaller pieces. After plugging and laddering, all the stubbles and uprooted weeds were removed and then the soil was made ready to use. After that, the experimental pots were filled with that soil. In each pot contain 8.0 kg soil.

3.8.2. Manures and fertilizers and its methods of application

The entire amount of cow dung and TSP were applied as basal dose during land preparation. Urea, TSP, MOP and Gypsum were applied at the rate of 2.64 g pot^{-1}, 0.96 g pot^{-1}, 1.44 g pot^{-1} and 1.2 g respectively. Urea and MOP were used as top dressing in equal splits at 20, 30 and 40 days after transplanting.

3.8.3. Transplanting of seedlings

Healthy and uniform 28 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental pots in 08 December, 2017 maintaining a spacing of 50 cm x 50 cm between the pots, respectively. This allowed an accommodation of1 plant in each pot. The plants was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting.

3.8.4 Intercultural Operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows:

3.8.4.1. Gap filling

When the seedlings were became strong and well established, the soil around the base of each seedling was granulated A few gaps filling was done by healthy and strong seedlings of the same stock where initial planted seedling failed to survive.

3.8.4.2. Weeding

Numbers of weed were removed with the help of nirani and whenever necessary to keep the crop free from weeds.

3.8.4.3. Staking

When the plants were well raised, staking was given to each plant by rope and plastic wire to keep them erect. Within a few days of staking, as the plants grew up, other cultural operations were carried out.

3.8.4.4. Tagging

Tagged were done in each plants by different salinity level & treatment by tag and rope in bamboo stick.

3.8.4.5. Irrigation

Number of irrigation was given throughout the growing period by garden pipe and watering cane. The first irrigation was given immediate after the transplantation where as other were applied when and when required depending upon the condition of soil.

3.8.4.6. Plant protection

From seedling to harvesting stage i.e. any stage, tomato is very sensitive to diseases and pest. After getting a maturity stage protection measure was taken against diseases and pests. So that, any insect or fungal infection and insect infestation cannot appear in the plant. To remove fruit loss from birds netting was done through the experimental area.

3. 8.4.7. Insect pests

Aktara10 EC were applied @ 10 ml/L against the fungal diseases, leaf curl disease and insect pests like cut worm, leaf hopper, fruit borer and others. The insecticide application was made fornightly for a week after transplanting to two weeks before first harvesting.

3.8.4.8. Harvesting

Fruits were harvested at 10 days intervals during early ripe stage when they attained slightly red color. Harvesting was started from 20 March, 2018 and was continued up to end of 10 April 2018.

3.9. Data collection

Data Collection from the experiment on different growth stages were done under the following heads as per as experimental requirements.

3.9.1 Plant height

The plant height was measured in centimeters from the base of plant to the terminal growth point of main stem on tagged plants was recorded at 20, 40 and harvest after transplanting. The average height was computed and expressed in centimeter.

3.9.2 Number of leaves plant^{-1}

The number of leaves plant^{-1} was manually counted at 20, 40 and harvest days after transplanting from plant. Mean value of data were calculated and recorded.

3.9.3 Number of branches plant^{-1}

The number of branches plant-^{1} was manually counted from plant to the pots. One number of branches of plant^{-1} was counted interval after 7 days in each pots.

3.9.4 Days to 1st flowering from transplanting

The number of flowers was counted at 1st flowering from transplanting to the pots. 20, 40 and final harvest after transplanting from the average number of flower produced plant^{-1} was recorded.

3.9.5 Number of flowers cluster^{-1}

The number of flower cluster^{-1} was counted at 50 and 60 days after transplanting from the pots. From each plant randomly five clusters were selected and counted the number of flowers cluster^{-1} to make an average .The final average value of number of flowers cluster^{-1} was calculated from plants.

3.9.6 Number of fruits cluster^{-1}

The number of fruits cluster^{-1} was counted at 60 DAT and harvesting time from selected plants. From each plant randomly clusters were selected and counted the number of fruits cluster^{-1} to make an average value for plant. The final average value of number of fruits cluster^{-1} was calculated from plants.

3.9.7 Number of fruits plant^{-1}

The number of fruits plant^{-1} was counted at 60 DAT and harvesting time from selected plants. From each plant randomly fruit were selected and counted the number of fruits fruit^{-1} to make an average value for plant. The final average value of number of fruits plant^{-1} was calculated from plants.

3.9.8 Length of fruit (cm)

Among the total number of fruit harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the length of fruit by slide calipers. The length of fruit was calculated by making the average of three fruits from each of the plants.

3.9.9 Diameter of fruit (cm)

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for 32 Dry weight of fruit Fresh weight of fruit determine the diameter of fruit by slide calipers. The diameter of fruit was calculated by making the average of five fruits from each of the plants.

3.9.10 Fruit Yield plant^{-1} (g)

Yield of tomato $^{-1}$ plant was recorded as the whole fruit $^{-1}$ plant and was expressed in gram (g). Harvested fruit sample from each pot and measuring the balance.

3.10 Chemical Analysis

Data Collection from the experiment on chemical analysis of fruits were done under the following heads as per as experimental requirements.

3.10.1 Preparation of plant extract

Fruit samples were separated into leaves, shoots and branches and then dried in an oven at 70^0C to obtain constant weight. Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. Exactly 1g oven-dried samples of different vegetables were taken in digestion tube. About 10 mL Di-acid mixture ($HCLO_4$ and HNO_3= 2:1) was taken in a digestion tube waited for 20 minutes and then transferred to a digestion chamber and continued heating at 100^0C. The temperature was increased to 365^0C gradually to prevent frothing (50^0C steps) and left to digest until yellowish colour of the solution turned to whitish colour. Then the digestion tubes were removed from the heating chamber and allowed to cool to room temperature. About 50 mL of de-ionized water was carefully added to the digestion tubes and the contents filtered through What man no. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with distil water. The samples were stored at room temperature in clearly marked containers.

3.10.2 Extract Preparation

First 0.5 g fruit sample were taken in a beaker and mixed with nitric acid and per chloric acid at 2:1 ratio. Than it was heated 220^0C temperature for 40 minutes. After heated those extract were cooled in one day and filtered. After filtering sample extract were collected in bottle with proper leveling.

3.10.3 Determination of Potassium

Potassium content in the digested fruit sample was determined by the flame photometer (Jenway, Model: PFP7).

3.10.4 Determination of Calcium

Calcium content in the digested fruit sample was determined by the flame photometer (Jenway, Model: PFP7).

3.10.5 Determination of Sodium

Sodium content in the digested fruit sample was determined by the flame photometer ((Jenway, Model: PFP7).

3.10.6 Determination of phosphorus

Phosphorus content in the digested fruit sample was determined by the Ascorbic acid blue colour method with the help of spectro photometer (Model no: UV-1800 -240V).

3.11 Statistical Analysis

Data were statistically analysed by analysis of variance (ANOVA) technique using MSTAT-C statistical computer computer package programme in accordance with the principles of Randomized Completely Block Design (Steel and Torrie, 1960). Duncan's multiple Range Test (DMRT) was used to compare variation among the treatment. Data were compiled and tabulated in proper form and were subjected to statistical analysis. Analysis of variance, Standard Deviation, Mean and Range was done in this study.

