EFFECT OF SALICYLIC ACID TO MITIGATE SALT STRESS IN CHILLI

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JUNE, 2017

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BY

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Reg. No.: 11-04572

A Thesis

Submitted to the Department of Horticulture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements for the degree
of

MASTER OF SCIENCE (MS)

IN

HORTICULTURE

SEMESTER: JANUARY-JUNE, 2017

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CERTIFICATE

This is to certify that the thesis entitled, ***"EFFECT OF SALICYLIC ACID TO MITIGATE SALT STRESS IN CHILLI,"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE,*** *embodies the result of a piece of bona fide research work carried out by* ***MANIR HOSSAN*** *Registration No****. 11-04572*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2017
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ACKNOWLEDGEMENTS

All praise, gratitude and thanks are due to the omniscient, Omnipresent and omnipotent Allah Who kindly enabled the author to complete this research work successfully and submit the thesis for the degree of Master of Science (MS) in Horticulture.

The author express his deepest sense of gratitude, sincere appreciation and immense indebtness to his supervisor ***Professor Dr. Md. Ismail Hossain****, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his guidance, constructive criticism and valuable suggestion in successful completion of the research work and preparation of this thesis.*

Profound gratitude is expressed to his honorable co-supervisor ***Assistant Professor Khursheda Parvin*** *for the scholastic guidance and constant inspiration throughout the research work and preparation of this thesis.*

The author is highly grateful to Professor Dr. Mohammad Humayun Kabir chairman, Departmert of Horticulture SAU, Dhaka. The author also express his heartfelt thanks to all the teachers of the Departmert of Horticulture SAU, for their help, valuable suggestions and encouragement during the period of the study..

The author wishes to acknowledge his heartfelt indebthness and profound respect to his father ***Md. Abul Kalam*** *and mother* ***Mrs. Halana Khaton*** *for their sacrifice, blessings, patierce and encouragement and continuous prays for his success. The author express his sincere appreciation to his brother, sisters, relatives, well-wishers and friends for their inspiration help and encouragement all time.*

The author

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ABSTRACT

A pot experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to April 2017. The two factors experiment was laid out in Completely Randomized Design with four replications. Factor A was different levels of salinity induced by sodium (Na+) viz. S_0: 0 ds/m, S_1:4 ds/m, S_2:8 d/sm, S_3:12 ds/m, S_4:16 ds/m and factor B was different concentration of Salicylic Acid viz. A_0: 0 mM, A_1: 0.5 mM, A_2: 1 mM. The experimental results showed that different levels of salinity significantly affects the morphological characters, yield contributing characters and yield of chilli plants. The higher levels of salinity showed greater reduction of growth, development and yield component to control. The highest plant height, branch number/plant, leaf chlorophyll content as measured in SPAD value, leaf area, canopy size, fruit length and breadth/plant, number of flower and fruit/plant and yield (59.25 g) were observed in control and the lowest (8.25 g) was observed at highest salinity level (16 ds/m) condition. In case of salicylic acid, the highest yield (55.90 g) was found in A_2 and lowest (54.05 g) from A_0. For treatment combination, the maximum yield/plant (5.45 g) were produced from S_0A_2 whereas the lowest value from S_4A_0. Finally, this result suggests that application of salicylic acid can effectively reduce the deleterious effect of salt stress in chilli.

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LIST OF ACRONYMS

ABBREVIATIONS		ELABORATIONS
ANOVA	:	Analysis of Variance
ABA	:	Abscisic acid
AEZ	:	Agro- Ecological Zone
Anon	:	Anonymous
ROS	:	Reactive Oxygen Species
ASC	:	Ascorbic acid
BARI	:	Bangladesh Agricultural Research Institute
Agric.	:	Agriculture
BBS	:	Bangladesh Bureau of Statistics
BINA	:	Bangladesh Institute of Nuclear Agriculture
CV	:	Coefficient of Variance
cv.	:	Cultivar(s)
DF	:	Degree of Freedom
SA	:	Salicylic acid
EC	:	Electrical conductivity
et al.	:	And others
CRD	:	Completely Randomized Design
S	:	Salinity
GA	:	Gibberellins
Res.	:	Research
J.	:	Journal
LSD	:	Least Significance difference

