MITIGATION OF SALT STRESS BY EXOGENOUS APPLICATION OF ASCORBIC ACID ON GROWTH AND YIELD OF TOMATO

SHEIKH FARHA SULTANA SOHAN

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2015

MITIGATION OF SALT STRESS BY EXOGENOUS APPLICATION OF ASCORBIC ACID ON GROWTH AND YIELD OF TOMATO

BY

SHEIKH FARHA SULTANA SOHAN
REGISTRATION No. 09-03359

A Thesis Submitted to
The Department of Horticulture, Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY– JUNE, 2015

APPROVED BY:

Dr. Md. Nazrul Islam **Professor** Dept. of Horticulture SAU, Dhaka **Supervisor**	**Md. Hasanuzzaman Akand** **Professor** Dept. of Horticulture SAU, Dhaka **Co- supervisor**

Dr. Tahmina Mostarin
Chairman
Examination Committee

Department of Horticulture

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/HORT/……..

CERTIFICATE

This is to certify that thesis entitled, ***"MITIGATION OF SALT STRESS BY EXOGENOUS APPLICATION OF ASCORBIC ACID ON GROWTH AND YIELD OF TOMATO"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in HORTICULTURE****, embodies the result of a piece of bona-fide research work carried out by* ***SHEIKH FARHA SULTANA SOHAN****, Registration No.* ***09-03359*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2015
Place: Dhaka, Bangladesh

……..…….....……

Dr. Md. Nazrul Islam
Professor
Dept. of Horticulture
SAU, Dhaka
Supervisor

ACKNOWLEDGEMENT

All praises to the Almighty and Kind full trust on to "Omnipotent Creator" for his never-ending blessing, it is a great pleasure to express profound thankfulness to the author's respected parents, who entitled much hardship inspiring for prosecuting her studies, thereby receiving proper education.

The author feels proud to express her earnest respect, sincere appreciation and enormous indebtedness to her reverend supervisor, **Dr. Md. Nazrul Islam**, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.

The author wishes to express her gratitude and best regards to her respected Co-Supervisor, **Md. Hasanuzzaman Akand**, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.

The author feels to express her heartfelt thanks to the departmental Chairman **Dr. Tahmina Mostarin** along with all other teachers and staff members of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka for their co-operation during the period of the study.

The author wishes to extend her special thanks to her lab mates Rajvin Akter, Jannatul Ferdous and Nusrat Akter for their keen help as well as heartiest co-operation and encouragement.

The author expresses her heartfelt thanks to her beloved parents, younger sister, friends, younger brother and all other family members for their prayers, encouragement, constant inspiration and moral support for her higher study.

The Author

MITIGATION OF SALT STRESS BY EXOGENOUS APPLICATION OF ASCORBIC ACID ON GROWTH AND YIELD OF TOMATO

By

SHEIKH FARHA SULTANA SOHAN

ABSTRACT

The pot experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to April 2014 to study the mitigation of salt stress in tomato by exogenous application of ascorbic acid. BARI Tomato 14 was used as planting material. The two factor experiment was laid out in Randomized Completely Block Design with three replications. The factors were: Factor A: Four levels of salinity such as, (i) S_0: 0 dS/m, (ii) S_1: 6 dS/m, (iii) S_2: 8 dS/m, (iv) S_3: 10 dS/m and Factor B: Three concentration of ascorbic acid as mitigating agent of salt stress (i) A_0: 0 mM AA, (ii) A_1: 0.5 mM AA, (iii) A_2: 1 mM AA respectively. The total treatment combination were 12, (3x4). At 80 DAT, the highest plant height (96.83 cm), number of leaves per plant (34.6), number of flower per plant (53.5), weight of individual fruit (80.4 g) and yield per pot (3.08 kg) were measured at control (0dS/m) and lowest value was observed at highest salinity level (10 ds/m) condition. The present result also showed that exogenous application of ascorbic acid significantly increased the growth contributing characters and yield of tomato in both saline and non-saline conditions. For treatment combination the tallest plant height (101.5 cm), highest number of fruit per plant (42.7), highest weight of individual fruit (81.1 g), yield per pot (3.12 kg) and yield per hectare (93.6 t) were produced from S_0A_2 which was very close to control (S_0A_0) , whereas the lowest value from S_3A_0. Finally, this result suggests that exogenous application of ascorbic acid can effectively mitigate the deleterious effect of salt stress in tomato up to a certain limit.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum L.*) botanically referred to the family Solanaceae is one of the most important and popular vegetable crop. The Centre of origin of the genus *Solanum* is the Andean zone particularly Peru-Ecuador-Bolivian areas (Salunkhe *et al.,* 1987), but cultivated tomato originated in Mexico. Tomato fruit is a major component of daily meals and constitutes an important source of minerals, vitamins, and antioxidant compounds. It is consumed either raw as salad or cooked. Food value of tomato is very rich because of higher contents of vitamins A, B and C (Bose and som, 1990). It is used for seasoning vegetables, curries and to impart them special color, flavor, taste and is used in many other ways. Tomato outranks all others in terms of total contribution of vitamins and minerals to the diet mainly because of the large volume consumed both in fresh and processed forms. It is adapted to wide range of soils and grown abundantly during winter season in Bangladesh. So it is one of the economically important vegetable crops.

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 defense mechanisms (Ghosh *et al.,* 2011).

The survival of plants under this stressful condition depends on their abilities to perceive the stimulus, generate and transmit a signal, and initiate various physiological and biochemical changes (Tanou *et al.,* 2009; El-Shabrawi *et al.,* 2010). Molecular and biochemical studies of the salt stress responses of plants have demonstrated significant increases in reactive oxygen species (ROS) such as, single oxygen ($1O_2$), superoxide ($O^{2.-}$), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH) (Mittler, 2002; Tanou *et al.,* 2009; Pérez-López *et al.,* 2010).

Tomato is one of the world most important and widespread crop with adverse effects of salinity (Bradbury and Ahmed, 1990; Liang *et al.,* 1996). 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 (Alian *et al.,* 2000).

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 phytohormones by molecular mechanisms.

Against abiotic stresses, ascorbic acid (AA) is regarded as one of the most effective growth regulator. AA not only acts as an antioxidant but the cellular levels of AA 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 M.S., 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 antioxidants (Foyer and Noctor 2005).

However, the response of plants to salt stress varies among the crop varieties and the dose and duration of stress. In addition, the role of exogenous protectants also variable in such conditions. Although there are several studies on the effect of salt stress on tomato but there is hardly any study regarding the role of exogenous protectants like Ascorbic acid in mitigating salt stress in tomato. This study was designed to understand the physiological mechanisms of 4 salt stress tolerance mediated by exogenous Ascorbic acid on one high yielding tomato variety such as BARI tomato 14 which were grown in saline condition. Therefore, the present study was undertaken keeping in mind the following objectives:

i. To investigate the effect of salinity on the growth, physiology and yield of tomato.

ii. To identify the effect of Ascorbic acid (AA) on the morphology, yield contributing characters and yield response 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 researchers for its various consumptions. It is adapted to a wide range of climate ranging from tropics within a few degree of the Arctic Circle. However, in spite of its broad adaption production is concentrated facing in a diverse biotic factor and abiotic stress conditions. But very few research works available related to growth, yield and development of the tomato due to stress especially salt stress on tomato and mitigating salt stress. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to 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 (M ha) of irrigated land which account to 20% of total land have been damaged by salt worldwide and 1.5 M ha are taken out of production each year due to high salinity levels in the soil (Läuchli, 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, 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 dS m^{-1}; T_2, 8 dS m^{-1}; T_3, 12 dS m^{-1} and T_4,16 dS m^{-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 w eight , 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 dS m^{-1} exhibited highest Na and Cl uptake which reduced the uptake of K+. At control (0 dSm^{-1}) salinity when Na and Cl 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 tomato (*Lycopersicon esculentum* L.) varieties for salinity tolerance. Three levels of salinity were 2.0-4.0 dS m^{-1}, 4.1-8.0 dS m^{-1} and 8.1-12.0 dS m^{-1}. Significant varietal and/or salinity treatment effects were registered on plant height, leaf area, plant growth, yield, dry matter $plant^{-1}$, Na+ and Cl

accumulation in tomato tissues. Variety BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 consistently showed superior biological activity at moderate salinity (4.1-8.0 dS m^{-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 Tomato 14, 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 200mM 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 rootstocks 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, Yeni Talya 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

Heman had highest root dry matter. Newton showed more shoot and root dry matter than other 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 P. O. 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 for the 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 dS/m) than the well and tap water (0.07 dS/m and 0.02 dS/m, respectively). Flowering and yield of tomato was high with crops treated with well water (45.22%; 99.08kg/ha) followed by the pond (27.70%; 43.76kg/ha) and tap water (27.08%; 27.25kg/ha) 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 0.01levels 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 $ds \cdot m^{-1}$) 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 $ds \cdot m^{-1}$to 10 $ds \cdot m^{-1}$. All seedling growth characters, except seedling height, were decreased with increasingly salinity levels. At germination and emergence stage, LA 3770were more tolerant to salinity than others.

A study was conducted by (Jogendra *et al*.2011) using ten genetically diverse genotypes along with their 45F1(generated by di allel 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 required in the production of tomato. In this study, germination rate, speed of germination, dry weight ratio and Na+/K+ ratio in root and shoot, were the parameters assayed 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 (Akinci *et al*. 2004).

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 that all 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 dS/m 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+ ratio while all other genotypes showed intermediate response.

An experiment was conducted by Harun (2008) at laboratory, glass house and pipe house of JICA Tsukuba, Japan to determine salinity tolerance level of tomato, to identify proper plant stage for screening and to find out tomato variety which tolerance to salinity. Three level of electrical conductivity (EC) of sodium chloride solution (0.3 dS/m; 8 dS/m and 12 dS/m) were tested for twenty tomato varieties. Varieties were selected for fruit stage screening on the basis of germination and seedling stage screening result and 3rd and 4th cluster harvesting stage showed that the screened varieties were quite capable to set fruit until salinity level EC 12 dS/m. There was highly correlation among screening result at germination stage– seedling stage – harvesting stage. Several varieties were supposed to be tolerance to salinity until EC level of 12 dS/m according to screening result from germination to harvesting stage. To confirm this result, it is better to conduct a continuation experiment in saline soil condition directly and good crop management.

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, Y. (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 anthesis to 3 or 6 grams per liter NaCI. Salinity shortened the time of fruit development by 4 to 15%. Fruits of salt-treated plants were smaller and tasted better than did fruits of control plants. This result was obtained both for ripe fruits tested on the day of picking and for those picked at 100% development and allowed to ripen at room temperature for 9 days. Percentage of dry weight, total soluble solids, and titratable acidity; content of reducing sugars, 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, polymethylgalacturonase, and polygalacturonase; were also higher in fruits of the saline-treated plants.

2.3 Effect of ascorbic acid on tomato plant

AA plays an important role in plant stress tolerance. Under stressed condition plants showed different capacity of AA metabolism which is due to the variation of AA synthesis and regeneration. Different studies showed that AA content in leaves of stressed plants tends to increase with increasing levels of salt stress.

The study was undertaken by Batool *et al.* (2012) to examine the effects of exogenous application of ascorbic acid (AA) through different modes on growth and associated biochemical parameters in *Lycopersicum spp*. hybrid cv. HSF-240, under salt stress. In a pot experiment, AA was applied through irrigation or foliar-spray at the concentrations of 0.1, 0.5, and 1 mM with or without 100 mM NaCl concentration. Vegetative growth measurements, antioxidant enzyme activities (POD and SOD), and protein and proline contents of plants were recorded to study the effects of these treatments. The presence of salt reduced the growth of sugarcane plants. The AA application not only mitigated the inhibitory effects of salt stress but also induced a stimulatory effect on all the studied growth parameters. The activities of antioxidant enzymes (POD and SOD) as well as proline contents of plants were increased, although the protein contents were decreased after AA application. The exogenous application of AA through either way significantly alleviated the adverse effects of salinity on growth and biochemical parameters of sugarcane plants. However, in this study, the AA application through irrigation proved to be a better option in mitigating the adverse effects of salinity.

Nahed *et al.* (2006) also conducted an experiment to study the effect of foliar spraying of ascorbic acid (0,200,400 ppm) on growth and chemical constituents under three level of salinity (1000,2000 and 3000 ppm) and tap water served as control. Salinity effect have a depressing effect on various growth parameters (i.e. stem length, stem diameter, root length, leaves number/plant, leaf area and fresh and dry weight of all plant organs. The same tendency was observed regarding total

sugar, chlorophyll a, b, carotenoids content as well as percentage and uptake of N, P and K. such depressive effect was increasingly prominent with increasing Salinity level. While proline content and the percentage and uptake of Na increased by increasing salinity level. On the contrary, all previous growth parameters and chemical constituents, except the percentage and uptake of Na, tended to increase by increasing the concentration of Ascorbic acid up to 400 ppm as compared to the untreated ones. It could be recommended to spray plants, grown in regions irrigated with saline water, with ascorbic acid to overcome destructive effect of salinity.