CHAPTER IV

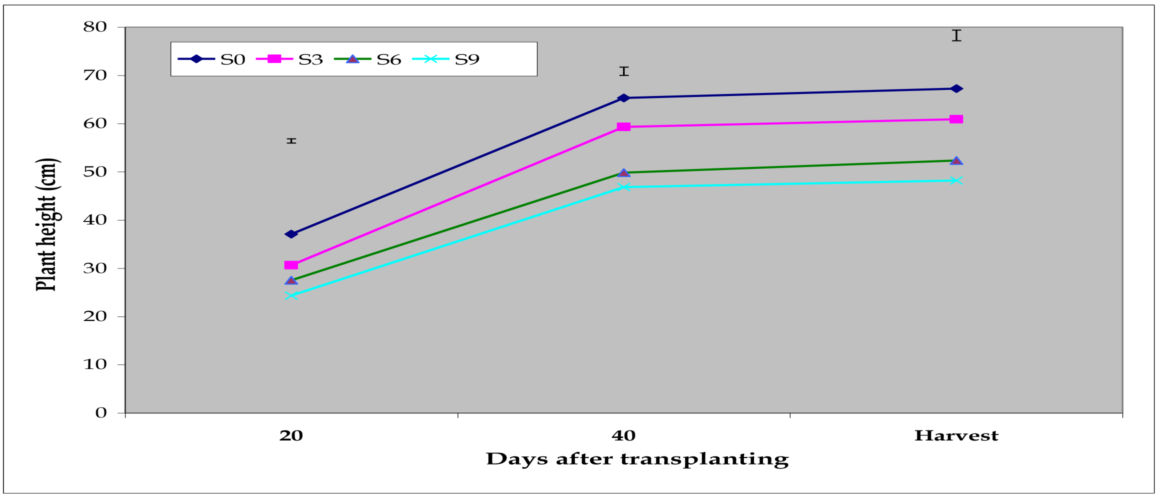
RESULTS AND DISCUSSION

The experiment was conducted to find out the alleviation of adverse effects of salt stress in tomato by salicylic acid. Data on different growth characters, yield attributes, yield and quality of tomato was recorded. The analyses of variance (ANOVA) of the data on different parameters have been presented in Appendix (III-VI). The results have been discussed with the help of different tables and graphs and possible interpretations given under the following headings:

4.1 Plant height

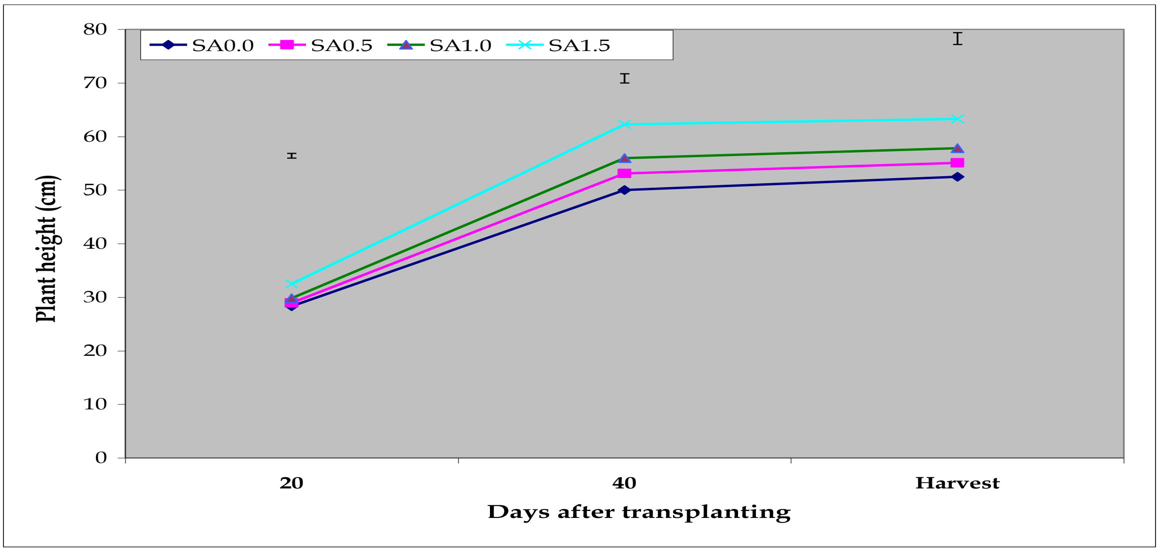
Plant height of tomato show statistically significant variation due to different salinity level at 20 and 40 days after transplanting (DAT) and final harvest (Appendix III).The reduction of salt stress on cell division and cell expansion. Data revealed that at 20 DAT, the tallest plant height (37.08 cm) was found from S_0, whereas the shortest plant height (24.33 cm) was found from S_9. At 40 DAT, the tallest plant height (65.33 cm) was found from S_0, whereas the shortest plant height (40.83 cm) was found from S_9. At final harvest, the tallest plants (67.25 cm) found from S_0, whereas the shortest plants (48.21 cm) was recorded from S_9 at (Figure 1). Generally different salinity level significantly reduce the plant height of tomato at different DAT and reduction was quite incremental with the increase of NaCl concentration. The natural plants height increased with increasing age but decreased with increasing salinity in tomato. The reduction of plant height may be due to inhibitory behavior of salt stress on cell division and cell expansion (Hernandez *et al*. 2003). Different levels of salicylic acid varied significantly in terms of plant height of tomato at 20, 40 DAT and final harvest (Appendix III). At 20 DAT, the tallest plant height (32.50 cm) was found from $SA_{1.5}$, the shortest plant height (28.33 cm) was found from $SA_{0.}$ At 40 DAT, the tallest height plant height was (62.29 cm) was found from $SA_{1.5}$, the shortest plant height (50.00 cm) was found from $SA_{0.}$ At final harvest, the tallest plant (63.29 cm) was recorded from $SA_{1.5}$, while the shortest plant (52.50 cm) was found from $SA_{0.0,}$

(Figure 2). Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the growth parameters of tomato.



S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

Figure 1. Effect of salinity levels on plant height at different days after transplanting (DAT) in tomato



$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

Figure 2. Effect of rate of salicylic acid on plant height at different days after transplanting (DAT) in tomato

Statistically significant variation was recorded for the interaction effect of different salinity levels of salicylic acid on plant height of tomato at final harvest (Appendix III). At 20 DAT, statistically not significant variation was recorded for interaction effect of salinity and salicylic acid but significant variation showed at 40 DAT and final harvest. At 20 DAT numerically the highest plant height (39.00) was recorded from $S_0SA_{1.5}$, and the lowest (23.00) was recorded from $S_9SA_{0.5}$. At 40 DAT and Final harvest the maximum plant height (69.00 and 70.33) respectively from $S_0SA_{1.5}$ which is statistically similar with $S_0SA_{1.0}$ and $S_3SA_{1.5}$ whereas the minimum plant height (40.0 and 41.67) was found from $S_9SA_{0.0}$. At the final harvest, the tallest plant height (70.33 cm) was observed from $S_3SA_{0.0}$ and the shortest plant (41.67 cm) from $S_9SA_{0.5}$ treatment combination (Table1).