CHAPTER I

INTRODUCTION

Chilli (*Capsicum* sp.) is an important spice in Bangladesh that belongs to the solanaceae family. Chilli is a native crop of central America and West Indies but extended fastly throughout the Tropical countries after the discovery of America and West Indies (Pruthi, 1993). Chilli is one of the important spices in many parts of the world. It is a favourite spice in Indian sub-continent. It is vitally a essential item in the kitchen for every day cooking. Chemical analysis of chilli have shown that red chilli fruit contains 15.9% protein, 31.6% carbohydrate, 50 mg/100g vitamin-C and small quantities of vitamin A, B and E with minerals like molybdenum, manganese, folate, potassium, thiamin. Chilli contains seven times more vitamin C than orange. Chillies have been included in ayurvedic medicines and used as tonic to remove many diseases.

Depending on yield and consumers preference a number of chilli genotypes are being cultivated throughout the country. Winter chilli contributes about 90 % of its total production (Anonymous, 1987). The actual area under chilli cultivation in Bangladesh is not available due to its seasonal nature of cultivation. The total cultivated area covered by chilli is about 352 thousands acres and total production of chilli is about 185 thousands M. Tons (BBS, 2015).

Different abiotic environmental stresses such as drought, high or low temperature, salinity, flooding, metal toxicity, etc., which pose serious threat to world agriculture. Salt stress is mainly one of the most serious environmental factors that limiting the productivity of crop plant (Ashraf, 1999). It is one of the major abiotic stresses, and approximately 800 million hectares of land are affected by high salt concentrations throughout the world (Munns, 2005). Both osmotic and ionic stresses can cause stunted growth and a reduced plant yield (Munns, 2002) and the irrigation with saline water is one of the principal factors that lead to salt accumulation and leads to a decrease in agriculture productivity.

Salinity is a threat to agriculture all over the world (Flowers and Colmer, 2008). High salt stress is an ever-existing and serious problem, generally degrading lands and resulting in low productivity in over 20 million ha in coastal and inland Asia. Coastal salinity, caused by seawater intrusion and shallow saline water tables, is severe during the dry season, while flooding in the monsoon season limits threat to agriculture all over the world. Salinity delays the onset, reduces the rate and increases the dispersion of germination events, resulting in reduced plant growth and final crop yield (Ashraf and Foolad, 2005). Chilli is a moderately sensitive to salt stress (Lee, 2006). Salinity imposes stress conditions on crop plants (Hajer *et al*., 2006) and affect growth and chemical contents and has been shown to limit chilli yield (Paridam and Das, 2005).

Salt stress severely inhibits plant growth for two reasons: first by an osmotic or water- deficit effect of salinity and second by a salt-specific or ion-excess effect of NaCl. Moreover, plants subject to salinity stress conditions produce cytotoxic activated oxygen that can seriously disrupt normal metabolism, through oxidative damage of lipids, proteins, and nucleic acids (Abbaspour, 2012). Several authors have shown that pepper is sensitive or moderately sensitive to salinity during different growth stages (Fernandez *et al*., 1977; Bethke and Drew, 1992; Gunes *et al*., 1996; Pascale *et al.*, 2003). One of the most effective ways to overcome salinity problems is the introduction of salt tolerant to crops or application of various growth regulator.

Salicylic acid (SA) is a phenolic compound which is considered as a PGR and plays an important role in defensive mechanisms against biotic and abiotic stresses in plants, flowering induction, plant growth and development, synthesis of ethylene, opening and closure of stomata and respiration are some of the important roles of SA in plants (Raskin, 1992).

SA protects plants from damages caused by oxidative stresses through increasing antioxidants enzymes activities (El-Tayeb; 2005 Idrees *et al.,* 2011). SA has received much attention due to its function in plants' responses to environmental stresses. Literature exists about some beneficial effects of SA on plants under drought (Jafari *et al*., 2009), low temperature, high temperature, salinity (El-Tayeb, 2005; Idrees *et al*., 2011), heavy metal and biotic stresses. Exogenous SA alters the activities of antioxidant enzymes and increases plant tolerance to abiotic stress by decreasing generation of ROS. It has been found that SA has different effects on stress adaptation and damage development of plants that depend on plant species, concentration, method and time of SA application (Metwally and Finkemeire Das, 2003).