Another study was conducted by Lila *et al*. (2006) on the effects of ascorbic acid on salt induced alfalfa (*Medicago sativa L*.) in in vitro culture. Ascorbic acid as an antioxidant agent has already been used for increasing of stress tolerance. Callus was produced from stem segments of alfalfa (*Medicago sativa L*.) on MS medium supplemented with 2,4 dichlorophenoxy acetic acid, naphthalene acetic acid and kinetin (2 mg/l each).Calli were then transferred to the same medium containing 0, 30, 60, 90, 120 mM NaCl and 0, 0.5, 1.0, 2.0 mM ascorbic acid. Addition of ascorbic acid to the medium improved seed germination and also increased the activity of acid phosphates, chlorophyll content, and dry mass. The Na^+ and K^+ content of stem-leaf and root was relatively increased with some variations. The fresh weight of calli was also increased by ascorbic acid under salt stress condition

The transition from reversible to permanent wilting, in whole tomato seedlings *(Lycopersicon esculentum*) Mill. Cv. M82 following severe salt stress by root exposure to 300 mM NaCl was investigated by Shalata, A., Peter. M., Neumann, (2001). Salinized seedlings wilted rapidly but recovered if return to non-saline nutrient solution within 6 h. However, after 9 h of salt treatment 100% of the seedlings remain wilted and die. Remarkably an addition of an antioxidant (0.5 mM ascorbic acid) to the root medium, prior to and during salt treatment of 9 h facilitated the subsequent recovery and long term survival of c. 50% of the wilted

seedlings. Other organic solute with known antioxidant activity were not effective. Salt stress increase the accumulation of root, stems and leaves, of lipid peroxidation products produced by interaction with damaging active oxygen species. Additional Ascorbic Acid partially inhibited this response but did not significantly reduced Na uptake or plasma membrane leakiness.

Similar investigation was conducted by Hameed et al., (2014) on effect of salinity and ascorbic acid on growth, water status and anti-oxidant in a perennial halophyte. The study showed that salinity causes oxidative stress in plants by enhancing production of reactive oxygen species, so that an efficient antioxidant system, of which ascorbic acid (AA) is a key component, is an essential requirement of tolerance. However, antioxidant responses of plants to salinity vary considerably among species. *Limonium stocksii* is a sub-tropical halophyte found in the coastal marshes from Gujarat (India) to Karachi (Pakistan) but little information exists on its salt resistance. In order to investigate the role of AA in tolerance, 2-month-old plants were treated with 0 (control), 300 (moderate) and 600 (high) mM NaCl for 30 days with or without exogenous application of AA (20 mM) or distilled water. Shoot growth of unsprayed plants at moderate salinity was similar to that of controls while at high salinity growth was inhibited substantially. Sap osmolality, AA concentrations and activities of AA-dependent antioxidant enzymes increased with increasing salinity. Water spray resulted in some improvement in growth, indicating that the growth promotion by exogenous treatments could partly be attributed to water. However, exogenous application of AA on plants grown under saline conditions improved growth and AA dependent antioxidant enzymes more than the water control treatment. Our data show that AA-dependent antioxidant enzymes play an important role in salinity tolerance of *L. stocksii*.

Hamada and Al-Hakimi, (2009) found that exogenously applied AA were generally effective partially or completely countering the inhibitory effects of salt stress on net photosynthetic rate, pigments biosynthesis and membrane integrity by exerting

a stimulatory action on these parameters, especially in plants subjected to moderate and low salinity levels. The leakage of K + was also reduced by the application of AA.

2.4 Role of Exogenous Protectants to Mitigate Salt-Induced Damages

Numerous research results have indicated that exogenous application of osmoprotectants, plant hormones, antioxidants, signaling molecules, polyamines and trace elements provided significant protection against salt-induced damages in plants. These protectants enhanced salt stress tolerance by enhancing their germination, growth, development, photosynthesis, antioxidative capacities and yield.

Tropism represent fascinating examples how plants respond to environmental signals by adapting their growth and development was investigated by Ampudia *et al.* (2013) and reported that salt induced phospholipase D activity stimulates clathrin-mediated endocytosis of PIN2 at the side of the root facing the higher salt concentration. The intracellular relocalization of PIN2 allow for auxin redistribution and for the directional bending of the root way for the higher salt concentration. Their results thus identify a cellular pathway essential for the integration of the environmental cues with auxin regulated root growth that likely plays a key role in adaptive responses to salt stress.

Leo *et al*., (2013) conducted a study with different methods, including seed soaking, root drenching, anthronecolorimetry, and Mo anti-antimony colorimetry were used to study the effects and the corresponding mechanisms of *Bacillus megaterium* CJLC2 on the salt tolerance of tomato and reported that when tomato seedlings were treated with 100 mM/L NaCl, CJLC2 could reduce the content of the Na by 11.25%. *B. megaterium* CJLC2 could improve the salt tolerance of tomato and promote the growth by enhancing the salt-tolerance related physiological and biochemical characters.

Tomato plants hybrid Astona and Gloria growing on pots by Posada and Rodrogueze (2009) with soil were exposed to 20, 40, 60 and 80 mmol NaCl under greenhouse conditions and the electrical conductivity values of treated soil were 2.95, 4.90, 6.56 and 7.70 ds m^{-1}. To soil of some salt stressed palnt, Humitron 60S (23.6% humic acid and 1.1% fulvic acid, from leonardite) was added 1.6 g per plant (40 kg ha^{-1}, proportionally) at transplanting time to reduce the negative effect of salinity on plants. The study was carried out in greenhouse in Tunja, Colombia. Result shows statistical difference between hybrids. Salinity, in general, reduced the values of evaluated growth and yield parameters, however, Leonardite ameliorate the negative effect of salinity on plant. The fruits of salt stressed plants had higher specific leaf area, total soluble solid and titratable acidity in comparison with those of control plants, while total dry matter, yield and leaf area were reduced. For most evaluated parameters, Leonardite had poor effect on alleviation of salt stressed in plants of 20 mmol NaCl treatment, but in soils subjected to 40 to 80 mmol NaCl an increase of yield and dry matter production per plant as well as reduction of total soluble solids and titratable acidity of fruits was observed. Results showed a possibility to reduce the negative effect of salinity on tomato plants growing under greenhouse condition by adding Leonardite salinized soils.

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

enzymes, and for NADP-dependent ferric reductase that is located in plasma membrane.

Glutathione (GSH) is a strong antioxidant which prevents damage to important cellular components caused by ROS (Pompella *et al*. 2003). It also plays an indirect role in protecting membranes by maintaining a-tocopherol and zeaxanthin in the reduced state. It can also function directly as a free radical scavenger by reacting with $1O_2$, $O^{2\bullet-}$ and HO•. GSH protects proteins from denaturation caused by oxidation of protein thiol groups under stress. In addition, GSH is a substrate for glutathione peroxidase (GPX) and glutathione-S-transferases (GST), which are also involved in the removal of ROS (Noctor and Foyer, 2002).

The effect of salt stress and adaption of salicylic acid (SA) content and on antioxidant and lipoxygenase (LOX) enzyme activity was studied by Molina *et al.* (2002) in tomato (Lycopersicon esculentum cv.*Pera*) cells. Application of 200 micro M SA+100 mM NaCl inhibited APX activity in both unadapted and adapted cells, induced the Mn-SOD in adapted cells and increase lipid peroxide in unadapted cells. The findings also indicated that adaption of tomato cells to NaCl-induced oxidative stress and suggest a role of SA in this response.

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

Chapter III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2013 to April 2014 to study mitigation of salt stress by exogenous application of ascorbic acid on growth and yield of tomato. This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, data collection and statistical analysis.

3.1 Location

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

3.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with adequate irrigation facilities and remain fallow during previous growing season. The soil texture of the experiment was sandy loam. The nutrient status of the farm soil under the experimental pot were collected and analyze in the soil research and development institute Dhaka and result has been presented in Appendix I.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity,

rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix II.

3.4 Planting Materials

30 days old seedlings of BARI tomato 14 were used as planting material. The seedling were grown at the seedbed of Sher-e-Bangla Agricultural University Horticulture farm. The experiment was conducted in a two side open plastic shade house.

3.5 Treatment of the experiment

The experiment consists of two factors

Factor A: Different levels of Salinity

i. S_0: 0 dS/m
ii. S_1: 6 dS/m
iii. S_2: 8 dS/m
iv. S_3: 10 dS/m

Factor B: Different levels of Ascorbic acid (AA)

i. A_0: Control ie. No Ascorbic acid
ii. A_1: 0.5 mM AA
iii. A_2: 1mM AA

There were 12 (4×3) treatments combination such as S_0A_0, S_0A_1, S_0A_2, S_1A_0, S_1A_1, S_1A_2, S_2A_0, S_2A_1, S_2A_2, S_3A_0, S_3A_1 and S_3A_2.

3.6 Design and layout of the experiment

The two factor experiment was laid out Randomized Completely Block Design (RCBD) with three replications. There were 36 pots all together replication with the given factors. The experiment area was divided into three equal blocks. Each block

was covered by 12 pots where 12 treatments combination were allotted. The distance between two blocks and two pots were 1.0 m and 0.5 m respectively.

3.7 Preparation of the pot

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

3.8 Application of manure and fertilizer

The sources of N, P_2O_5, K_2O as Urea, TSP and MP were applied respectively. The entire amount of TSP and MP were applied during final land preparation. Urea was applied at three equal installments 15, 30 and 45 days after seedling transplanting. Well rotten cowdung 10 t/ha also applied during final land preparation. The following amount of manures and fertilizers were used which shown as tabular form recommended by BARI (2005).

Table 1. Fertilizer and manure applied for the experimental pot

Manures and Fertilizers	Dose/ha	Dose/ Pot/g	Application (%)			
			Basal	15 DAT	30 DAT	45 DAT
Cowdung	10 ton	303 g	100	---	---	---
N_2	250 kg	8 g	---	33.33	33.33	33.33
P_2O_5 (TPS)	175 kg	5 g	100	---	---	---
K_2O (MP)	150 kg	4 g	100	---	---	---

3.9 Raising of seedlings

Tomato seedlings were raised in one seedbed of 3m × 1m size for BARI Tomato-14. 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 soil. 3g seeds were sown on each seedbed on 11 November, 2013. After sowing, seeds are covered with light soil. Heptachlor 40 WP was applied @ 4kg/ha, around each seedbed as precautionary measure against ant and worm. The emergence of seedlings took place with 5 to 6 days after sowing, weeding, mulching and irrigation were done as and when required.

3.10 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 10 December, 2013. This allowed an accommodation of 01 plant in each pot. The seedbed was watered before uprooting the seedling from the seedbed so as to minimize damage to the roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the hot sun and removed after seedling were established. They (transplants) were kept open at night to allow them receiving dew. Each pot allow two seedlings in the pot and one seedling is removed from pot after healthy establishment of seedlings.

3.11 Preparation of different level of salinity and Ascorbic acid

As per the treatment the required amount of saline solution was applied in the pot during application of water. The tray was used in the bottom of the each pot to collect the water. Ascorbic acid was foliar sprayed according to treatment combination. 1st application of saline solution and ascorbic acid applied in the pot soil at 25 days after transplanting.

3.12 Intercultural operation

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

3.12.1Weeding

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

3.12.2 Earthing up

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

3.12.3 Irrigation

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

3.12.4 Pest and disease control

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

3.13 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they attain slightly red color. Harvesting was started from 17 March, 2014 and continued upto 30 April, 2014.

3.14 Data collection

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

3.14.1 Plant height

Plant height was measured from plant of each unit pot from the ground level to the tip of the longest stem and mean value was calculated. Plant height was calculated at 20 days interval started from the 20 days of planting upto 80 days to observe the growth rate of the plant.

3.14.2 Number of branches per plant

Total number of branches per plant was counted from the plant of each of unit pot. Data recorded at 20 days interval started from the 20 days of planting upto 80 days.

3.14.3 Number of leaves per plant

Total number of leaves per plant was counted from the plant of each of unit pot. Data was recorded at 20 days interval started from the 20 days of planting upto 80 days.

3.14.4 Days required for transplanting to 1st flowering

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

3.14.5 Number of flower cluster per plant

Total number of flower cluster per plant was recorded from the plant of each of unit pot and number of flower cluster produced per plant.

3.14.6 Number of flower per cluster

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

3.14.7 Number of flower per plant

Total number of flower per plant was counted from the plant of each of unit pot and number of flower produced per plant were calculated.

3.14.8 Number of fruits per cluster

Total number of fruits per cluster was counted from the plant of each of unit pot and number of fruits produced per cluster were calculated.

3.14.9 Number of fruits per plant

Total number of fruits per plant was counted from the plant of each of unit pot and number of fruits produced per plant were calculated.

3.14.10 Length of the fruits

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

3.14.11 Diameter of the fruit

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

3.14.12 Dry matter of the plant

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

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

3.14.13 Dry matter of the fruits

After harvesting, randomly selected 150 g fruit sample previously sliced into thin pieces put into envelop and placed in oven maintained 70º for 72 hours. The sample

was transferred into desiccator and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter content of the fruit was computed by the simple calculation from the weight recorded by the following formula:

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

3.14.14 Weight of the individual fruit

Among the total number fruits during the period from the first to final harvest fruits, except the first and final harvest, was considered for determining the individual fruit weight.

3.14.15 Yield per pot

Yield of the tomato per plant was calculated as the whole fruit per plant and was expressed in kilogram.

3.14.16 Yield per hectare

According to field condition number of plant per hectare was calculated considering plant to plant distance 75 × 40 cm. The experimental pot was arranged according to that distance and thus yield per pot was converted to yield per hectare in ton.

3.15 Statistical analysis

The data obtained for different characters were statistically analyze by using MSTAT-C computer package program to find out the significance of the difference for salt stress and ascorbic acid for yield and yield contributing characters of the tomato. The mean value of the all recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combination of the mean was estimated by Duncan's Multiple Range Test (DMRT) at 5% of probability.