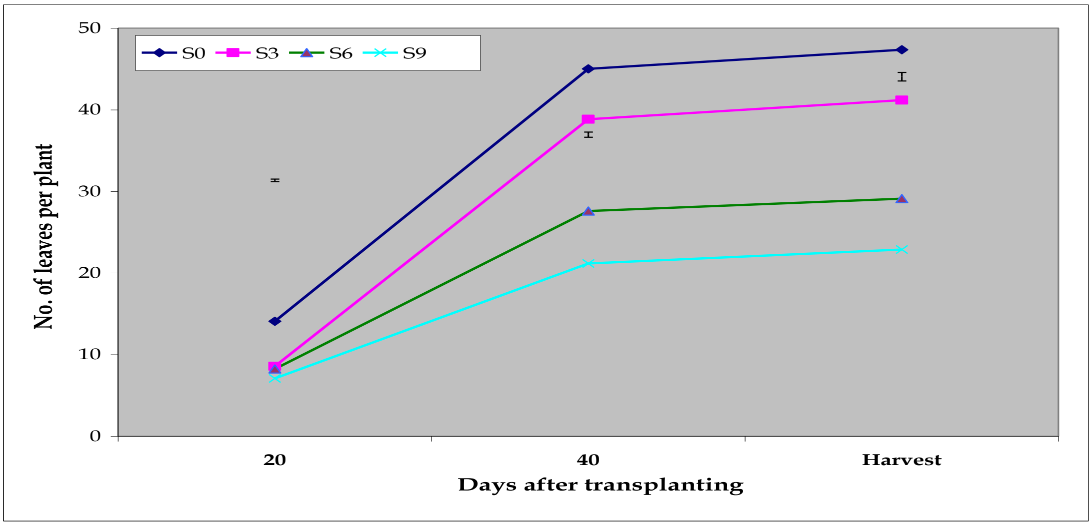
Table 1. Interaction effect of salinity levels and rate of salicylic acid on plant height of tomato at different days after transplanting (DAT)

Treatment combination		Plant height (cm) at different DAT		
		20	40	Harvest
S_0	$SA_{0.0}$	35.33	60.33 d	63.67 bc
	$SA_{0.5}$	35.33	65.33 bc	66.67 abc
	$SA_{1.0}$	36.33	66.67 ab	68.33 a
	$SA_{1.5}$	39.00	69.00 a	70.33 a
S_3	$SA_{0.0}$	37.67	52.67 f	56.00 d
	$SA_{0.5}$	29.00	55.33 ef	56.67 d
	$SA_{1.0}$	30.00	62.33 cd	63.33 c
	$SA_{1.5}$	30.33	67.00 ab	67.67 ab
S_6	$SA_{0.0}$	33.33	47.00 gh	48.67 efg
	$SA_{0.5}$	26.00	47.33 gh	51.33 ef
	$SA_{1.0}$	26.00	48.33 g	52.00 e
	$SA_{1.5}$	27.00	56.67e	57.33 d
S_9	$SA_{0.0}$	23.00	40.00 i	41.67 h
	$SA_{0.5}$	31.00	44.33 h	45.67 g
	$SA_{1.0}$	23.33	46.50 gh	47.67 fg
	$SA_{1.5}$	24.33	56.50 e	57.83 d
$LSD_{0.05}$		1.52	3.04	3.81
Level of significance		NS	**	**
CV (%)		3.06	3.30	4.01

** = Significant at 1% level of probability, NS = Not significant
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

4.2 Number of leaves plant^{-1}

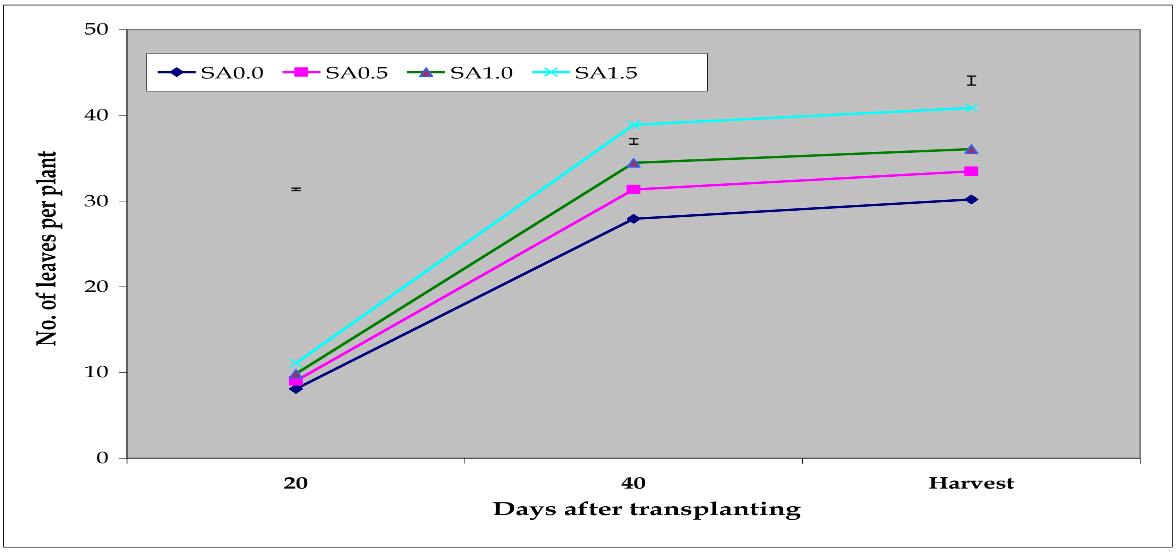
The leaf number is the very important character for plant growth and development .leaf is the main photosynthetic organ. Salinity adversely affected the production of leaf number plant^{-1} in tomato. (Appendix IV). At 20 DAT, 40 DAT and the final harvest highest number of leaves plant^{-1} (14.08, 45.00 and 47.36 respectively) were found from S_0. Whereas the lowest number of leaves plant^{-1} was (7.08, 21.17 and 22.87 respectively) recorded from S_9. (Figure 3). Although number of leaves plant^{-1} is a genetically characters but the management practices also influences the number of branches per plant but varieties itself also manipulated it. Biswas *et al*. (2015) recorded maximum number of branches (16.0 plant^{-1}) from BARI Tomato-14.



S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

Figure 3. Effect of salinity levels on number of leaves plant^{-1} at different days after transplanting (DAT) in tomato

Statistically significant variation was recorded due to different levels of salicylic acid on number of leaves plant^{-1} of tomato at 20 DAT, 40 DAT and final harvest (Appendix IV). At 20 DAT, 40 DAT and final harvest the highest number of leaves plant^{-1} (11.08, 38.81 and 40.84 respectively) were recorded from $SA_{1.5}$, whereas the lowest number of leaves plant^{-1} (8.08, 27.92 and 30.17) were recorded $SA_{0.0.}$ (Figure 4).