Furthermore, SA is a potential non-enzymatic antioxidant and an important signal molecule for modifying plant responses to environmental stressors. Some earlier reports display that exogenous SA can ameliorate the impairing effects of drought stress in different species. SA has obtained particular attention because of inducing protective effects on plants under NaCl salinity. Bangladesh is an over populated country and to fullfil the current need of chilli for added population, the yield of chilli needs to be increased and saline prone area must be undertaken in chilli cultivation through proper use of mitigating the toxicity of salt.

Objectives:

i) To study the effect of salt stress on growth, yield contributing characters and yield of chilli;

ii) To alleviate the harmful effect of salinity stress through foliar application of salicylic acid

CHAPTER II

REVIEW OF LITERATURE

Salinity is a great problem in the coastal region of Bangladesh, where a vast area remains fallow for long time. Chilli is an important crop plant which supply Vitamin A, E C as well as used as a spice and condiment by the people of Bangladesh. It is a great source of vitamin C for poor people of the coastal area. The scientists of Bangladesh are conducting different experiments to adopt different crops in the saline area and chilli is one of theme. Very little research works have been conducted to adapt chilli crop in the saline area of Bangladesh. An attempt has been made to find out the performance of chilli at different levels of salinity as well as to find out the possible mitigation ways by using salicylic acid in the saline stressed chilli plants. The research findings related to the present investigation so far in country and abroad have been reviewed are presented below.

2.1 Literature on the effect of salinity

Marco *et al*. (2011) studied the effect of two sources of nitrogen on plant growth and fruit yield of chilli (*Capsicum annuum* L.) grown in greenhouse to increased salinity. An organic source extracted from grass clippings in rates of 120 and 200 kg N ha^{-1}, and another inorganic (ammonium nitrate) in rate of 120 kg ha^{-1} were combined with low, moderate and high (1.5, 4.5, and 6.5 dSm^{-1}) salinity levels arranged in a randomized complete block design replicated four times. They found that salinity treatments reduced dry matter production, leaf area, relative growth rate and net assimilation rate but increased leaf area ratio. Mean fresh fruit yields decreased for each N rate and source combinations as soil salinity increased. The organic fertilizer may be an effective N source for pepper and other vegetable crops grown under non- and salt-stressed conditions.

Abari *et al.* (2011) conducted an experiment for studying germination of pepper spp. under salt stress with different NaCl and KCl concentrations. Seeds of Bindu, Picnic, and Hotmaster after subjected to sulphuric acid and boiling water were grown on medium under eight salinity levels (0, 50, 100, 150, 200, 250 and 300 mM) in a complete randomized design under laboratory conditions. Germination of both species decreased by increasing salinity. Both pepper species showed higher tolerance to increased level of NaCl than to KCl.

Ghorbanpour *et al*. (2011) investigated the effect of salinity and drought stress on fenugreek germination indices. To create salinity stress, sodium chloride (NaCl) at the levels of 0 (as control), -3, -6 and -9 bar, and for drought stress, polyethylene glycol 6000 (PEG 6000) in osmotic levels at 0 (as control), -3, -6 and -9 bar were used. Result showed significant difference between evaluated indices. They found that increasing of stress levels led to reduction of germination and epicotyls and hypocotyls length. Also, both salinity and drought cause reduction in germination and growth indices, however, a few of the seeds conserved germination viability. Therefore, Fenugreeks have relative resistance to salinity and drought stress in germination stage.

Seeds of four spinach cultivars were used by Turhan *et al.* (2011) to investigate the effects of different NaCl concentrations on their germination percentage, germination index, relative germination rate and germination time. The results showed that different treatments of salinity had statistically considerable effects on the germination percentage, germination index, relative germination rate and germination time.