CHAPTER IV

RESULT AND DISCUSSION

The experiment was conducted to study the effect of salinity and ascorbic acid on growth and yield of tomato. The analysis of variance (ANOVA) of the data are presented in Appendix III-VII. The result has been presented by using table and graphs and discussed with possible interpretations under the following headings:

4.1 Plant height

Plant height of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Appendix III). At 20 days, the longest plant height was recorded from S_0 (26.2 cm) treatment which was statistically identical with S_1 (23.7 cm) and followed by S_2 (20.2 cm) treatment, while the shortest plant from S_3 (16.6 cm) (Figure.1). At 40 DAT, the longest plant was recorded from S_0 (69.6 cm) treatment which was statistically identical with S_1 (66.9 cm) and followed by S_2 (64.1cm) treatment and the shortest plant from S_3 (61.2 cm). At 60 DAT, the longest plant was recorded from S_0 (88.8 cm) treatment which was statistically identical with S_1 (85.3 cm) and followed by S_2 (79.6 cm) treatment and the shortest plant from S_3 (75.0 cm). At 80 DAT, the longest plant was recorded from S_0 (96.8 cm) which was statistically followed byS_1 (93.2 cm) and S_2 (86.5 cm) respectively, while the shortest plant from S_3 (81.7 cm) treatment. Leo *et al*., (2003) reported that under the salt stress of NaCl, the increase of NaCl concentration had stronger inhibitor effect on tomato growth. Agong *et al*., (2003) reported that significant genotype and/or salt treatment effect registered on plant height.

Plant height of tomato varied significantly due to different levels of ascorbic acid at different days after transplanting (DAT) (Figure 2 and Appendix III). At 20 days, the longest plant was recorded from A_2 (25.6 cm) which was statistically identical with A_1 (21.9 cm), while the shortest plant from A_0 (17.5 cm) (Figure.2). At 40

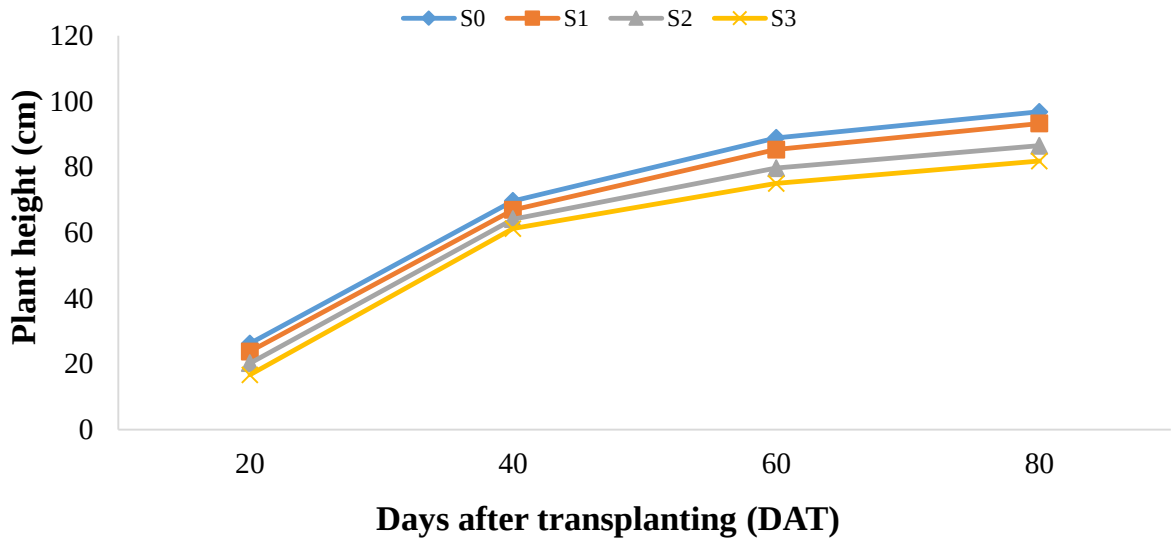

Figure 1. Effect of salinity on plant height at different days after transplanting

S_0= 0 dS/m S_1 = 6 dS/m S_2 = 8 dS/m S_3 = 10 dS/m

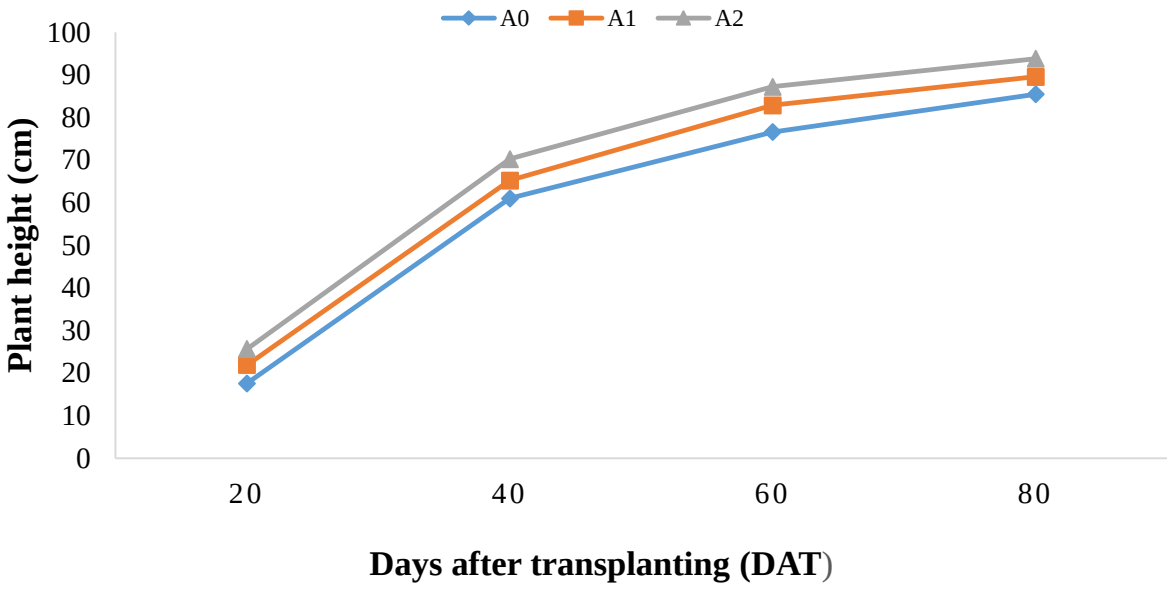

Figure 2. Effect of ascorbic acid on plant height at different days after transplanting

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1 mM

Table 2. Combined effects of salinity levels and ascorbic acid doses on plant height of tomato at different days after transplanting (DAT)

Treatment combination	Plant height (cm) at different DAT			
	20	40	60	80
S_0A_0	21.0	65.0	82.3	92.0
S_0A_1	26.6	70.0	89.0	97.0
S_0A_2	31.0	74.0	95.3	101.5
S_1A_0	19.6	63.0	80.0	90.3
S_1A_1	23.3	66.8	86.5	93.5
S_1A_2	28.3	71.0	89.5	96.0
S_2A_0	16.3	60.0	75.0	82.1
S_2A_1	21.0	63.0	80.0	86.0
S_2A_2	23.3	69.3	84.0	91.3
S_3A_0	13.3	56.0	69.0	77.3
S_3A_1	16.6	61.0	76.0	81.6
S_3A_2	20.0	66.6	80.0	86.3
$LSD_{0.05}$	1.38	1.41	1.82	1.73
Level of significance	**	*	*	*
CV (%)	3.76	1.28	1.31	1.14

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

DAT, the longest plant was recorded from A_2 (70.2 cm) which was statistically identical with A_1 (65.2 cm), while the shortest plant from A_0 (61.0 cm). At 60 DAT, the longest plant was recorded from A_2 (87.2 cm) treatment, which was statistically followed by A_1 (82.8 cm) and the shortest plant from A_0 (76.5 cm). At 80 DAT, the longest plant was recorded from A_2 (93.7 cm) treatment which was statistically followed by A_1 (89.5 cm), while the shortest plant from A_0 (85.4 cm) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for plant height at 20, 40, 60 and 80 DAT (appendix III). At 20 DAT, the longest plant was recorded from S_0A_2 (31.0 cm) treatment combination and the shortest plant (13.3 cm) was recorded from S_3A_0. At 40 and 60 DAT, the similar trend of combined effect between saline water and ascorbic acid showed on the plant height of tomato (Table 2). At 80 DAT, the longest plant (101.5 cm) was recorded from S_0A_2 (No saline + 1 Mm ascorbic acid) treatment combination and the shortest plant (77.3 cm) was recorded from S_3A_0 (10 ds/m saline water + no ascorbic acid) treatment combination.

4.2 Number of branches per plant

Number of branches per plant of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Appendix IV). At 20 days, the highest number of branches per plant was recorded from S_0 (4.00) treatment which was statistically identical with S_1 (3.55) and followed by S_2 (3.11), while the lowest number of branches per plant from S_3 (2.77) (Figure 3). At 40 DAT, the highest number of branches per plant was recorded from S_0 (8.66) treatment, which was statistically identical with S_1 (8.22) and followed by S_2 (7.66) and the lowest number of branches per plant from S_3 (6.33). At 60 DAT, the highest number of branches per plant was recorded from S_0 (19.4) treatment which was statistically identical with S_1 (17.6) and followed by S_2 (16.3) and the lowest number of branches

per plant from S_3 (15.3). At 80 DAT, the highest number of branches per plant was recorded from S_0 (24.3) treatment which was
statistically followed by S_1 (23.1) and S_2 (20.5) respectively, while the lowest number of branches per plant from S_3 (17.5) treatment.

Number of branches per plant of tomato varied significantly due to different levels of ascorbic acid at different days after transplanting (DAT) (Figure 4 and Appendix IV). At 20 days, the highest number of branches per plant was recorded from A_2 (3.91) treatment which was statistically identical with A_1 (3.33) treatment, while the lowest number of branches per plant from A_0 (2.83) (Figure 4). At 40 DAT, the highest number of branches per plant was recorded from A_2 (8.08) treatment which was statistically identical with A_1 (7.75), while the lowest number of branches per plant from A_0 (7.33). At 60 DAT, the highest number of branches per plant was recorded from A_2 (17.5) which was statistically followed by A_1 (17.1) and the lowest number of branches per plant from A_0 (16.8). At 80 DAT, the highest number of branches per plant was recorded from A_2 (22.0) which was statistically followed by A_1 (21.5), while the lowest number of branches per plant from S_3 (20.5) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of branch per plant at 20, 40, 60 and 80 DAT (Table 3 and appendix IV). At 20 DAT the highest number of branch per plant was recorded from S_0A_2 (4.67) treatment combination and the lowest number of branch per plant (2.33) was recorded from S_3A_0 (10 ds/m salinity + No ascorbic acid) treatment combination. At 40 and 60 DAT the similar trend of combined effect between saline water and ascorbic acid showed on number of branch per plant of tomato (Table 3). At 80 DAT, the highest number of branch (25.0) was recorded from S_0A_2 (No saline + 1 Mm ascorbic acid) treatment combination and the lowest number of branch per plant (16.3) was recorded from S_3A_0 (10 ds/m salinity + no ascorbic acid) treatment combination.

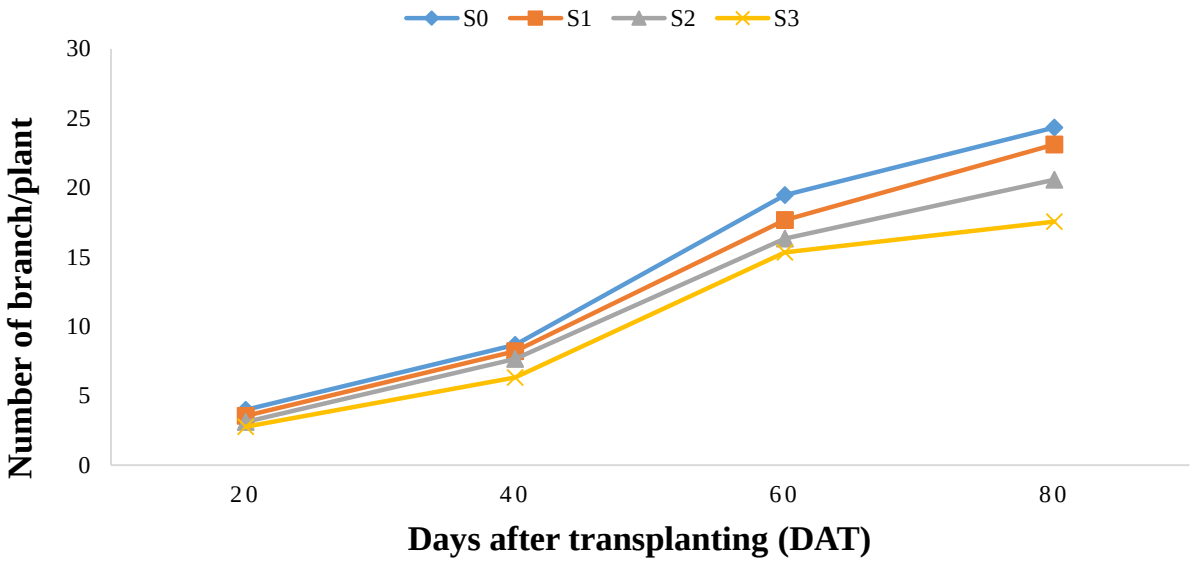

Figure 3. Effect of salinity on number of branch per plant

S = 0 dS/m S = 6 dS/m S = 8 dS/m S = 10 dS/m

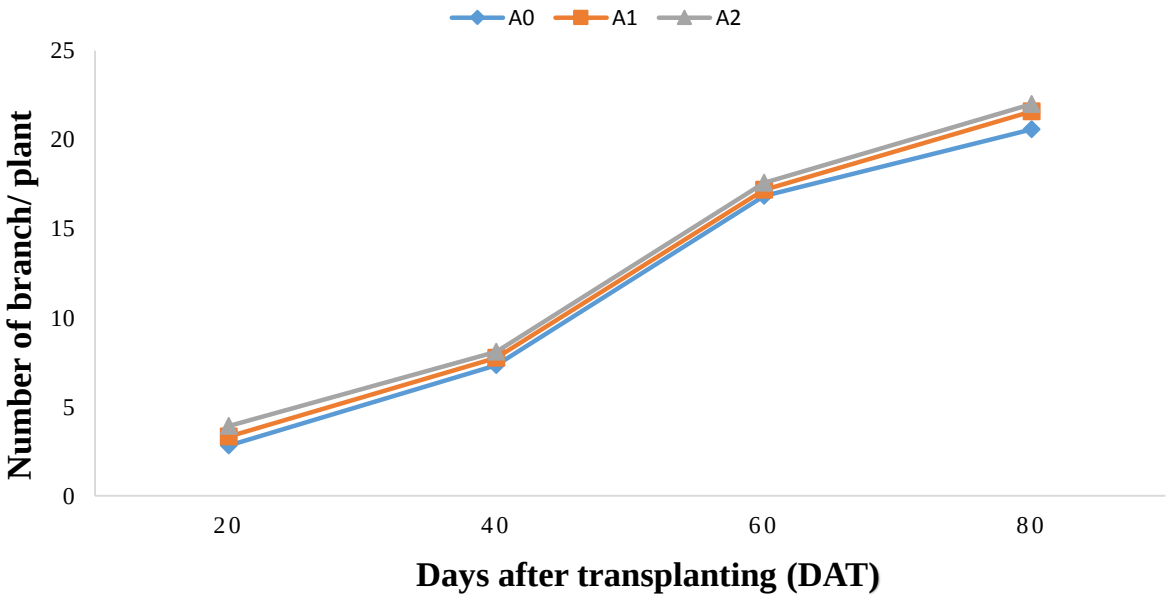

Figure 4. Effect of ascorbic acid on no of branch per plant at different days after transplanting