$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

Figure 4. Effect of rate of salicylic acid on number of leaves plant^{-1} at different DAT in tomato

Interaction effect of different levels of salicylic acid showed statistically significant variation in terms of number of leaves plant^{-1} of tomato at final harvest (Appendix Iv). At 20 DAT, significantly the highest number of leaves plant^{-1} (17.33) was round from $S_0SA_{1.5}$ and those are statistically significance with (51.67 and 53.50) was found from $S_0SA_{1.5.}$ The lowest number of leaves plant^{-1} was recorded (5.33) from $S_9SA_{0.0}$. At 40 DAT, the maximum number of leaves plant^{-1} (51.67) from $S_0SA_{1.5}$ and minimum number of leaves plant^{-1} was recorded (17.33) from $S_9SA_{0.0.}$At final harvest, the maximum number of leaves plant^{-1} (53.50) was recorded from $S_0SA_{1.5}$, whereas the minimum number of leaves plant^{-1} (20.08) was found from $S_9SA_{0.5}$ treatment combination (Table 2).

Table 2. Interaction effect of salinity levels and rate of salicylic acid on number of leaves plant^{-1} of tomato at different days after transplanting (DAT)

Treatment combination		No. of leaves plant^{-1} at different DAT		
		20	40	Harvest
S_0	$SA_{0.0}$	11.33 c	37.67 e	38.67 d
	$SA_{0.5}$	13.67 b	45.00 c	48.27 b
	$SA_{1.0}$	14.00 b	45.67 c	49.00 b
	$SA_{1.5}$	17.33 a	51.67 a	53.50 a
S_3	$SA_{0.0}$	8.00 e	32.33 g	35.56de
	$SA_{0.5}$	8.33 de	34.33 f	37.10 d
	$SA_{1.0}$	9.00 d	41.00d	42.33 c
	$SA_{1.5}$	9.00 d	47.67 b	49.78 b
S_6	$SA_{0.0}$	7.67 e	24.33 j	25.37 gh
	$SA_{0.5}$	8.00 de	26.67 i	28.33 fg
	$SA_{1.0}$	8.33 de	28.67 h	29.36 f
	$SA_{1.5}$	9.00 d	30.67 g	33.33 e
S_9	$SA_{0.0}$	5.33 f	17.33 m	20.15 j
	$SA_{0.5}$	6.00 f	19.33 l	21.08ij
	$SA_{1.0}$	8.00 e	22.50 k	23.50 hi
	$SA_{1.5}$	9.00 d	25.50 ij	26.75 fg
$LSD_{0.05}$		0.866	1.81	3.01
Level of significance		**	**	**
CV (%)		5.48	3.29	5.15

** = Significant at 1% level of probability
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

4.3 Number of branches plant^{-1}

In case of salinity levels number of branches plant^{-1} varied significantly (Appendix v). Maximum number of branches plant^{-1} (5.62) was found in S_0 and minimum number of branches plant^{-1} (2.83) was found in S_9 (Table 3).

Similar results were reported by Sk. Rahul *et al.* (2017). Significant difference among the tomato varieties in case of the number of branches per plant. In case of effect of rate of salicylic acid, the number of branches plant^{-1} varied significantly (Appendix V). Maximum number of branches plant^{-1} (5.58) was found $SA_{1.5}$ and minimum numbers of branches (3.12) were found in $SA_{0.0}$ (Table 4).

Table 3. Effect of salinity levels on yield and yield contributing characters of tomato

Salinity levels	No. of branches plant^{-1}	Days to 1st flowering from transplanting	No. of flowers cluster^{-1}	No. of flower clusters plant^{-1}	No. of flowers plant^{-1}
S_0	5.62 a	30.93 c	5.50 a	7.26 a	17.71 a
S_3	4.58 b	31.44 c	5.25 b	6.57 b	12.36 b
S_6	3.95 c	32.64 b	4.89 c	6.11 c	12.42 b
S_9	2.83 d	33.81 a	4.62 d	5.39 d	8.78 c
$LSD_{0.05}$	0.402	0.896	0.105	0.162	0.821
Level of significance	**	**	**	**	**
CV (%)	11.37	3.35	2.49	3.06	7.70

** = Significant at 1% level of probability
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

Table 4. Effect of salicylic acid doses on yield and yield contributing characters of tomato

Rate of salicylic acid	No. of branches plant $^{-1}$	Days to 1st flowering from transplanting	No. of flowers cluster^{-1}	No. of flower clusters plant^{-1}	No. of flowers plant^{-1}
$SA_{0.0}$	3.12 d	33.19 a	4.64 d	5.57 d	10.48 d
$SA_{0.5}$	3.75 c	32.65 ab	4.92 c	6.08 c	11.62 c
$SA_{1.0}$	4.54 b	31.82 bc	5.14 b	6.54 b	13.07 b
$SA_{1.5}$	5.58 a	31.17 c	5.56 a	7.15 a	16.09 a
$LSD_{0.05}$	0.402	0.896	0.105	0.162	0.821
Level of significance	**	**	**	**	**
CV (%)	11.37	3.35	2.49	3.06	7.70

** = Significant at 1% level of probability
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

In case of combination treatment the number of branches plant^{-1} varied significantly (Appendix V). Maximum number of branches (6.67) was found in $S_0SA_{1.5}$ which statistically similar with $S_0SA_{1.0}$, $S_3SA_{1.5}$, $S_6SA_{1.5}$ and minimum number of branches (2.33) was found in $S_9SA_{0.0}$ which statistically similar with $S_6SA_{0.0}$, $S_9SA_{0.5}$, $S_9SA_{1.0}$ (Table 5).

Table 5. Interaction effect of salinity levels and rate of salicylic acid on yield and yield contributing characters of tomato

Treatment combination		No. of branches plant $^{-1}$	Days to 1st flowering from transplanting	No. of flowers cluster^{-1}	No. of flower clusters plant $^{-1}$	No. of flowers plant $^{-1}$
S_0	$SA_{0.0}$	4.00 cd	31.90	4.95 f	6.32 d	16.17 cd
	$SA_{0.5}$	5.33 b	31.50	5.33 cd	6.89 c	17.15 bc
	$SA_{1.0}$	6.50 a	30.33	5.67 b	7.50 b	18.33 ab
	$SA_{1.5}$	6.67 a	30.00	6.08 a	8.35 a	19.18 a
S_3	$SA_{0.0}$	3.67 cde	32.33	4.80 fg	5.79 ef	9.33 ij
	$SA_{0.5}$	4.00 cd	32.00	5.20 de	6.30 d	11.11 gh
	$SA_{1.0}$	4.33 c	30.95	5.33 cd	6.70 c	13.33 f
	$SA_{1.5}$	6.33 a	30.50	5.67 b	7.50 b	15.67 cde
S_6	$SA_{0.0}$	2.50 fg	33.66	4.50 hi	5.50 fg	10.33 hi
	$SA_{0.5}$	3.00 efg	32.89	4.67 gh	5.90 e	11.33 gh
	$SA_{1.0}$	4.33 c	32.33	4.90 f	6.30 d	12.67 fg
	$SA_{1.5}$	6.00 ab	31.67	5.50 bc	6.75 c	15.33 de
S_9	$SA_{0.0}$	2.33 g	34.89	4.33 i	4.67 h	6.100 l
	$SA_{0.5}$	2.67 fg	34.20	4.50 hi	5.25 g	6.89 kl
	$SA_{1.0}$	3.00 efg	33.67	4.67 gh	5.67 ef	7.97 jk
	$SA_{1.5}$	3.33 def	32.49	5.00 ef	6.00 de	14.20 ef
$LSD_{0.05}$		0.805	1.79	0.210	0.324	1.64
Level of significance		**	NS	*	*	**
CV (%)		11.37	3.35	2.49	3.06	7.70

** = Significant at 1% level of probability,
* = Significant at 5% level of probability, NS = Not significant
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

4.4 Days to 1^{st} flowering after transplanting

Statistically significant variation was recorded in terms of days from transplanting to 1^{st} flowering of tomato for salinity levels (Appendix III). The lowest (30.93) days from transplanting to 1^{st} flowering was recorded from S_0, whereas the highest (33.81) days was found from S_9 (Table 3).