Salt tolerance of five cultivars of (*Capsicum annuum* L.) were evaluated by Niu *et al*. (2010). Seedlings were transplanted in late May to Field raised beds containing loamy sand soils in a semi-arid environment. Plants were well irrigated throughout the experiment. Three saline solution treatments, prepared by adding NaCl, $MgSO_4$, and $CaCl_2$ to tap water at different amounts to create three salinity levels of 0.82 dS m^{-1} (control, tap water), 2.5 dS m^{-1}, and 4.1 dSm^{-1} conductivity (EC), were initiated on 15th June and ended in late August. The most tolerant to salinity had the lowest leaf Na+ accumulation while the most sensitive to salinity had the highest Na+ in the leaves .

Unlukara (2010) studied the effects of irrigation water salinity on eggplant growth, yield, water consumption and mineral matter accumulation in leaves and fruits in greenhouse experiment. For this purpose, five saline irrigation water with electrical conductivities of 1.5, 2.5, 3.5, 5.0, 7.0 dSm^{-1} and tap water as a control treatment were used. Throughout the experiment, the amounts of irrigation water applied were determined based on the weight changes of each pot. After irrigation the amount of drainage water volume was measured in drain pans placed underneath of each pot. The fruit yield results revealed that eggplant was moderately sensitive to salinity. Plant water consumption and water use efficiency decreased with increasing salinity. The crop yield coefficient (Ky) was 2.3. Salinity caused a decrease in K content and increased Cl content of leaves. Although mineral concentration of the leaves did respond to increased mineral concentration of irrigation water, mineral concentration of fruits did not .

Effect of seven salinity levels on seed germination and seedling length, fresh and dry weights, carbohydrates contents and amylase activity of (*Solanum melongena*) eggplant was studied by Basalah (2010). Salinity progressively decreased the percentage of germination. The seedling length and the fresh and dry weights of root and shoot increased with increasing level of salinity up to 8.5 mM EC, indicating that eggplant tolerate, quite high level of salinity at seedling stage. The soluble and insoluble carbohydrates contents and amylase activity were also affected by salinity.

Bybordi (2010) conducted an experiment to study the salinity stress effects resulted from sodium chloride on germination, vegetative growth, elements concentration and proline accumulation in five canola cultivars. The results showed that different salinity stress levels had significant effect on germination percentage, germination speed, shoot and root length. In the pot experiment, there was a significant effect on plant height, leaf area, dry matter, elements concentration, proline accumulation and seed yield due to salinity stress

The response of six tomato cultivars (*Lycopersicon esculentum* Mill.) to salt stress was investigated by Azami *et al*. (2010) under in vitro conditions. Callus relative growth rate (RGR), dry matter percentage (DM), osmotic potential and proline content were evaluated. Significant differences were found among cultivars regarding above traits. It was concluded that the more the salt tolerant genotype the more is the reduction in osmotic potential and proline content.

A field experiment was conducted by Chauhan *et al.* (2007) for three years on a sandy loam soil at the experimental farm of college in Bichpuri, Agra to assess the salt tolerance of onion (*Allium cepa* L.) and garlic (*Allium sativum* L.) using different saline waters (EC 2-8 dS/m). In response to canal water the relative yields of onion averaged 97, 71, 55 and 33% with EC 2, 4, 6 and 8 dS/m respectively while the corresponding yields of garlic was 93, 85, 65 and 51%. The relative yields of onion improved to 99, 84, 68 and 56% when saline waters were applied after canal water irrigation at transplanting. The piece-wise linear response functions showed the threshold salinity (EC) to be 2.9, 3.4 and 2.6 dS/m) for a period of four weeks. The effects of NaCl priming on increasing salt tolerance in both onion cultivars were examined on the bases of total emergence rate, mean emergence time, tolerance ratio and tolerance index parameters. The total emergence rates decreased due to the increase in NaCl concentrations in both the onion cultivars. However, seedlings derived from primed seeds were more tolerant to salinity than those of the non-primed ones. 'TEG-502' was more tolerant to salinity than 'Valencia'. for onion and garlic irrigated with saline waters throughout and onion irrigated with saline waters after canal water irrigation at transplanting respectively while the percent decline in yield with each unit increase in salinity beyond EC were 12.7, 10.8 and 9.6, respectively.