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1 mM

Table 3. Combined effects of salinity levels and ascorbic acid doses on number of branches/plant of tomato at different days after transplanting (DAT)

Treatment combination	Number of branches/plant at different DAT			
	20	40	60	80
S_0A_0	3.33	8.33	19.0	23.6
S_0A_1	4.00	8.67	19.3	24.3
S_0A_2	4.67	9.00	20.0	25.0
S_1A_0	3.00	7.67	17.3	22.3
S_1A_1	3.67	8.33	17.6	23.3
S_1A_2	4.00	8.67	18.0	23.6
S_2A_0	2.67	7.33	16.0	20.0
S_2A_1	3.00	7.67	16.3	20.6
S_2A_2	3.67	8.00	16.6	21.0
S_3A_0	2.33	6.00	15.0	16.3
S_3A_1	2.67	6.33	15.3	18.0
S_3A_2	3.33	6.67	15.6	18.3
$LSD_{0.05}$	0.199	0.169	0.160	0.480
Level of significance	**	*	*	*
CV (%)	3.51	1.28	0.57	1.33

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

4.3 Number of leaves per plant

Number of leaves per plant of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Appendix V). At 20 days, the highest number of leaves per plant was recorded from S_0 (7.89) treatment which was statistically identical with S_1 (7.00) and followed by S_2 (6.00),while the lowest number of leaves per plant from S_3 (5.22) treatment (Table 4). At 40 DAT, the highest number of leaves per plant was recorded from S_0 (17.0) which was statistically identical with S_1 (15.8) and followed by S_2 (15.4) and the lowest number of leaves per plant from S_3 (13.8). At 60 DAT, the highest number of leaves per plant was recorded from S_0 (33.2) which was statistically identical with S_1 (29.6) and followed by S_2 (27.1) and the lowest number of leaves per plant from S_3 (22.2). At 80 DAT, the highest number of leaves per plant was recorded from S_0 (34.67) which was statistically followed by S_1 (32.6) and S_2 (29.1) respectively, while the lowest number of leaves per plant from S_3 (23.7) treatment.

Number of leaves per plant of tomato varied significantly due to different levels of ascorbic acid at different days after transplanting (DAT) (Table 4 and appendix V). At 20 days, the highest number of leaves per plant was recorded from A_2 (7.25) treatment which was statistically identical with A_1 (6.58), while the shortest plant from A_0 (5.74). At 40 DAT, the highest number of leaves per plant was recorded from A_2 (16.58) which was statistically identical with A_1 (15.4), while the lowest number of leaves per plant from A_0 (14.66). At 60 DAT, the highest number of leaves per plant was recorded from A_2 (28.9) which was statistically followed by A_1 (28.08) and the lowest number of leaves per plant from A_0 (27.17). At 80 DAT, the highest number of leaves per plant was recorded from A_2 (30.67) which was statistically followed by A_1 (30.17), while the shortest plant from S_3 (29.33) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of leaves per plant at 20, 40, 60 and 80 DAT (Appendix V). At 20 DAT the highest number of leaves per plant was recorded from S_0A_2 (8.67)

Table 4. Effect of salinity levels on number of leaves per plant of tomato at different days after transplanting (DAT)

Treatment	Number of leaves/plant at different DAT			
	20	40	60	80
Salinity levels				
S_0	7.89	17.0	33.2	34.6
S_1	7.00	15.8	29.6	32.6
S_2	6.00	15.4	27.1	29.1
S_3	5.22	13.8	22.2	23.7
$LSD_{0.05}$	0.111	0.529	0.377	0.115
Level of significance	**	**	**	**
CV (%)	1.77	3.50	1.38	0.40
Ascorbic acid doses				
A_0	5.74	14.6	27.1	29.3
A_1	6.58	15.4	28.0	30.1
A_2	7.25	16.5	28.9	30.6
$LSD_{0.05}$	0.096	0.458	0.326	0.099
Level of significance	**	**	**	**
CV (%)	1.77	3.50	1.38	0.40

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

Table 5. Combined effects of salinity levels and ascorbic acid doses on number of leaves/plant of tomato at different days after transplanting (DAT)

Treatment combination	Number of leaves/plant at different DAT			
	20	40	60	80
S_0A_0	7.00	16.3	32.0	34.0
S_0A_1	8.00	16.6	33.3	34.6
S_0A_2	8.67	18.0	34.3	35.3
S_1A_0	6.33	15.3	29.0	32.0
S_1A_1	7.00	16.0	29.6	32.6
S_1A_2	7.67	16.3	30.3	33.3
S_2A_0	5.33	14.6	26.6	28.3
S_2A_1	6.00	15.3	27.0	29.3
S_2A_2	6.67	16.3	27.6	29.6
S_3A_0	4.33	12.3	21.0	23.0
S_3A_1	5.33	13.6	22.3	24.0
S_3A_2	6.00	15.6	23.3	24.3
$LSD_{0.05}$	0.192	0.917	0.653	0.199
Level of significance	*	*	*	*
CV (%)	1.77	3.50	1.38	0.40

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

treatment combination and the lowest number of leaves per plant (4.33) was recorded from S_3A_0 (10 ds/m salinity + No ascorbic acid) treatment combination. At 40 and 60 DAT the similar trend of combined effect
between saline water and ascorbic acid showed on the plant height of tomato (Table 5). At 80 DAT, the highest number of leaves per plant (35.3) was recorded from S_0A_2 (No saline + 1 Mm ascorbic acid) and the lowest number of leaves per plant (23.0) was recorded from S_3A_0 (10 ds/m salinity + no ascorbic acid) treatment combination.

4.4 Days from transplanting to 1st flower initiation

Days from transplanting to 1st flower initiation showed statistically significant variation due to different level of saline water (Appendix VI). The maximum days from transplanting to 1st visible flower (43.3) was recorded from S_3 (10 dS/m salinity) treatment whereas the minimum days from transplanting to 1st visible flower (39.7) was recorded S_0 (No saline) treatment which was statistically identical with S_1 (41.3) and S_2 (42.33) respectively (Table 6).

Statistically significant variation due to different level of ascorbic acid was recorded from transplanting to 1st flower initiation (Appendix VI). The maximum days from transplanting to 1st visible flower (43.3) was recorded from A_0 (No ascorbic acid) treatment whereas the minimum days from transplanting to 1st visible flower (39.8) was recorded from A_2 (1 mM AA) treatment which was statistically identical with A_1 (0.5 mM AA) and the value was 41.92 (Table 6).

Combined effect of saline water and ascorbic acid showed statistically significant variation for days from transplanting to 1st flower initiation (Appendix VI). The maximum days from transplanting to 1st flower initiation was (45.3) recorded from S_3A_0 (10 dS/m salinity + no AA) and the minimum days from transplanting to 1st flower initiation was (38.3) recorded from S_0A_2 (No saline + 1mM ascorbic acid) treatment combination (Table 7).

4.5 Number of flower cluster per plant

Number of flower cluster per plant showed statistically significant variation due to different level of saline water (Appendix VI). The highest number of flower cluster per plant was recorded from S_0 (8.60) treatment which was statistically identical with S_1 (8.17) treatment and followed by S_2 (7.88), while the lowest number of flower cluster per plant was recorded from S_0 (7.15) (Figure 5).

Significance difference was recorded due to different levels of ascorbic acid for number of flower cluster per plant (Appendix VI). The maximum number of flower cluster per plant was recorded from A_2 (8.02) treatment which was closely followed by A_1 (7.76) (Figure 6), while the minimum number of flower cluster per plant was recorded from A_0 (7.16) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of flower cluster per plant (Appendix VI). The maximum number of flowers per plant (8.88) was recorded from S_0A_2 (No saline + 1 mM AA) treatment combination, while the minimum number of flowers per plant (6.50) was recorded from S_3A_0 (10 dS/m salinityl + no AA) treatment combination (Figure 7).

4.6 Number of flower per cluster

Number of flower per cluster per plant showed statistically significant variation due to different level of saline water (Appendix VI). The highest number of flowers per cluster per plant was (7.11) recorded from S_0 (No saline) treatment which was statistically identical with S_1 (6.66) and followed by S_2 (6.00), while the lowest number of flowers per plant was (5.44) recorded from S_3 (10 dS/m salinity) treatment (Table 6).

Significance difference from was recorded due to different levels of ascorbic acid for number of flower per cluster per plant (Appendix VI). The maximum number of flower per cluster per plant was (6.83) recorded from A_2 (1mM AA) treatment