Different levels of salicylic acid showed statistically significant variation in terms of days from transplanting to 1^{st} flowering of tomato (Appendix III). The lowest (31.17) days from transplanting to 1^{st} flowering was recorded from $SA_{1.5}$, while the highest (33.19) days from transplanting to 1^{st} flowering was observed from $SA_{0.0}$ which is statistically similar with $SA_{0.5}$ (Table 4). Yildirim and Dursun (2009) reported that SA treatments increased the early yield of tomato compared to the control.

Days from transplanting to 1^{st} flowering did not show statistically significant variation due to the interaction effect of salinity levels and doses of salicylic acid in terms of (Appendix v). Numerically The lowest (30.00) days from transplanting to 1^{st} flowering was found from $S_0SA_{1.5}$ and the highest (34.89) days from transplanting to 1^{st} flowering was recorded from $S_9SA_{0.0}$ treatment combination (Table 5).

4.5 Number of flowers cluster^{-1}

Number of flowers cluster^{-1} of tomato varied significantly due to different level of salinity (Appendix V). The highest (5.62) number of flowers cluster^{-1} was found from S_0 and the lowest (2.83) number of flowers cluster^{-1} was observed from S_9 (Table 3). Biswas *et al*. (2015) reported the maximum number of flowers (6.1cluster^{-1}) from BARI Tomato-14. Different levels of salicylic acid showed statistically significant variation in terms of number of flowers cluster^{-1} of tomato (Appendix V). The highest (5.56) number of flowers cluster^{-1} was observed from $SA_{1.5}$, while the lowest (4.64) number of flowers cluster^{-1} was recorded from $SA_{0.0}$ (Table 4).

Statistically significant variation was recorded due to the interaction effect of different levels of salicylic acid in terms of number of flowers cluster^{-1} (Appendix VI). The highest (6.08) number of flowers cluster^{-1} was recorded from $S_0SA_{1.5}$, whereas the lowest (4.33) number of flowers cluster^{-1} was found from $S_9SA_{0.0}$ treatment combination which is statistically similar with $S_6SA_{0.0,}$ $S_9SA_{0.5}$ (Table 5).

4.6 Number of flower clusters plant^{-1}

Number of flower clusters plant^{-1} of tomato varied significantly due to salinity levels (Appendix v). The highest (7.26) number of flower clusters plant^{-1} was recorded from S_0, while the lowest (5.39) number of flowers plant^{-1} was observed from S_9 (Table 3).

Different levels of salicylic acid showed statistically significant variation in terms of number of flower clusters plant^{-1} of tomato (Appendix v). The highest (7.15) number of flower clusters plant^{-1} was found from $SA_{1.5}$, whereas the lowest (5.57) number of flower clusters plant^{-1} was observed from $SA_{0.0}$ (Table 4). Yildirim and Dursun (2009) reported that SA treatments increased the yield contributing characters of tomato compared to the control.

Statistically significant variation was recorded due to the interaction effect of different levels of salicylic acid in terms of number of flower clusters plant^{-1} (Appendix V). The highest (8.35) number of flowers plant $^{-1}$ was observed from $S_0SA_{1.5}$, while the lowest (4.67) number of flower clusters plant^{-1} was recorded from $S_9SA_{0.0}$ treatment combination (Table 5).

4.7 Number of flowers plant^{-1}

Number of flowers plant^{-1} of tomato varied significantly due to different salinity levels (Appendix V). The highest (17.71) number of flowers plant^{-1} was recorded from S_0, while the lowest (8.78) number of flowers plant $^{-1}$ was observed from S_9 (Table 3). Different levels of salicylic acid showed statistically significant variation in terms of number of flowers^{-1} of tomato (Appendix V). The highest (16.09) number of flowers plant^{-1} was found from $SA_{1.5}$ whereas the lowest (10.48) number of flowers plant^{-1} was observed from $SA_{0.0}$ (Table 4). Yildirim and Dursun (2009) reported that SA treatments increased the yield contributing characters of tomato compared to the control. Statistically significant variation was recorded due to the interaction effect of different levels of salinity and doses of salicylic acid in terms of number of flowers plant^{-1} (Appendix V). The highest (19.18) number of flowers plant^{-1} was observed from $S_0SA_{1.5}$ which is statistically similar with $S_0SA_{1.0}$ while the lowest (6.100) number of flowers plant^{-1} was recorded from $S_9SA_{0.0}$ treatment combination which is statistically similar with $S_9SA_{0.5}$ (Table 5).

4.8 Number of fruits plant^{-1}

Number of fruits per plant of tomato varied significantly due to salinity levels (Appendix V). The highest (10.00) number of fruits plant^{-1} was observed from S_0, while the lowest (5.44) number of fruits plant^{-1} was recorded from S_9 (Table 6).

Different levels of salicylic acid showed statistically significant variation in terms of number of fruits plant^{-1} of tomato (Appendix V). The highest (8.44) number of fruits plant^{-1} was found from $SA_{1.5}$, whereas the lowest (6.47) number of fruits plant^{-1} was observed from $SA_{0.0}$ (Table 7). Javaheri *et al*. (2014) reported the highest fruit number in bush obtained by mean of 66.75 in the application of SA_1 (SA at 10^{-2} M) which is support the present study. Statistically significant variation was recorded due to the interaction effect of salinity levels and doses of salicylic acid in terms of number of fruits plant^{-1} (Appendix V). The highest (11.78) number of fruits plant $^{-1}$ was recorded from $S_0SA_{1.5}$ and the lowest (4.88) number of fruits plant-$^{-1}$ was observed from $S_9SA_{0.0}$ treatment combination (Table 8).

4.9 Length of fruit

Significant difference was revealed on length of fruit (cm) with salinity levels. Among those S_0 gave the longest fruit length (5.94cm) while S_9 gave the shortest fruit length (4.39cm), (Table 6). This is may be due to different salinity level characteristics. Hossain (2001), Singh and Sahu (1998) also reported salinity level influence on the length of fruit.

Significant variation was found for length of fruit (cm) in case of different growth (Appendix V). Maximum length of fruit (5.87cm) was observed in ($SA_{1.5}$) treatment and minimum length of fruit (4.69 cm) was observed in $SA_{0.0}$ (Table7). Chapagain *et al.* (2011) reported largest fruit size in US-04 with a diameter of 5.7 cm. Significant variation was found for length of fruit (cm) in case of combined effect (Appendix V). Maximum length of fruit (6.49cm) was found in $S_0SA_{1.5}$ which statistically similar with $S_0SA_{1.0}$ @ 10^{-7} M application of growth doses and minimum length of fruit (4.05 cm) was found in $S_9SA_{0.0}$ @ 10^{-4} M application of growth (Table 8).