A pot culture experiment was conducted during 1996-97 at Bapatla to evaluate the performance of six chilli genotypes viz., LCA 235, LCA 315, LCA 324, LCA 334, CA 960 and 64 at different levels of saline water viz., 0.66 (control), 2, 4, 6, and 8 dSm^{-1}. The plant growth characters like plant height, leaf area and dry matter production per plant were significantly reduced by 46.3, 33.7 and 58.7% respectively with increasing levels of salinity in irrigation water. Such declining trend was also observed in fruit characters like pod weight, pod volume and number of pods per plant. Among six varieties, LCA 235 was found to be more salt tolerant followed by 64, while LCA 334 was found to be sensitive under saline conditions Kameswari and Prasad (2005).

Selection and breeding approaches to increase tolerance are more efficient if selection is based on physiological and biochemical characters. Chilli cultivars CA-26, CA-66 and K-1 were tested under saline and sodic soils in Tamil Nadu, India for their tolerance. Crop growth rate (CGR) and relative growth rate (RGR) were reduced due to increasing salt stress. Among the three cultivars, CA-26 recorded the highest CGR and RGR at all stress conditions. CA-26 accumulated the maximum total chlorophyll under salt stress and recorded the maximum proline content under stress conditions. Similarly, the leaf protein content decreased with increased salinity and sodicity. CA-26 exhibited the minimum decrease in protein content under salt environment and registered the maximum yield under salinity and sodicity conducted by Balamohan and Kulasekaran (2002).

Nawaz *et al.* (2010) carried out a study of salt tolerance induction in two cultivars of sorghum by exogenous application of different levels (0, 50 mM and 100 mM) of proline. Salt treatments (100 mM) adversely affected the germination percentage, growth and chlorophyll contents of both cultivars. However, applications of proline alleviated the adverse effects of salt stress. However, high concentration of proline (100 mM) was not as much effective as compared to low concentration i.e. 50 mM in both cultivars.

The effects of NaCl concentrations on physiological behaviour of organs of five leguminous plants were evaluated by Taffouo *et al*. (2009) in Cameroon. Plants were subjected to 5 levels of salt stress at the roots (0, 50, 100, 150 and 200 mM of NaCl). Results showed that sodium chloride had an under rating effect on growth of stems and seed germination of the species studied. The germination rates of seeds of Glycine max and Phaseolus vulgaris (sensitive glycophytes) were affected from 3 g/l of NaCl, with critical thresholds at 9 and 12 g/l, respectively. In contrast, critical thresholds with Mucunapoggei (facultative halophyte), (*Vigna unguiculata*) (moderately tolerant glycophyte) and *(P. adenanthus*) (natural halophyte) was found to be above 21 g/l. The reduction of stems growth rate were not significant in (*P. adenanthus*) whereas in (*M. poggei*) and (*V. unguiculata*) this inhibition was observed just when nutritive solutions were enriched with 200 mM. The lipid contents were reduced in all the species under salt stress, whereas proteins and proline contents in the leaves were substantially increased in tolerant species. In contrast, proteins and leaf proline contents were negatively affected by salt concentrations. Seed germination, proteins and proline could be used as physiological criteria of early selection for salt tolerant leguminous plants.

Kaveh *et al.* (2011) carried out an experiment on the effect of high salt concentrations in soil and irrigation water which restricted 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 to improve production efficiency. In order to find any kind of tolerance to saline condition, effects of four salinity levels in irrigation water (0.5, 2.5, 5, and 10 dsm^{-1} on seed germination and seedling emergence, and growth of tomato lines LA3770, R205, CT6, Fla, and ME were investigated in a greenhouse. They found that germination percentage and rate, emergence percentage and rate of all tomato lines were delayed and decreased by salinity. All seedling growth characters, except seedling height were decreased with increasing salinity levels. At germination and emergence stage, LA 3770 were more tolerant to salinity than others.