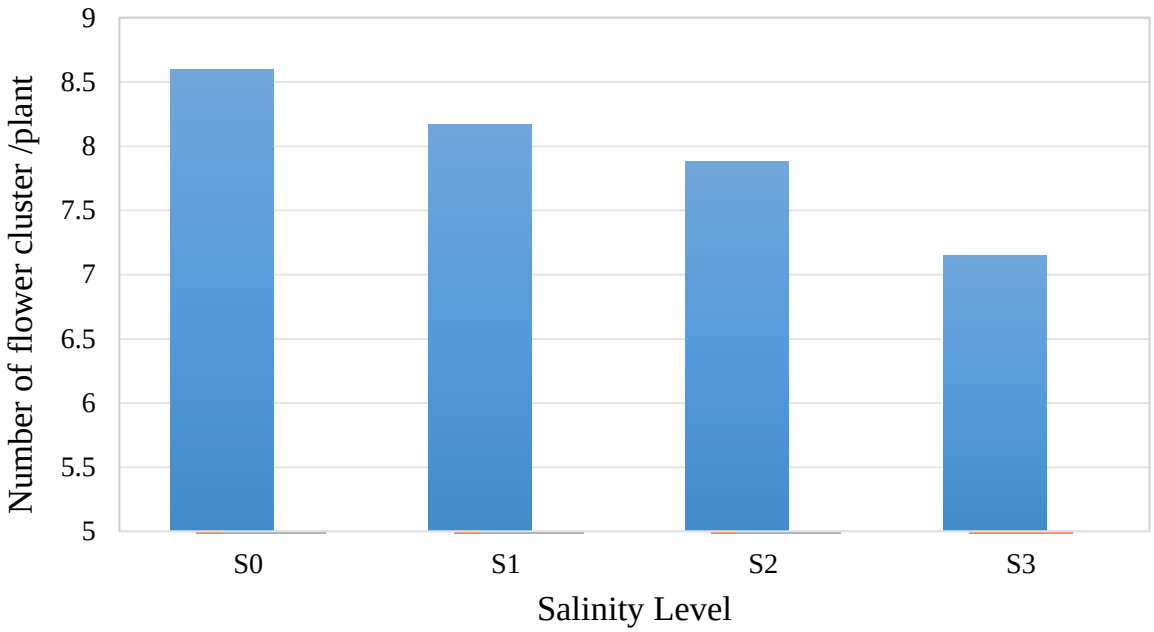

Figure 5. Effect of salinity on number of flower cluster per plant

S_0 = 0 dS/m S_1 = 6 dS/m S_2 = 8 dS/m S_3 = 10 dS/m

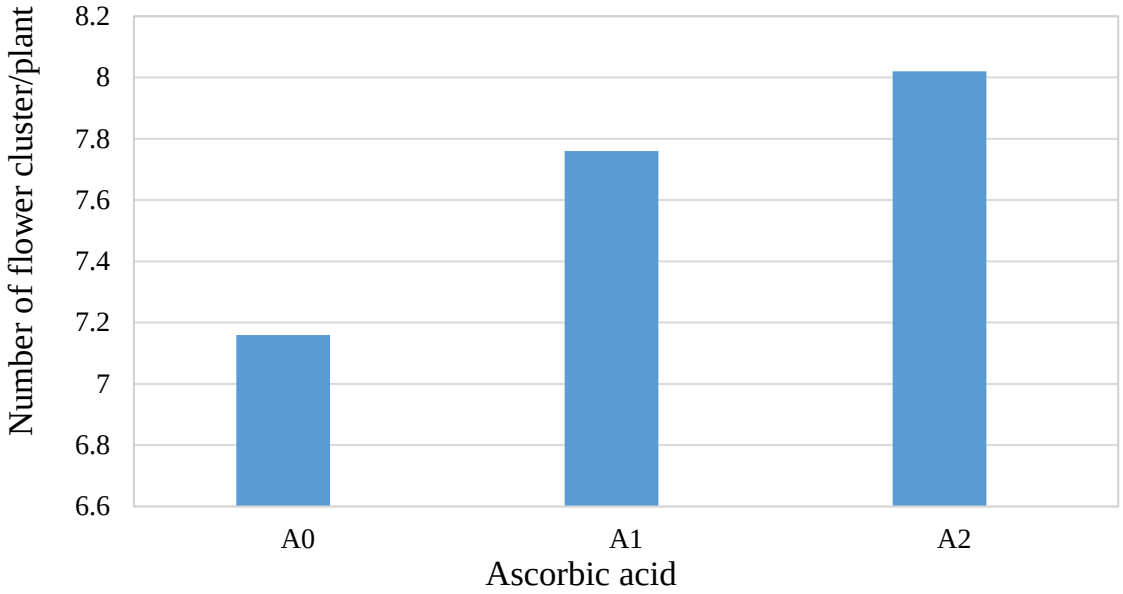

Figure 6. Effect of ascorbic acid on number of flower cluster per plant

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1.0 mM

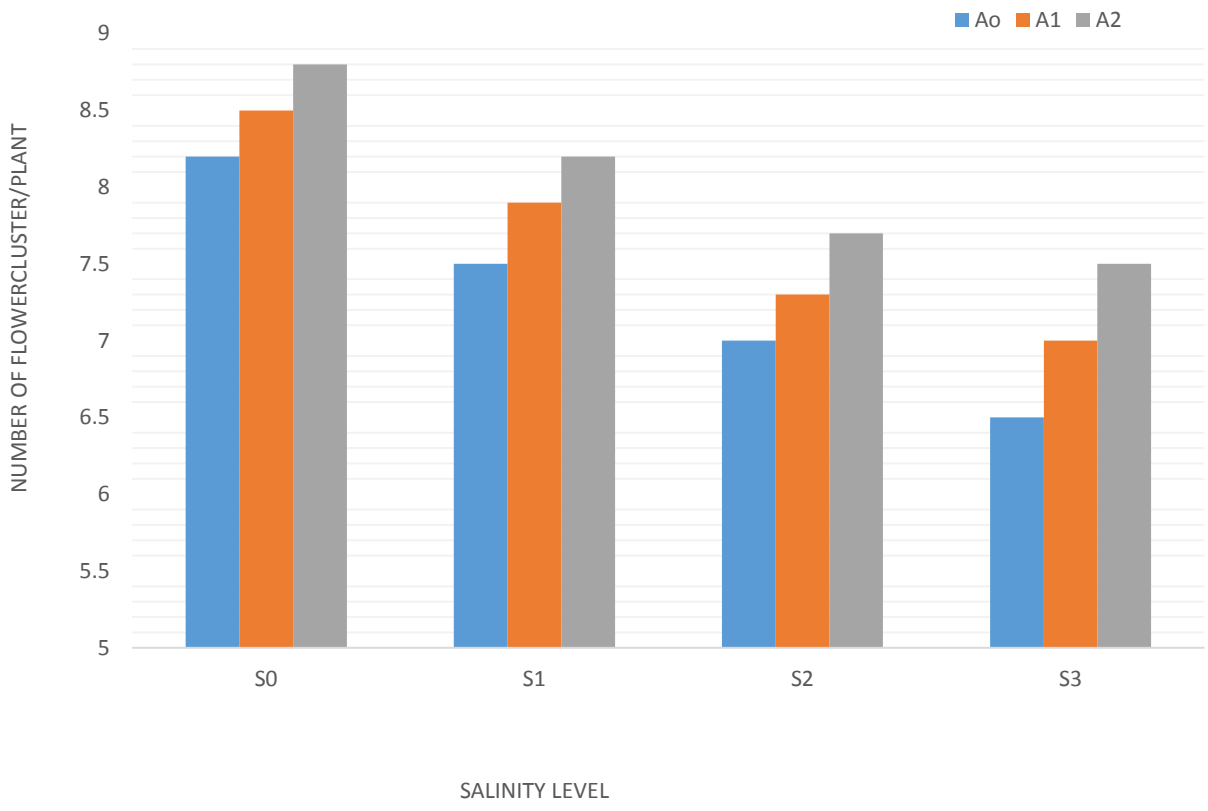

Figure 7. Combined effect of salinity and ascorbic acid on number of flower cluster per plant

S_0 = 0 dS/m S_1 = 6 dS/m S_2 = 8 dS/m S_3 = 10 dS/m

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1.0 mM

which was closely followed by A_1 (6.16) (Table 6), while the minimum number of flower per cluster per plant (5.91) was recorded from A_0 (No ascorbic acid).

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of flower per cluster per plant (Appendix VI). The maximum number of flower per cluster per plant (8.00) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination, while the minimum number of flower per cluster per plant (5.0) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 7).

4.7 Number of flowers per plant

Number of flowers per plant showed statistically significant variation due to different level of saline water (Appendix VI). The highest number of flowers per plant was (53.5) recorded from S_0 (No saline) treatment which was statistically identical with S_1 (42.8) and followed by S_2 (39.5), while the lowest number of flowers per plant was (34.8) recorded from S_3 (10 dS/m salinity) (Table 6).

Significance difference was recorded due to different levels of ascorbic acid for number of flowers per plant (Appendix VI). The maximum number of flowers per plant was (48.75) recorded from A_2 treatment which was closely followed by A_1 (41.9) (Table 6), while the minimum number of flowers per plant (35.2) was recorded from A_0 (No ascorbic acid).

Combination effect of saline water and ascorbic acid showed statistically significant variation for number of flowers per plant (Appendix VI). The maximum number of flowers per plant (62.6) was recorded from S_0A_2 (No saline + 1 mM AA) treatment combination, while the minimum number of flowers per plant (27.0) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 7).

Table 6. Effect of salinity levels and ascorbic acid on yield contributing characteristics on tomato

Treatments	Days from transplanting to flowering	Number of flower/cluster	Number of Flower/ plant	Number of fruit/cluster
Salinity levels				
S_0	39.7	7.11	53.5	5.00
S_1	41.3	6.66	42.8	4.44
S_2	42.3	6.00	36.5	4.11
S_3	43.3	5.44	34.8	3.33
$LSD_{0.05}$	0.671	0.265	1.61	0.119
Level of significance	**	**	**	**
CV (%)	1.65	4.33	3.93	2.91
Ascorbic acid				
A_0	43.3	5.91	35.2	3.83
A_1	41.9	6.16	41.9	4.16
A_2	39.8	6.83	48.7	4.66
$LSD_{0.05}$	0.581	0.229	1.39	0.103
Level of significance	**	**	**	**
CV (%)	1.65	4.33	3.93	2.91

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

Table 7. Combined effects of salinity levels and ascorbic acid doses on yield contributing characteristics

Treatment combination	Days from flowering to transplanting	Number of flower/ cluster	Number of flower / plant	Number of fruit / cluster
S_0A_0	40.3	6.33	44.6	4.67
S_0A_1	40.6	7.00	53.3	5.00
S_0A_2	38.3	8.00	62.6	5.33
S_1A_0	43.3	6.33	36.3	4.00
S_1A_1	41.3	6.67	42.0	4.33
S_1A_2	39.3	7.00	50.3	5.00
S_2A_0	44.3	6.00	35.0	3.67
S_2A_1	42.3	5.67	36.0	4.00
S_2A_2	40.3	6.33	40.6	4.67
S_3A_0	45.3	5.00	32.0	3.00
S_3A_1	43.3	5.33	36.3	3.33
S_3A_2	41.3	6.00	41.3	3.67
$LSD_{0.05}$	1.16	0.458	2.78	0.206
Level of significance	*	**	**	*
CV (%)	1.65	4.33	3.93	2.91

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

4.8 Number of fruit per cluster

Number of fruit per cluster showed statistically significant variation due to different level of saline water (Appendix VI). The highest number of fruit per cluster (5.00) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (4.44) and followed by S_2 (4.11) treatment, while the lowest number of fruit per cluster (3.33) was recorded from S_3 (10 dS/m salinity) treatment (Table 6).

Significance difference was recorded due to different levels of ascorbic acid for number of fruit per cluster (Appendix VI).). The maximum number of fruit per cluster (4.66) was recorded from A_2 (1mM AA) treatment which was closely followed by A_1 (0.5 mM AA) (4.16) (Table 6), while the minimum number of fruit per cluster (3.83) was recorded from A_0 (No ascorbic acid).

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of fruit per cluster (Appendix VI). The maximum number of fruit per cluster (5.33) was recorded from S_0A_2 (No saline + 1 mM AA), while the minimum number of fruit per cluster (3.00) was recorded from S_3A_0 (10 dS/m salinity + no AA) (Table 7).

4.9 Number of fruit per plant

Number of fruit per plant showed statistically significant variation due to different level of saline water (Appendix VI). The highest number of fruit per plant (44.0) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (6 dS/m salinity) (40.5) and followed by S_2 (8 dS/m salinity) (38.3), while the lowest number of fruit per plant (30.9) was recorded from S_3 (10 dS/m salinity) treatment (Figure 8).

Significance difference was recorded due to different levels of ascorbic acid for number of fruit per plant (Appendix VI). The maximum number of fruit per plant (41.4) was recorded from A_2 (1mM AA) treatment which was closely followed by