4.10 Diameter of fruit

Diameter of fruit of tomato varied significantly due to different salinity level (Appendix V). The highest (5.98 cm) diameter of fruit was observed from S_0 and the lowest (4.69 cm) diameter of fruit was recorded from S_9 (Table 6).

Different levels of salicylic acid showed statistically significant variation in terms of diameter of fruit of tomato (Appendix IV). The highest (5.87 cm) diameter of fruit was found from $SA_{1.5}$, which is statistically similar with $SA_{1.0}$, while the lowest (4.69 cm) diameter of fruit was recorded from $SA_{0.0}$ (Table 7). (Javaheri *et al*. 2014) reported the highest fruit diameter in SA_1 (SA at 10-2 M) with mean of 51.75 mm.

Statistically not significant variation was recorded due to the interaction effect of different levels of salicylic acid in terms of diameter of fruit (Appendix V). Numerically the highest (6.75cm) diameter of fruit was recorded from $S_0SA_{1.5}$, whereas the lowest (4.20cm) diameter of fruit was found from $S_9SA_{0.0}$ treatment combination (Table 8).

4.11 Fruit yield plant^{-1}

Fruit yield per plant of tomato varied significantly due to salinity levels (Appendix V). The highest (362.17 g) fruit yield plant^{-1} was observed from S_0, whereas the lowest (173.25 g) fruit yield plant^{-1} from S_9 (Table 6). Different levels of salicylic acid showed statistically significant variation in terms of fruit yield plant^{-1} of tomato (Appendix V). The highest (296.75 g) fruit yield plant^{-1} was observed from $SA_{1.5}$, while the lowest (207.88 g) fruit yield plant^{-1} was found from $SA_{0.0}$ (Table 7). Singh and Singh (2016) reported that the exogenous applications of salicylic acid improved the yield contributing factors that resulted in significant increases in tomato fruit yield. Statistically significant variation was recorded due to the interaction effect of salinity levels and doses of salicylic acid in terms of fruit yield plant^{-1} (Appendix V). The highest (470.30 g) fruit plant^{-1} was found from $S_0SA_{1.5}$ and the lowest (161.50 g) fruit yield plant^{-1} was observed from $S_9SA_{0.0}$ treatment combination which is statistically similar with $S_9SA_{0.5}$, $S_9SA_{1.0}$ (Table 8).

Table 6. Effect of salinity levels on yield and yield contributing characters of tomato

Salinity levels	Length of fruit (cm)	Diameter of fruit (cm)	No. of fruits plant^{-1}	Fruit yield plant^{-1} (g)
S_0	5.94 a	5.98 a	10.00 a	362.17 a
S_3	5.31 b	5.48 b	8.74 b	265.58 b
S_6	5.03 c	5.10 c	5.90 c	195.33 c
S_9	4.39 d	4.69 d	5.44 d	173.25 d
$LSD_{0.05}$	0.156	0.303	0.233	10.28
Level of significance	**	**	**	**
CV (%)	3.61	6.87	3.74	4.96

** = Significant at 1% level of probability
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

Table 7. Effect of rate of salicylic acid on yield and yield contributing characters of tomato

Rate of salicylic acid	Length of fruit (cm)	Diameter of fruit (cm)	No. of fruits plant^{-1}	Fruit yield plant^{-1} (g)
$SA_{0.0}$	4.54 d	4.69 c	6.47 c	207.88 d
$SA_{0.5}$	4.97 c	5.08 b	7.50 b	238.10 c
$SA_{1.0}$	5.41 b	5.60 a	7.68 b	254.08 b
$SA_{1.5}$	5.76 a	5.87 a	8.44 a	296.75 a
$LSD_{0.05}$	0.156	0.303	0.233	10.28
Level of significance	**	**	**	**
CV (%)	3.61	6.87	3.74	4.96

** = Significant at 1% level of probability
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

Table 8. Interaction effect of salinity levels and rate of salicylic acid on yield and yield contributing characters of tomato

Treatment combination		No. of fruits $plant^{-1}$	Length of fruit (cm)	Diameter of fruit (cm)	Fruit yield $plant^{-1}$ (g)
S_0	$SA_{0.0}$	8.11 d	5.25 d	5.19	256.70 ef
	$SA_{0.5}$	10.00 b	5.67 c	5.70	341.30 c
	$SA_{1.0}$	10.11 b	6.35 a	6.30	381.70 b
	$SA_{1.5}$	11.78 a	6.49 a	6.75	470.30 a
S_3	$SA_{0.0}$	7.44 e	4.51 ef	4.89	236.70 fg
	$SA_{0.5}$	8.66 c	5.15 d	5.25	249.00 ef
	$SA_{1.0}$	8.89 c	5.60 c	5.67	266.70 e
	$SA_{1.5}$	9.99 b	6.00 b	6.11	311.70 d
S_6	$SA_{0.0}$	5.44 h	4.35 fg	4.50	176.70 hij
	$SA_{0.5}$	5.91 fgh	4.79 e	4.80	190.70 hi
	$SA_{1.0}$	6.11 fg	5.25 d	5.50	194.70 h
	$SA_{1.5}$	6.16 f	5.75 bc	5.60	220.80 g
S_9	$SA_{0.0}$	4.88 i	4.05 g	4.20	161.50 j
	$SA_{0.5}$	5.44 h	4.29 fg	4.58	171.50 ij
	$SA_{1.0}$	5.61 gh	4.45 f	4.95	173.40 hij
	$SA_{1.5}$	5.84 fgh	4.80 e	5.03	186.70 hi
$LSD_{0.05}$		0.467	0.311	0.607	20.56
Level of significance		**	*	NS	**
CV (%)		3.74	3.61	6.87	4.96

** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

4.12 Nutrient content (%)

In case of salinity levels, significant difference was revealed on nutrient content with tomato (Appendix VI). Among them S_0 showed the maximum nutrient K, Ca and P content percentage (1.43 %, 0.048 % and 0.520% respectively) whereas, S_9 showed the minimum nutrient content (K :1.34 %, Ca:0.040 % and P: 0.430 % respectively) (Table 9) on the other hand S_9 showed the maximum Na content percentage (0.074 %), whereas S_0 showed lowest nutrient content (0.030 %).

Significant difference was revealed on nutrient content with salicylic acid doses (Appendix VI). Among them $SA_{1.5}$ showed the maximum nutrient K, Na, Ca and P content percentage 1.46 %, 0.080 %, 0.050 % and 0.563% respectively whereas, $SA_{0.0}$ showed the minimum nutrient content (K :1.31 %, Na: 0.062 %, Ca: 0.035 % and P: 0.417 %) (Table 10).