A laboratory study was carried out by Mohammadi (2009) to investigate the effect of NaCl priming on seed germination and seedling growth of canola. Canola seeds were primed with 1% NaCl solution for 24 hours at 20°C. Then primed and non-primed seeds were irrigated with seven different saline solutions consisted of 0 (control), 0.25, 0.50, 0.75, 1.00, 1.25 and 1.50% concentrations of NaCl. Results indicated that NaCl priming increased germination percentage, germination rate and seedling dry weight as compared with non-primed seeds. Overall, increased NaCl level led to the reductions in the traits under study but reductions were higher for non-primed compared to primed seeds. At the 1.25% level of salinity, the reduction for germination percentage, germination rate and seedling dry weight were 36.30, 39.52 and 50% for primed and 69.47, 89.92 and 87.5% for non-primed seeds, respectively, as compared with control. However, at 1.50% level of salinity non-primed seeds failed to germinate, while, germination percentage was 45% for primed seeds. The study revealed that under salinity condition, seed priming with NaCl could be used as a method for improving seed performance in canola. However, further studies are needed to investigate the effects of NaCl priming on later growth and development stages of this crop.

Datta *et al.* (2009) studied the impact of salt stress under different salinity levels (0, 25, 50, 75, 100, 125, 150 mM NaCl) on five varieties of wheat. The data of their experiment showed that different level of salinity significantly affected the growth attributes by reducing root and shoot length, for salinity below 125mM, fresh weight and dry weight of root and shoot were reduced significantly with subsequent treatment of different salinity levels. Regarding biochemical analysis, the sugar, proline content increased with increasing salinity level where as protein content decreased in the physiologically active leaves of different treatments for all the varieties of wheat.

Houimli *et al*. (2008) investigated the inhibitory effect of salinity on pepper plants. A short-term experiment was conducted in greenhouse to test different concentrations of 24-epibrassinolide by foliar application on growth and development. They found that its effects were more pronounced on the shoot than root growth. An exogenous supply of 24-epibrassinolide was found to be successful in alleviating of the inhibitory effects of salt stress on shoot growth parameters and the leaf relative water contents.

An experiment was conducted by Yildirim and Guvenc (2006) to evaluate the effect of salinity on the germination and emergence of pepper cultivars and to investigate the potential for genetic salt tolerance during germination and seedling growth. Thus, seeds of 11 pepper cultivars were germinated using 0, 85, 170, and 215 mM NaCl solutions for 14 days. Germination percentage decreased with increased NaCl concentration. All cultivars germinated in all salinities with the exception of Kandil Dolma in 215 mM NaCl. The highest germination percentage at 215 mM of NaCl was 71% for 11-B-14. NaCl salinity at different concentrations adversely affected germination rates of the 11 pepper cultivars. The highest and the lowest germination rates at 215 mM NaCl were obtained for 11-B-14 cultivar (2.42) and Kandil Dolma (0.00), respectively. In the presence of salt stress, the greatest shoot height (3.40 cm) and root length (11.81 cm) were obtained with 11-B-14, while the greatest fresh weight (72.30 mg) and dry weight (6.75 mg) was obtained from Demre. Based on the results of the experiment, Demre,Il›ca 250, 11-B-14, Ba.c› Carliston, Mini Ac› Sivri, Yalova Carliston, and Ya.l›k 28 could be useful as genetic resources for the development of pepper cultivars with improved germination under salt stress.

Jamil *et al*. (2006) conducted an experiment where four vegetables species were treated with different concentrations of salt solution to study their response to salinity. Results indicated that salinity caused significant reduction in germination percentage, germination rate, root and shoot lengths and fresh root and shoot weights.

The effect of sea water salinity (1500, 2500 and 3500 ppm) on the growth of tomato (*Lycopersicon esculentum*) cultivars was studied by Hajer *et al.* (2006). They found that sea water salinity delayed seed germination and reduced germination percentage especially with increasing salinity level. Chlorophyll b content was higher than chlorophyll a, and both of them decreased with increasing salinity. The seedling height increased with time but decreased with increasing salinity in all cultivars. Seedlings fresh and dry shoot and root weights were decreased with increasing salinity. The growth of stem, leave and root after over 80 days of exposure to sea water salinity was affected by sea water dilution.

An experiment was carried out by Bano and Aziz (2003) on the effect of different concentrations (150 mM and 300 mM) of NaCl alone or combination with drought stress on chilli varieties. The plants were grown in pots under natural conditions with protective measures against rain. Drought was induced for 7d to salt stressed plants at three leaf stage by withholding the supply of salt/water (in case of control). The response of salt and drought were studied on growth parameters and yield of chilli. The proline contents of leaves and the concentration of abscisic acid and giberrelic acid were also measured at the three leaf stage. The increasing concentration of NaCl had a significant inhibitory effect on the growth parameters. It was found that the combined effect salt and drought was more inhibitory than salt alone.