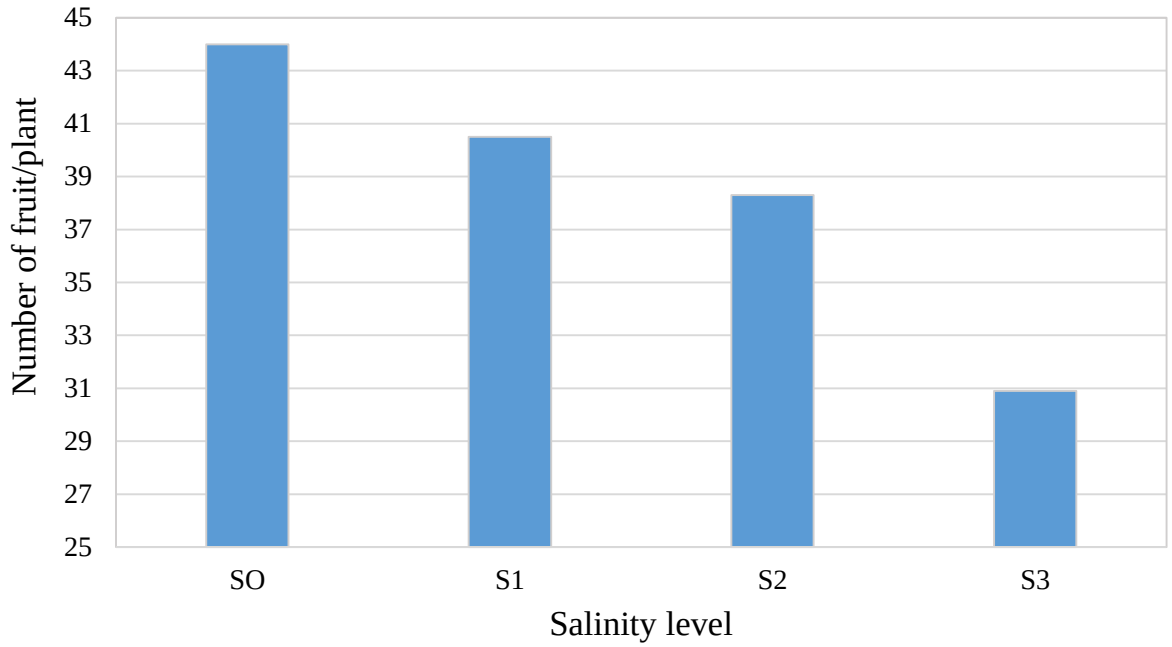

Figure 8. Effect of salinity on number of fruits per plant

S_0 = 0 dS/m S_1 = 6 dS/m S_2 = 8 dS/m S_3 = 10 dS/m

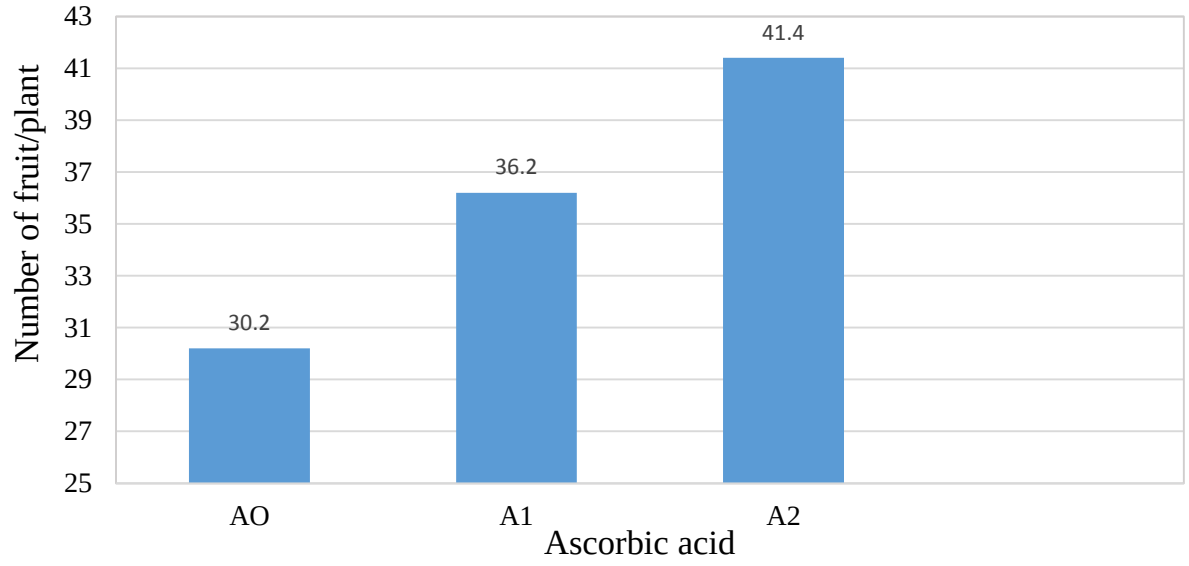

Figure 9. Effect of ascorbic acid on number of fruits per plant

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1.0 mM

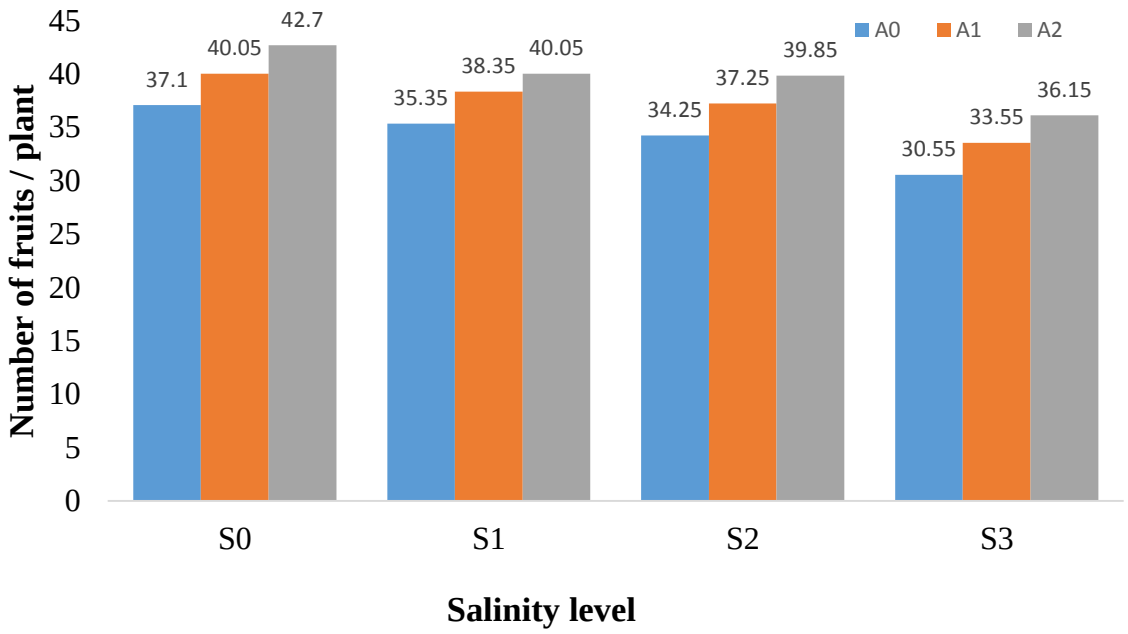

Figure 10. Combined effect of salinity and ascorbic acid on number of fruits per plant

S_0 = 0 ds/m **S_1 = 6 ds/m** **S_2 = 8 ds/m** **S_3= 10 ds/m**

A_0 = 0 mM **A_1 = 0.5 mM** **A_2 = 1 mM**

A_1 (36.2) (Figure 9), while the minimum number of flowers per plant (30.2) was recorded from A_0 (No ascorbic acid).

Combined effect of saline water and ascorbic acid showed statistically significant variation for number of fruit per plant (Appendix VI). The maximum number of fruit per plant (42.7) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination, while the minimum number of fruit per plant (30.5) was recorded from S_3A_0 (10 dS/m salinity + no AA) (Figure 10).

4.10 Length of fruit

Length of fruits showed statistically significant variation due to different level of saline water (Appendix VII). The maximum length of fruit (9.33 cm) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (8.85 cm) and followed by S_2 (7.99 cm), while the minimum length of fruit per plant (6.69 cm) was recorded from S_3 (10 dS/m salinity) (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for length of fruits (Appendix VII). The maximum length of fruits (8.85 cm) was recorded from A_2 (1Mm AA) treatment which was closely followed by A_1 (8.20 cm) (Table 8), while the minimum length of fruits (7.59 cm) was recorded from A_0 (No ascorbic acid) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for length of fruits (Appendix VII). The maximum length of fruits (10.0 cm) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination, while the minimum length of fruits per plant (6.10 cm) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 9).

4.11 Diameter of fruit

Diameter of fruits varied significantly due to different level of saline water (Appendix VII). The maximum diameter of fruit (6.11 cm) was recorded from S_0

(No saline) treatment which was statistically identical with S_1 (5.54 cm) and followed by S_2 (4.90 cm), while the minimum diameter of fruits per plant (4.47cm) was recorded from S_3 (10 dS/m salinity) treatment (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for diameter of fruits (Appendix VII). The maximum diameter of fruits (5.77cm) was recorded from A_2 (1Mm AA) treatment which was closely followed by A_1 (5.23cm) (Table 8), while the minimum diameter of fruits (4.77cm) was recorded from A_0 (No ascorbic acid) treatment.

Interaction effect of saline water and ascorbic acid showed statistically significant variation for diameter of fruits (Appendix VII). The maximum diameter of fruits (6.70cm) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination, while the minimum diameter of fruits per plant (4.07cm) was recorded from S_3A_0 (10 dS/m salinity + no ascorbic acid) treatment combination (Table 9).

4.12 Dry matter content in fruit

Dry matter content in fruits varied significantly due to different level of saline water (Appendix VII). The highest dry matter content in fruits (8.35%) was recorded from S_0 (No saline) which was statistically identical with S_1 (8.08%) treatment and followed by S_2 (7.36%). On the other hand, the lowest dry matter content in fruits per plant (6.95%) was recorded from S_3 (10 dS/m salinity) (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for dry matter content in fruits (Appendix VII). The highest dry matter content in fruits (7.95%) was recorded from A_2 (1mM AA) which was closely followed by (7.7%) (Table 8), while the lowest dry matter content in fruits (7.41%) was recorded from A_0 (No ascorbic acid) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for dry matter content in fruits (Appendix VII). The highest dry matter content in fruits (8.57%) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment

combination, while the lowest dry matter content in fruits per plant (6.67%) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 9).

4.13 Dry matter content in plant

Dry matter content in plant statistically varied significantly due to different level of saline water (Appendix VII). The highest dry matter content in plants (13.2%) was recorded from S_0 (No saline) treatment which was statistically identical with S_1 (13.0%) and followed by S_2 (12.3%). On the other hand, the lowest dry matter content in plants (11.7%) was recorded from S_3 (10 dS/m salinity) treatment (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for dry matter content in plant (Appendix VII). The highest dry matter content in plants (12.9%) was recorded from A_2 (1mM AA) treatment which was closely followed by A_1 (12.6%) (Table 8), while the lowest dry matter content in plants (12.1%) was recorded from A_0 (No ascorbic acid) treatment.

Interaction effect of saline water and ascorbic acid showed statistically significant variation for dry matter content in plants (Appendix VII). The highest dry matter content in plants (13.5%) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination, while the lowest dry matter content in plants per plant (11.3%) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 9).

4.14 Weight of individual fruit

Due to different level of saline water statistically significant variation was recorded for weight of individual fruit (Appendix VII). The highest weight of individual fruit (80.4 g) was recorded from S_0 (No saline) treatment which was statistically similar with S_1 (75.9 g) and closely followed by S_2 (71.5 g), while the lowest weight of individual fruit (64.9 g) was recorded from S_3 (10 dS/m salinity) treatment (Figure 11).

Table 8. Effect of salinity and ascorbic acid levels on yield contributing characters and yield of tomato

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in fruit (%)	Dry matter content in plant (%)	Yield per pot (kg)	Yield per hectare (t/ha)
Salinity levels						
S_0	9.33	6.11	8.35	13.2	3.08	92.5
S_1	8.85	5.54	8.08	13.0	2.9	87.2
S_2	7.99	4.90	7.36	12.3	2.53	76.0
S_3	6.69	4.47	6.95	11.7	2.12	63.6
$LSD_{0.05}$	0.053	0.182	0.075	0.110	0.141	3.91
Level of significance	**	**	**	**	**	*
CV (%)	0.64	3.55	0.97	0.92	8.72	1.18
Ascorbic acid						
A_0	7.59	4.77	7.41	12.1	2.55	76.5
A_1	8.20	5.23	7.70	12.6	2.65	79.5
A_2	8.85	5.77	7.95	12.9	2.78	83.4
$LSD_{0.05}$	0.046	0.158	0.065	0.096	0.122	3.91
Level of significance	**	**	**	**	**	*
CV (%)	0.64	3.55	0.97	0.92	8.72	1.18

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

Table 9. Combined effects of salinity levels and ascorbic acid doses on yield contributing characters and yield of tomato

Treatment combination	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in fruit (%)	Dry matter content in plant (%)	Yield per pot (kg)	Yield per hectare (t/ha)
S_0A_0	8.67	5.53	8.17	12.9	3.05	91.5
S_0A_1	9.33	6.10	8.33	13.2	3.08	92.4
S_0A_2	10.0	6.70	8.57	13.5	3.12	93.6
S_1A_0	8.30	5.13	7.70	12.4	2.80	84.0
S_1A_1	8.83	5.67	8.17	13.1	2.91	87.3
S_1A_2	9.43	5.83	8.38	13.4	3.01	90.3
S_2A_0	7.30	4.37	7.13	12.0	2.39	71.7
S_2A_1	7.97	4.72	7.33	12.4	2.51	75.3
S_2A_2	8.70	5.63	7.63	12.6	2.7	81.0
S_3A_0	6.10	4.07	6.67	11.3	1.96	58.8
S_3A_1	6.67	4.43	6.97	11.8	2.1	63.0
S_3A_2	7.30	4.93	7.23	12.1	2.3	69.0
$LSD_{0.05}$	0.092	0.315	0.131	0.192	0.244	3.91
Level of significance	**	*	*	**	**	*
CV (%)	0.64	3.55	0.97	0.92	8.72	1.18

S_0 = 0 dS/m, S_1 = 6 dS/m, S_2 = 8 dS/m, S_3 = 10 dS/m, A_0 = 0 mM, A_1 = 0.5 mM, A_2 = 1.0 mM

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

A statistically significant difference from was recorded due to different levels of ascorbic acid for weight of individual fruit per plant (Appendix VII). The maximum number of fruits per plant (73.8 g) was recorded from A_2 (1mM AA) treatment which was closely followed by A_1 (73.1 g) (Figure 12), while the minimum weight of individual fruit (72.4 g) was recorded from A_0 (No ascorbic acid) treatment.

Combination effect of saline water and ascorbic acid showed statistically significant variation for weight of individual fruit (Appendix VII). The maximum weight of individual fruit (81.1 g) was recorded from S_0A_2 (No saline + 1 mM AA) treatment combination, while the minimum weight of individual fruit (64.5 g) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Figure 13).

4.15 Yield per pot

Yield per pot in tomato showed statistically significant variation due to different level of saline water (Figure Appendix VII). The highest yield per pot (3.08 kg) was recorded from S_0 (No saline) treatment which was statistically similar with S_1 (2.90 kg) and closely followed by S_2 (2.53 kg), while the lowest yield per pot (2.12 kg) was recorded from S_3 (10 dS/m salinity) treatment (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for yield per pot (Appendix VII). The highest yield per pot (2.78 kg) was recorded from A_2 (1mM AA) treatment which was closely followed by A_1 (2.65 kg) (Table 8), while the lowest yield per pot (2.55 kg) was recorded from A_0 (No ascorbic acid).

Combination effect of saline water and ascorbic acid showed statistically significant variation for yield per pot (Appendix VII). The highest yield per pot (3.12 kg) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination which was close to control (3.05 kg) while the lowest yield per pot (1.96 kg) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 9).