Table 9. Effect of salinity levels on nutrient content of tomato

Salinity levels	K%	Na%	Ca%	P%
S_0	1.43 a	0.030 c	0.048 a	0.520 a
S_3	1.39 ab	0.063ab	0.046 ab	0.477 b
S_6	1.38 bc	0.070b	0.042 bc	0.452 c
S_9	1.34 c	0.074 a	0.040 c	0.430 c
$LSD_{0.05}$	0.053	0.0054	0.0047	0.022
Level of significance	**	**	**	**
CV (%)	4.59	9.14	12.76	5.73

** = Significant at 1% level of probability
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}

Table 10. Effect of rate of salicylic acid on nutrient content of tomato

Rate of salicylic acid	K%	Na%	Ca%	P%
$SA_{0.0}$	1.31 c	0.062 c	0.035 c	0.417 c
$SA_{0.5}$	1.37 b	0.068 b	0.042 b	0.438 c
$SA_{1.0}$	1.40 b	0.077 a	0.048 a	0.461 b
$SA_{1.5}$	1.46 a	0.080 a	0.050 a	0.563 a
$LSD_{0.05}$	0.053	0.0054	0.0047	0.022
Level of significance	**	**	**	**
CV (%)	4.59	9.14	12.76	5.73

** = Significant at 1% level of probability
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

In case of combined effect of salinity levels and salicylic acid doses, nutrient content (%) tomato did not show significant variation on % k, %Na, % Ca but significant on % P (Appendix VI). Among them $S_0SA_{1.5}$ showed the maximum nutrient K, Ca and P content percentage (1.52%, 0.55% and 0.723% respectively),on the other hand $S_0SA_{1.5}$ showed minimum nutrient content Na percent (0.053) whereas, $S_9SA_{0.0}$ showed the minimum nutrient content (K: 1.26%, Ca: 0.030 % and P: 0.397 %) on the other hand $S_9SA_{0.0}$ showed the minimum nutrient content (0.087 %) (Table 11).

Table 11. Interaction effect of salinity levels and rate of salicylic acid on nutrient content of tomato

Treatment combination		K%	Na%	Ca%	P%
S_0	$SA_{0.0}$	1.37	0.063	0.040	0.423 defg
	$SA_{0.5}$	1.41	0.057	0.047	0.460 cdef
	$SA_{1.0}$	1.43	0.055	0.050	0.474 cd
	$SA_{1.5}$	1.52	0.053	0.055	0.723 a
S_3	$SA_{0.0}$	1.33	0.077	0.040	0.437 defg
	$SA_{0.5}$	1.36	0.075	0.040	0.443 defg
	$SA_{1.0}$	1.40	0.073	0.050	0.470 cde
	$SA_{1.5}$	1.49	0.067	0.053	0.557 b
S_6	$SA_{0.0}$	1.29	0.080	0.030	0.410 fg
	$SA_{0.5}$	1.36	0.079	0.040	0.430 defg
	$SA_{1.0}$	1.39	0.078	0.050	0.460 cdef
	$SA_{1.5}$	1.46	0.077	0.047	0.507 c
S_9	$SA_{0.0}$	1.26	0.087	0.030	0.397 g
	$SA_{0.5}$	1.34	0.085	0.040	0.420 efg
	$SA_{1.0}$	1.37	0.083	0.043	0.440 defg
	$SA_{1.5}$	1.38	0.081	0.047	0.463 cde
$LSD_{0.05}$			0.0011	0.0093	0.0045
Level of significance		NS	NS	NS	**
CV (%)		4.59	9.14	12.76	5.73

** = Significant at 1% level of probability, NS = Not significant
S_0 = 0 dSm^{-1}, S_3 = 3 dSm^{-1}, S_6 = 6 dSm^{-1}, S_9 = 9 dSm^{-1}
$SA_{0.0}$ = 0 mM, $SA_{0.5}$ = 0.5 mM, $SA_{1.0}$ = 1.0 mM, $SA_{1.5}$ = 1.5 mM

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

In order to study the alleviation of adverse effects of salt stress in tomato by foliar application of salicylic acid at Sher-e-Bangla Agricultural University, Dhaka, during period from November, 2017 to August, 2018. Two factorial experiment included salinity levels viz. 0, 3, 6 and 9 dSm $^{-1}$ and salicylic acid (4 Doses): 0 mM, 0.5 mM, 1.0 mM and 1.5 mM was outlined in Completely Randomized Design (CRD) with three replications. Collected data were statistically analysed for the evaluation of treatments for the detection of the salinity levels and salicylic acid rates. The findings and conclusion have been described in this segment.

Significant variations were observed in case of salinity levels all parameters like as following-

At 20 DAT, 40 DAT and harvest, the highest plant height (37.08 cm, 65.33 cm and 67.25 cm respectively) were found from $S_{0,}$ whereas the lowest plant height (24.33 cm, 40.83 cm and 44.21 cm respectively) were found from S_9. At 20 DAT, 40 DAT and harvest, the maximum number of leaves plant^{-1} (14.08, 45.00 and 47.36 respectively) were found from S_0, whereas the minimum number of leaves plant^{-1} (7.08, 21.17 and 22.87 respectively) were found from $S_{9.}$ The maximum number of branches plant^{-1}, number of flowers cluster^{-1} , number of flower clusters plant^{-1}, number of flowers plant^{-1} , number of fruits plant^{-1}, diameter of fruit, fruit length, fruit yield plant^{-1} (5.62, 5.50, 7.26, 17.71, 10.00, 5.98 cm , 5.94 cm and 362.17 g respectively) were found from S_0, whereas The minimum number of branches plant^{-1}, number of flowers cluster^{-1} , number of flower clusters plant^{-1}, number of flowers plant^{-1} , number of fruits plant^{-1}, diameter of fruit, fruit length, fruit yield plant^{-1} (2.83, 4.62, 5.39, 8.78, 5.44, 4.69 cm , 4.39 cm and 173.25 g respectively) were found from S_9. The maximum nutrient K, Ca and P content percentage (1.43 %, 0.048 % and 0.520% respectively) were found from $S_{0,}$ whereas the minimum nutrient content (K :1.34 %, Ca:0.040 % and P: 0.430 % respectively) were found from S_9.On the other hand, S_9 showed the highest Na content percentage (0.074 %), whereas S_0 showed lowest nutrient content (0.030 %).

Significant variations were observed in case of salicylic acid all parameters like as following-

At 20 DAT, 40 DAT and harvest, the highest plant height (32.50 cm, 62.29 cm and 63.29 cm respectively) were found from $SA_{1.5,}$ whereas the lowest plant height (28.33 cm, 50.00 cm and 52.50 cm respectively) were found from SA_0. At 20 DAT, 40 DAT and harvest, the maximum number of leaves plant^{-1} (11.08, 38.81 and 40.84 respectively) were found from $SA_{1.5,}$ whereas the minimum number of leaves plant^{-1} (8.01, 27.92 and 30.17 respectively) were found from $SA_{0.0.}$ The maximum number of branches plant^{-1}, number of flowers cluster^{-1} , number of flower clusters plant^{-1}, number of flowers plant^{-1} , number of fruits plant^{-1}, diameter of fruit, fruit length, fruit yield plant^{-1} (5.58, 5.56, 7.15, 16.09, 8.44, 5.87 cm , 5.76 cm and 296.75 g respectively) were found from $SA_{1.5,}$ whereas The minimum number of branches plant^{-1}, number of flowers cluster^{-1} , number of flower clusters plant^{-1}, number of flowers plant^{-1} , number of fruits plant^{-1}, diameter of fruit, fruit length, fruit yield plant^{-1} (3.12, 4.64, 5.57, 10.48, 6.67, 4.69 cm , 4.54 cm and 207.88 g respectively) were found from $SA_{0.0.}$The maximum nutrient K, Na, Ca and P content percentage (1.46%, 0.080 % ,0.050%, 0.563% respectively) were found from $SA_{1.5}$, whereas the minimum nutrient content (K :1.34 %, Na: 0.062%, Ca:0.040% and P: 0.430% respectively) were found from $SA_{0.0}$.

Significant variations were observed in combination of salinity level and salicylic acid all parameters like as following-

At 20 DAT, 40 DAT and harvest, the highest plant height (39.00 cm, 69.00 cm and 70.33 cm respectively) were found from $S_0SA_{1.5,}$ whereas the lowest plant height (23.00 cm, 40.00 cm and 41.67 cm respectively) were found from $S_9SA_{0.0}$. At 20 DAT, 40 DAT and harvest, the maximum number of leaves plant^{-1} (17.33, 51.67 and 53.50 respectively) were found from $S_0SA_{1.5,}$ whereas the minimum number of leaves plant^{-1} (5.33, 17.33 and 21.08 respectively) were found from $S_9SA_{0.0.}$ The maximum number of branches plant^{-1}, number of flowers cluster^{-1} , number of flower clusters

$plant^{-1}$, number of flowers $plant^{-1}$, number of fruits $plant^{-1}$, diameter of fruit, fruit length, fruit yield $plant^{-1}$ (6.67, 6.08, 8.35, 19.18, 11.78, 6.75 cm , 6.69 cm and 470.30 g respectively) were found from $S_0SA_{1.5}$, whereas The minimum number of branches $plant^{-1}$, number of flowers $cluster^{-1}$, number of flower clusters $plant^{-1}$, number of flowers $plant^{-1}$, number of fruits $plant^{-1}$, diameter of fruit, fruit length, fruit yield $plant^{-1}$ (2.33, 4.33, 4.67, 6.10, 4.88, 4.20 cm , 4.05 cm and 161.50 g respectively) were found from $S_9SA_{0.0}$. The maximum nutrient K, Ca and P content percentage (1.49%, 0.055 % and 0.723% respectively) were found from $S_0SA_{1.5,}$ whereas the minimum nutrient content (K :1.26%, Ca:0.030 % and P: 0.397 % respectively) were found from $S_9SA_{0.0}$. On the other hand, the highest Na content percentage (0.087%) was found from $S_9SA_{0.0}$, whereas lowest nutrient content (0.053 %) Was found from $S_0SA_{1.5}$.

5.2 Conclusion

In respect as the above results, it can be concluded that the fruit weight of tomato gradually decreased by the increase of salinity levels and this reduction rate was decreased by foliar application of salicylic acid and tomato showed significant variation to salinity levels and salicylic acid doses. According to result, salinity levels (S_0) showed maximum tallest plant height, leaves number, maximum branch number, days to flower, flower cluster^{-1}, flower plant^{-1}, fruit cluster^{-1}, fruit plant^{-1}, single fruit weight, fruit yield plot^{-1} and nutrient content. On the other hand, ($SA_{1.5}$) doses of salicylic acid application performed excellent among the salicylic acid treatment applied in terms of all parameters. Besides the combination, salinity (S_0) with $SA_{1.5}$ salicylic acid application performed the best combination. Regarding correlation studies, it can be easily stated that branch number, flower cluster plant^{-1}, plant height and days to flowering was significantly positively correlated with all of yield. To sum up, it can be articulated that (S_0) was the most outstanding salinity levels and ($SA_{1.5}$) of salicylic acid application and combination treatment ($S_0SA_{1.5}$) was the best for growth, yield and quality attributes of tomato.

In this experiment-

- Salinity adversely affected morphological characters, yield and nutrient contents (except Na) of BARI Tomato -14 ,
- Salicylic Acid showed better effect in yield and quality characters under salinity in tomato,
- Among the different concentration of salicylic acid, tomato showed better response with 1.5 mM concentration of salicylic acid.

5.3 Recommendations

Considering the findings of the present experiment, further studies in the following areas may be suggested-

1. Field experiments were need to be considered in different Agro-ecological zones of Bangladesh,

2. Different salinity level were need to be considered in different Agro-ecological zones of Bangladesh for regional trial before final recommendation,

3. Another higher level of salicylic acid need to be considered in different agro-ecological zones of Bangladesh for regional trial before final recommendation.

CHAPTER VI

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CHAPTER VII

APPENDICES

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

Figure 1. The Map of Bangladesh Showing Experimental Site

Appendix II

A. Morphological characteristics of soil of the experimental plot

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay 30	30
Textural class	Silty Clay
pH	5.8- 6.5
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

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

Appendix III. Analysis of variance (mean square) of the data for plant height of tomato at different days after transplanting (DAT)

Source of variation	df	Plant height (cm) at different DAT		
		20	40	Final harvest
Salinity levels (A)	3	355.743**	874.00**	877.39**
Rate of salicylic acid (B)	3	40.743**	329.26**	256.31**
A x B	9	0.854 NS	16.30**	14.31**
Error	32	0.839	3.33	5.26

** = Significant at 1% level of probability, NS = Not significant

Appendix IV. Analysis of variance (mean square) of the data for number of leaves plant^{-1} of tomato at different days after transplanting (DAT)

Source of variation	df	No. of leaves per plant at different DAT		
		20	40	Final harvest
Salinity levels (A)	3	117.00**	1389.243**	1491.816**
Rate of salicylic acid (B)	3	19.500**	260.701**	243.377**
A x B	9	3.093**	14.627**	18.499**
Error	32	0.271	1.187	3.271

** = Significant at 1% level of probability

Appendix V. Analysis of variance (mean square) of the data for yield and yield contributing characters of tomato

Source of variation	df	No. of branches $plant^{-1}$	Days to 1st flowering from transplanting	Length of fruit (cm)	Diameter of fruit (cm)	No. of flowers $cluster^{-1}$	No. of flower clusters $plant^{-1}$	No. of flowers $plant^{-1}$	No. of fruits $plant^{-1}$	Fruit yield (g)
Salinity levels (A)	3	16.375**	19.872**	4.916**	3.635**	1.813**	7.411**	162.003**	58.180**	86981.45**
Rate of salicylic acid (B)	3	13.514**	9.623**	3.367**	3.334**	1.798**	5.410**	70.733**	7.929**	16697.68**
A x B	9	1.093**	0.106 NS	0.087*	0.064 NS	0.035*	0.086*	3.994**	0.973**	3840.53**
Error	32	0.234	1.162	0.035	0.133	0.016	0.038	0.974	0.079	152.79

** = Significant at 1% level of probability, * = Significant at 5% level of probability

NS = Not significant

Appendix VI. Analysis of variance (mean square) of the data for Nutrient content of tomato

Source of variation	df	K%	Na%	Ca%	P%
Salinity levels (A)	3	0.0187**	0.00057**	0.000160**	0.01759**
Rate of salicylic acid (B)	3	0.0463**	0.00080**	0.000585**	0.04933**
A x B	9	0.0011NS	0.000038NS	0.000021NS	0.00756**
Error	32	0.0041	0.000043	0.000031	0.00072

** = Significant at 1% level of probability, NS = Not significant

LIST OF PLATES

Plate 1. Photograph showing tomato seedlings; BARI Tomato-14

Plate 2. Photograph showing experimental plot.

Plate 3. Photograph showing green tomato; BARI Tomato-14

Plate 4. Photograph showing ripen tomato; BARI Tomato-14.