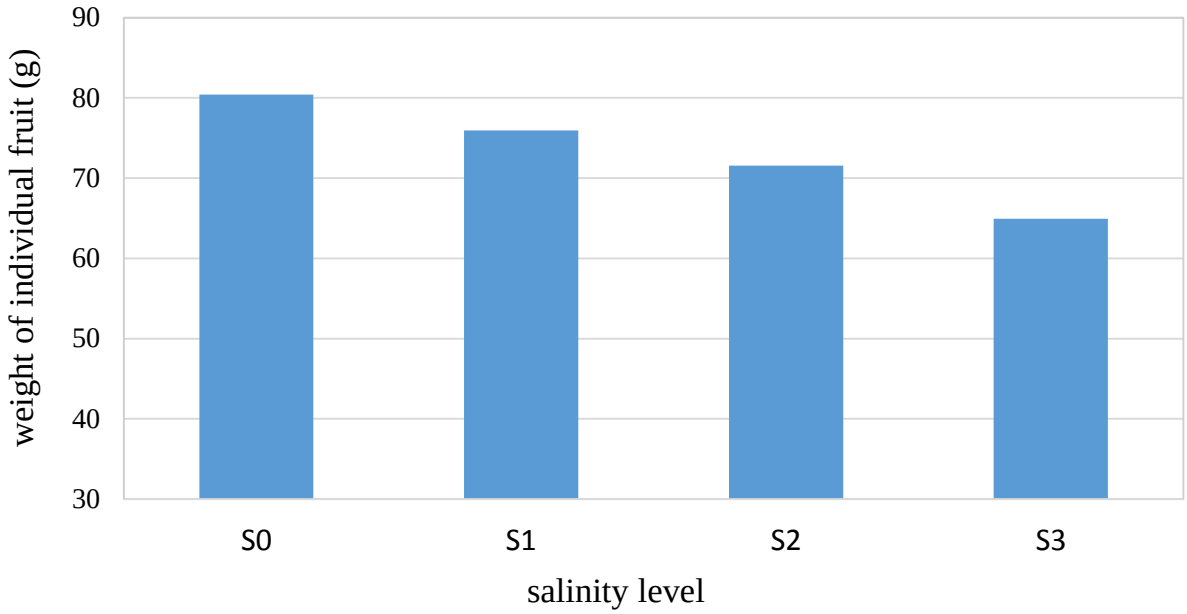

Figure 11. Effect of salinity on individual fruit weight

S_0 = o ds/m S_1 = 6 ds/m S_2 = 8 ds/m S_3 = 10 ds/m

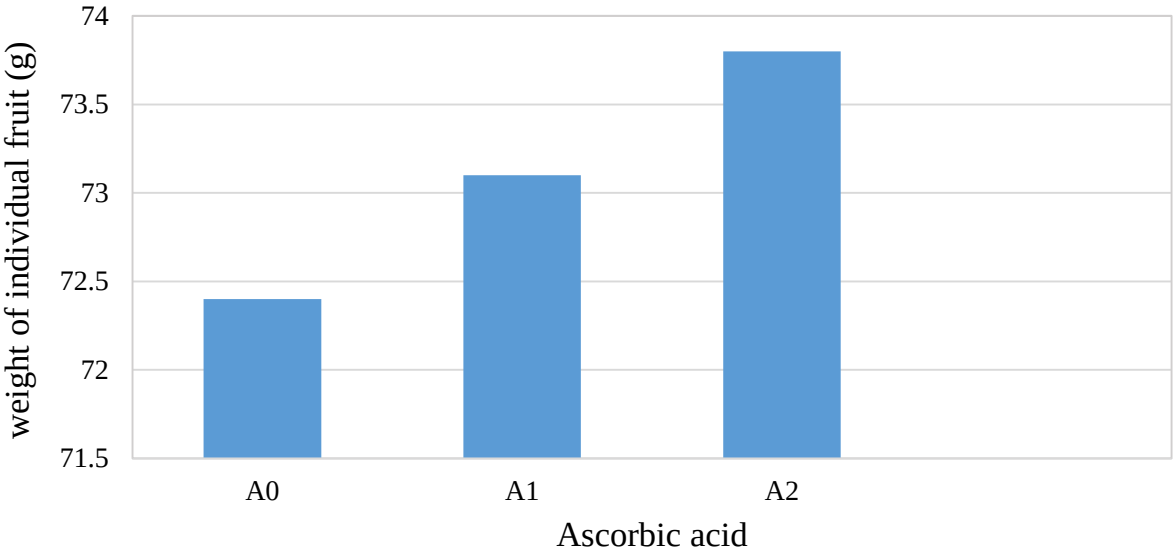

Figure 12. Effect of Ascorbic acid on individual fruit weight

A_0 = o ds/m A_1 = 6 ds/m A_2 = 8 ds/m

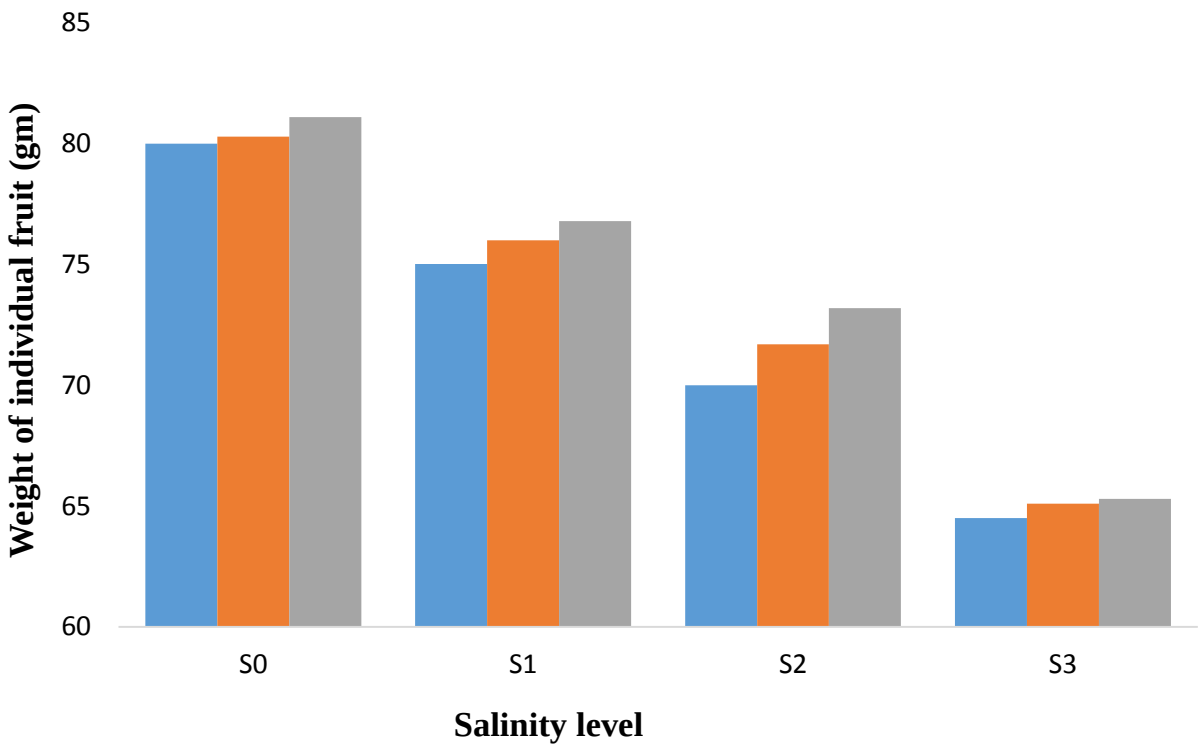

Figure 13. Combined effect of salinity and ascorbic acid on individual fruit weight

S_0 = 0 ds/m S_1 = 6 ds/m S_2 = 8 ds/m S_3 = 10 ds/m

A_0 = 0 mM A_1 = 0.5 mM A_2 = 1 mM

4.16. Yield per hectare

Yield per hectare in tomato showed statistically significant variation due to different level of saline water (Figure Appendix VII). The highest yield per hectare (92.5 t) was recorded from S_0 (No saline) treatment which was statistically similar with S_1 (87.2 t) and closely followed by S_2 (76.0 t), while the lowest yield per hectare (63.6 t) was recorded from S_3 (10 dS/m salinity) treatment (Table 8).

A statistically significant difference was recorded due to different levels of ascorbic acid for yield per hectare (Appendix VII). The highest yield per hectare (83.4 t) was recorded from A_2 (1mM AA) treatment which was closely followed by A_1 (79.5 t) (Table 8), while the lowest yield per pot (76.5 t) was recorded from A_0 (No ascorbic acid) treatment.

Combined effect of saline water and ascorbic acid showed statistically significant variation for yield per pot (Appendix VII). The highest yield per hectare (93.6 t) was recorded from S_0A_2 (No saline + 1 Mm AA) treatment combination which was close to control (91.5 t) while the lowest yield per pot (58.8 t) was recorded from S_3A_0 (10 dS/m salinity + no AA) treatment combination (Table 9).

Chapter V

SUMMARY AND CONCLUSION

The present piece of work was done at the experimental shed of the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2013 to April, 2014 to find out mitigation the of salt stress by exogenous application of Ascorbic acid on tomato. Seedling of 30 days of BARI Tomato-14 were used as test crop. The experiment consist of two factors: factor A: Salinity concentrations (four levels) as S_0: 0 dS/m, S_2: 6 dS/m, S_3 : 8 dS/m and S_4 :10 dS/m; Factor B: Ascorbic acid (three levels) as A_0 : 0 mM , A_1 :0.5 mM and A_2 :1 mM ascorbic acid concentration. The experiment was laid out in a Randomized Completely Block Design (RCBD) with three replications. There were 36 pots all together replication with the given factors. Empty earthen pots with 18 inch depth were used for the experiment. There were 12 treatment combinations.

At 20, 40, 60 and 80 DAT the tallest plant (26.2 cm, 69.6 cm, 88.8 cm and 96.8 cm) was recorded from S_0 , whereas the shortest plant (16.6 cm, 61.2 cm, 75.0 cm and 81.7 cm) from S_3. At 20, 40, 60 and 80 DAT the maximum number of branches per plant (4.00, 8.66, 19.4 and 24.3) was recorded from S_0, and the minimum number of branches per plant (2.77, 6.33, 15.3 and 17.5) from S_3. At 20, 40, 60 and 80 DAT the maximum number of leaves per plant (7.89, 17.0, 33.2 and 34.6) was recorded from S_0, and the minimum number of leaves per plant (5.22, 13.8, 22.2 and 23.7) from S_3. The maximum days from transplanting to 1st flowering (43.3) was recorded from S_3 and minimum days (39.7) from S_0. The highest number of flower cluster per plant (8.6) was found from S_0 and lowest number (7.15) from S_3. The highest number of flower per cluster (7.11) was found from S_0 and lowest number (5.44) from S_3. The highest number of flower per plant (53.5) was found from S_0 and lowest number (34.8) from S_3. The maximum number of fruits per cluster (5.00) was recorded from S_0, and the minimum number of fruits per cluster (3.33) from S_3. The maximum number of fruit per plant (44.0) was found from S_0 and minimum number

(30.9) from S_3. The highest length of fruit per plant (9.33 cm) was found from S_0 and lowest number (6.69 cm) from S_3. The highest diameter of fruit per plant (6.11cm) was found from S_0 again while lowest number (4.47cm) from S_3. The highest dry matter in fruit per plant (8.35%) was found from S_0 and lowest (6.95%) from S_3. The highest dry matter in plant (13.22%) was found from S_0 again while lowest (11.74%) from S_3. The highest weight of individual fruit per plant (80.4 g) was found from S_0 and lowest (54.9 g) from S_3. The highest yield per pot (3.08 kg) was found from S_0 and lowest (2.12 kg) from S_3. The highest yield per hectare (92.5 t) was computed from S_0 and lowest (63.6 t) from S_3.

At 20, 40, 60 and 80 DAT the tallest plant (25.6 cm, 70.2 cm, 87. 2 cm and 93.7 cm) was recorded from A_2, whereas the shortest plant (17.5 cm, 61.0 cm, 76.5 cm and 85.4 cm) from A_0. At 20, 40, 60 and 80 DAT the maximum number of branches per plant (3.91, 8.08, 17.5 and 22.0) was recorded from A_2, and the minimum number of branches per plant (2.83, 7.33, 16.8 and 20.5) from A_0. At 20, 40, 60 and 80 DAT the maximum number of leaves per plant (7.25, 16.5, 28.9 and 30.6) was recorded from A_2, and the minimum number of leaves per plant (5.74, 14.6, 27.1 and 29.3) respectively from A_0. The minimum days from transplanting to 1st flowering (39.7) was recorded from A_2 and maximum days (43.3) from A_0. The highest number of flower cluster per plant (8.02) was found from A_2 and lowest number (7.16) from A_0. The highest number of flower per cluster (6.83) was found from A_2 and lowest number (5.91) from A_0. The highest number of flower per plant (48.7) was found from A_2 and lowest number (35.2) from A_0. The maximum number of fruits per cluster (4.66) was recorded from A_2, and the minimum number of fruits per cluster (3.83) from A_0. The maximum number of fruit per plant (41.4) was found from A_2 and minimum number (30.2) from A_0. The highest length of fruit per plant (8.85 cm) was found from A_2 and lowest number (7.59 cm) from A_0. The highest diameter of fruit per plant (5.77 cm) was found from A_2 again while lowest number (4.77 cm) from A_0. The highest dry matter in fruit per plant (7.95%) was found

from A_2 and lowest (7.41%) from A_0. The highest dry matter in plant (12.9%) was found from A_2 again while lowest (12.1%) from A_0. The highest weight of individual fruit per plant (73.8 g) was found from A_2 and lowest (72.4 g) from A_0. The highest yield per pot (2.78 kg) was found from A_2 and lowest (2.55 kg) from A_0. The highest yield per hectare (83.4 t) was computed from S_0 and lowest (76.5 t) from S_3.

At 20, 40, 60 and 80 DAT the tallest plant (31.0 cm, 74.0 cm, 95.3 cm and 101.5 cm) was recorded from S_0A_2, whereas the shortest plant (13.3 cm, 56.0 cm, 69.0 cm and 77.3 cm) from S_3A_0. At 20, 40, 60 and 80 DAT the maximum number of branches per plant (4.67, 9.00, 20.0 and 25.0) was recorded from S_0A_2, and the minimum number of branches per plant (2.33, 6.00, 15.0 and 16.3) from S_3A_0. At 20, 40, 60 and 80 DAT the maximum number of leaves per plant (8.67, 18.0, 34.3 and 35.3) was recorded from S_0A_2, and the minimum number of leaves per plant (4.33, 12.3, 21.0 and 23.0) from S_3A_0. The maximum days from transplanting to 1st flowering (45.3) was recorded from S_3A_0 and minimum days (38.3) from S_0A_2. The highest number of flower cluster per plant (8.80) was found from S_0A_2 and lowest number (6.50) from S_3A_0. The highest number of flower per cluster (8.00) was found from S_0A_2 and lowest number (5.00) from S_3A_0. The highest number of flower per plant (62.6) was found from S_0A_2 and lowest number (32.0) from S_3A_0. The maximum number of fruits per cluster (5.33) was recorded from S_0A_2, and the minimum number of fruits per cluster (3.00) from S_3A_0. The maximum number of fruit per plant (42.7) was found from S_0A_2 and minimum number (30.5) from S_3A_0. The highest length of fruit per plant (10.0 cm) was found from S_0A_2 and lowest number (6.10 cm) from S_3A_0. The highest diameter of fruit per plant (6.70 cm) was found from S_0A_2 again while lowest number (4.07 cm) from S_3A_0. The highest dry matter in fruit per plant (8.57%) was found from S_0A_2 and lowest (6.67%) from S_3A_0. The highest dry matter in plant (13.5%) was found from S_0A_2 again while lowest (11.3%) from S_3A_0. The highest weight of individual fruit per plant (81.1 g)

was found from S_0A_2 and lowest (64.5 g) from S_3A_0. The highest yield per plant (3.12 kg) was found from S_0A_2 which was close to control (3.05 kg) and lowest (1.96 kg) from S_3A_0. The highest yield per hectare (93.6 t) was computed from S_0A_2 treatment combination which was close to control (91.5 t) and lowest (58.8 t) from S_3A_0.

Above findings revealed that 1 mM ascorbic acid was more suitable in consideration of yield contributing characters and yield of tomato plant and also mitigate salt stress condition in some extent.

REFERENCES

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

Ahmet, T., Vedat, S., and Hayrettin, K. (2009). Genotypic variation in the response of tomato to Salinity. *African J. of Biot.* Vol**. 8** (6) pp. 1062-1068.

Alian, A., Altman, A. and Heuer, b. (2000). Genotypic differences in salinity and water stress tolerance of fresh market tomato cultivars. *Plant Science*. **152:** 59-65

Alquada, A. M., Samarah, N. H., Mullen, R. E. (2011). Drought stress effect on crop pollination seed set, yield and quality. *E. Lichtfouse*, In: alternative farming system biotechnology, drought stress and ecological fertilization, sustainable agriculture review **6.**

Ampudia, G., Darwish, M. M., Gandullo, E. (2013). Halotropism is a response of plant roots to avoid a saline environment. Current Biol., **23**(20): 2044-2050.

Annonymous. 1989. Annual report 1987-88. Bangladesh Agricultural Research Council. P**.**45.

Bahar, G. O. and Tuzel, Y. (2011). Comparative salinity responses among tomato genotype and rootstock. *Pak. J. Bot*. **43**(6): 2665-2672.

BARI. (2005). Krishi Projukti Hatboi, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. P. 30.

Batool, E. Zahoor, A. S., Aftab, F. (2012). Effect of exogenous application of ascorbic acid on antioxidant enzyme activities, proline contents, and growth parameters of *Saccharum spp.* hybrid cv. HSF-240 under salt stress. *Turk J Biol*. **36 :** 630-640.

Beltagi, M. S. (2008). Exogenous ascorbic acid (vitamin C) induced anabolic changes for salt tolerance in chick pea (*Cicer arietinum L*.) plants. *Afr J Plant Sci.* **2:** 118-123.

Boamah, P. O., Sam-Amoah, L. K. and Onumah, J. (2011). Effect of salinity level of irrigation water on the yield of tomato. *J. Agril. Bio. Sci*. Vol. **6**, No. 8.

Bose, T. K. and Some, M.G. (1990).Vegetable crops in India. Naya prokash, Calcutta-six, India. p. 687-691.

Bradhury, M. and Ahmad, R. (1990). The effect of silicon on growth of *prosopis Julilfora* growing in saline soil. *Plant soil*. **125 :** 71-78.

El-Shabrawi, H., Kumar, B., Kaul, T., Reddy, M. K., Singla-Pareek, S. L., Ghosh, N., Adak, M. K., Ghosh, P. D., Gupta, S., Sen Gupta, D. N. and Mandal, C. (2011). Differential responses of two rice varieties to Salt stress. *Plant Biotechnol*. Rep. **5** (1): 89-103.

Einset, J., Nielsen, E., connoly, E.L., (2007). Membrane-trafficking RabA4c involved in the effect of the glycine betain on recovery of the chilling stress in Arabidopsis. *Physiologia plantarum*. **130**: 511-518.

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

Foyer, C. and Noctor, G. (2000). Oxygen processing in photosynthesis: regulation and signaling. *New Phytol*. **146** (3): 359-388.

Hasanuzzaman, M., Hossain, M. A., da Silva, J. A. T. and Fujita, M. (2012). Plant responses and tolerance to abiotic oxidative stress: antioxidant defenses is a key factors. *Springer, Berlin.* pp. **261–316**.

Hamed, Nemati, H., Farsi, M. and Jartoodeh, S.V., (2011). How salinity affect germination and emergence of tomato lines. *J. BIOL. ENVIRON. SCI*., **5** (15), 159-163.

Hamada, A. M., Al-Hakimi, A. M. (2009). Exogenous ascorbic acid or thiamine increases the resistance of sunflower and maize plants to salt stress. *Acta Agron Hung.* **57**:335–347.

Jamal, A. F. M., Shimul, M. A. H., Shin- ichi, Sadia, S. and Roni, M. Z. K. (2014). Response of tomato *(Lycopersicon esculentum*) to salinity on hydroponic study. *Bangladesh research publication journal*. Volume: 10, Issue**: 3**, P**:** 249-254.

Jogendra, S. E. V., Sastry, D. & Singh, V. (2012). Effect of salinity on tomato (*Lycopersicon esculentum Mill*.) during seed germination stage. *Physiol Mol Biol Plants*. **18** (1):45–50.

Kisthitani, S., Watanabe, K., Yasuda, S. (1994). Accumulation of glycinebetanine during cold acclimation and freezing tolerance in leaves of winter and spring barley. Plant cell Env., **17**:89-95.

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

Lila, A., Akbar, A. (2006). The effects of ascorbic acid on salt induced alfalfa (*Medicago sativa L.)* in in vitro culture. *Nigerian Society for Experimental Biology*. **18** (2):63-69.

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

Liang, Y. C., Shen, Q. R. and Ma, T. S. (1996). Effect of silicon on salinity tolerance of two Barley cultivars. *J plant nutr*. **19**: 173-183.

Luo, H., Wu, H. J., Xic, Y. L. and Gao, X. W. (2013). Effect of *Bacillus megaterium* CJLC2 on growth and salt tolerance related physiological and biochemical

characters of tomato under salt stress. *Acta phytophyl acica Sinica*. **40**(5): 431-436.

Mahajan, S. and Tuteja, N. (2005). Cold, salinity and drought stresses: An overview. *Arch. Biochem. Biophys*. **444** (2):139-158.

Mirajhi, Y. (1981). Effect of salinity on tomato fruit ripening. *Plant Physio*l. **69**: 966-97.

Mittler, R. (2002). Oxidative stress, antioxidants and stress tolerance. *Trends Plant Sci.***7** (9): 405-410.

Mondal, M. K., Bhuiyan, S. I., and Franco, D.T. (2001). Soil salinity reduction and production of salt dynamics in the coastal rice lands of Bangladesh. *Agric. Water Manage*. **47** (1): 9-23.

Munns, R. (2002 a). Comparative physiology of salt and water stress. *Plant Cell Environ*. **25** (2): 239-250.

Munns, R. (2002 b). Salinity, growth and phytohormones. In: Läuchli, A. and Lüttge, U. (eds) Salinity: Environment-Plants-Molecules. *Kluwer Academic, the Netherlands*. pp**.** 271-290.

Nahed, G., Mazhar,A. M. and El-habba, E. (2006). Effect of foliar spraying of ascorbic acid on growth and chemical constituents of *Lycopersicon esculentum* grown under salt condition. *J. agric. & Environ. Sci*. **1**(3): 207-214.

Noctor, G. and Foyer, C. H. (1998). Ascorbate and glutathione: keeping active oxygen under control. Ann. Rev. *Plant Physiol.* Plant Mol. Biol. **49**: 249-279.

Parida, A. K., Das, A. B. and Mohanty, P. (2004). Investigations on the antioxidative defense responses to NaCl stress in a mangrove, Bruguiera parviflora:

different regulations of isoforms of some antioxidative enzymes. *Plant Growth Regul*. **42**(3): 213-226.

Pérez-López, U., Robredo, A., Lacuesta, M., Sgherri, C., Muňoz-Rueda, A., Navari-Izzo, F. and Mena-Petite, A. (2010). The oxidative stress caused by salinity in two barley cultivars is mitigated by elevated CO2. Physiol. Plant. **135** (1): 29-42.

Sulunkhi, F.C., Marui, K. and Nakano, Y. (1987). Origin of the genus *Lycopersicon.* Workshop papers agricultural Economics and social sciences Programme. BARC. Dhaka. No. 1. p. 4.

Shameem, R., Shokat, S., Azhar, F.M., and Khan, A.A., (2009). Screening of tomato *(Solanum lycopersicum L.)* genotypes at different salinity levels. *J. of Plant Breeding and Crop Science* Vol. **4**(6), pp. 94-100.

Shalata, A. and Neumann, P. M. (2001). Exogenous ascorbic acid Increases resistance to salt stress reduces lipid peroxidation. *Journal of Experimental Botany.* **52:** 2207-211**.**

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

Singh J., E. V. D. Sastry and V. Singh. (2012). Effect of salinity on tomato (*Lycopersicon esculentum* Mill.) during seed germination stage. *Physiol Mol Biol Plants*., **18** (1):45–50.

Sonneveld, C. and Van der Burg, A. M. M. 1991. Sodium chloride salinity in fruit vegetable crops in soil less culture. *Netherlands J. Agri. Sci*., **39**: 115-122.

SRDI, (2001). Soil salinity in Bangladesh. Soil Resource Development Instiute, Ministry of Agriculture, Dhaka, Bangladesh.

Tanou, G., Job, C., Rajjou, L., Arc, E., Belghzi, M., Diamantidis, G., Molassiotis, A. and Job, D. (2009). Proteomics reveal the overlapping roles of hydrogen peroxide and nitric oxide in the acclimation of citrus plants to salinity. *Plant J*. **60** (5): 795-804.

Tavakkoli, E., Rengasamy, P. and McDonald, G. K. (2010). High concentrations of Na+ and Cl– ions in soil solution have simultaneous detrimental effects on growth of faba bean under salinity stress. J. Exp. Bot. **61**(15): 4449–4459.

Türkan, I. and Demiral, T. (2009). Recent developments in understanding salinity tolerance. *Environ. Exp. Bot*. **67** (1): 2-9.

APPENDICES

Appendix I. Soil characteristics of experimental field

A. Morphological characteristics of experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Texture class	Silty-clay
pH	5.6
Organic matter (%)	0.78
Total N (%)	0.003
Available P (ppm)	20.00
Exchangeable K (me/100g soil)	0.10
Available S (ppm)	45

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

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

Month	Air temperature (C°)		Relative Humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October,2013	26.5	19.4	81	22	6.9
November,2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	31.4	19.6	54	11	8.2
April, 2014	34.4	23.1	64	119	8.2

Appendix III. Analysis of variance (mean square) of the data for plant height of tomato at different days after transplanting as influenced by different level of salt stress and ascorbic acid

Source of variation	df	Plant height (cm) at different DAT			
		20	40	60	80
Salinity levels (A)	3	156.878**	118.929**	338.444**	409.960**
Ascorbic acid (B)	2	196.365**	257.410**	342.507**	208.318**
A x B	6	2.433**	1.729*	3.007*	2.641*
Error	24	0.667	0.699	1.156	1.049

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

Appendix IV. Analysis of variance (mean square) of the data for number of branches/plant of tomato at different days after transplanting as influenced by different level of salt stress and ascorbic acid

Source of variation	df	Number of branches/plant at different DAT			
		20	40	60	80
Salinity levels (A)	3	2.549**	9.226**	28.607**	81.108**
Ascorbic acid (B)	2	3.538**	1.706**	1.671**	6.367**
A x B	6	0.047**	0.027*	0.025*	0.214*
Error	24	0.014	0.010	0.009	0.081

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

Appendix V. Analysis of variance (mean square) of the data for number of leaves/plant of tomato at different days after transplanting as influenced by different level of salt stress and ascorbic acid

Source of variation	df	Number of leaves/plant at different DAT			
		20	40	60	80
Salinity levels (A)	3	12.202**	14.959**	192.622**	205.196**
Ascorbic acid (B)	2	6.822**	11.201**	9.185**	5.441**
A x B	6	0.035*	0.824*	0.379*	0.036*
Error	24	0.013	0.296	0.150	0.014

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

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

Source of variation	df	Days after transplanting to 1st flowering	Flower cluster / plant	Number of flower/cluster	Number of flower/plant	Number of fruit/Cluster	Number of fruit/plant
Salinity levels (A)	3	20.694**	3.435**	4.841**	643.74**	4.367**	587.858**
Ascorbic acid (B)	2	37.194**	7.576**	2.697**	546.77**	2.109**	196.130**
A x B	6	1.194*	0.326**	0.288**	16.21**	0.037*	8.231**
Error	24	0.476	0.049	0.074	2.72	0.015	1.246

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

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

Source of variation	df	Length of fruit (cm)	Diameter of fruit (cm)	Dry matter content in fruit (%)	Dry matter content in plant (%)	Weight of individual fruit (g)	Yield/pot (kg)	Yield (t/ha)
Salinity levels (A)	3	12.103**	4.624**	3.731**	4.037**	284.25**	3.764**	338.444**
Ascorbic acid (B)	2	4.803**	2.993**	0.860**	1.763**	154.28**	1.533**	342.507**
A x B	6	0.011**	0.089*	0.017*	0.045**	14.23*	0.093**	3.007*
Error	24	0.003	0.035	0.006	0.013	5.10	0.021	1.156

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