Cuartero and Fernandez (1999) studied the effects of salinity on growth and fruit production of tomato to develop the cultural techniques which can be applied to alleviate the deleterious effects of salt and the possibilities of breeding salt tolerant tomatoes are reviewed. Salinity reduces tomato seed germination and lengthens the time needed for germination to such an extent that the establishment of a competitive crop by direct seeding would be difficult in soils where the electrical conductivity (EC) of a saturated extract was equal to or above 8 ds^{-1}.Seeds primed with 1 M NaCl For 36 h seems advisable to establish a crop by direct sowing in saline soils and seedling conditioning either by exposure to moderately saline water exposure or by withholding watering until seedlings wilt for 20±24 h can be recommended for crops that are to be established by transplanting. Yields are reduced when plants are grown with a nutrient solution of 2.5 ds^{-1} or higher and above 3.0 ds^{-1} an increase of 1 ds^{-1} results in a yield reduction of about 9±10%. They found that salinity reduces tomato seed germination and lengthens the time needed for germination to such an extent that the establishment of a competitive crop by direct seeding would be difficult in soils.

An experiment on the effect of salt tolerance of two greenhouse bell-pepper hybrids was studied during germination, seedling growth and vegetative growth in hydroponic culture was carried out by Chartzoulakis and Klapaki (2000). Salinity treatments were imposed by irrigating with half-strength Hoagland solution containing 0, 10, 25, 50, 100 and 150 mM/l of NaCl. Salinities up to 50 mM delayed germination but did not reduce the germination percentage. It was reduced significantly at 100 and 150 mM NaCl in both hybrids. Seedling growth was reduced significantly with salinities higher than 10 mM NaCl. Plant growth parameters such as plant height, total leaf area and dry weight were significantly (P.0.05) reduced at salinities higher than 25 mM NaCl in both hybrids. Roots had the highest Na concentration compared to leaves, which increased with increasing salinity, while Cl in leaves was much higher than Na. Potassium concentration of plant tissues was less affected than Na and Cl by salinity increase. Total fruit yield in both hybrids was significantly reduced at salinities higher than 10 mM NaCl, the reduction being 95% at 150 mM NaCl. Both, fruit number per plant and fruit weight were reduced by the salinity. They reported that salinities delayed germination but did not reduce the germination percentage. Seedling growth was reduced significantly with salinities. Plant growth parameters such as plant height, total leaf area and dry weight were significantly reduced at higher salinity levels in both hybrids.

Uddin *et al*. (2005) conducted an experiment to study salt tolerance of (*B. napus* and *B. campestris*) varieties under saline conditions (1.2-11.5 dSm^{-1}) and observed that siliqua number and seeds per siliqua decreased with increased salinity.

2.2 Literature on the Effect of Salicylic Acid

Benavides *et al.* (2002) . Salicylic acid (SA) is a stress signalling compound in plants. To verify if the exogenous application of SA and a sulfur derivative induces resistance to cold stress, six hours of treatment of pepper seeds with a water solution of SA and sulfo salicylic acid (SSA) at 0, 10-5, 10-4 and 10-3 M was conducted under controlled temperature chamber. After germination, the seeds were transferred to containers with peat moss and Douglas nutritive solution. After 22 days of transplanting, the seedlings were exposed to cold stress twice at 4 degrees C without light. There were four days between the first and second cold treatments. Seed treatment of SA at 10-4 M and SSA at 10-4 M was effective in inducing seedling resistance to cold stress, manifested as high leaf number, tall seedlings and high plant fresh and dry weight. On the other hand, SA and SSA at 10-3 M and 10-5 M showed a negative effect on seedling final fresh and dry weight. Stomatal index and stomatal density were negatively affected by SA and SSA 10-3 M. On the other hand, SA and SSA at 10-4 and 10-5 M increased the stomatal index and stomatal density in abaxial side, showing the opposite response in the adaxial side. Stomatal density in abaxial side showed a low but significant correlation with plant weight, leaf number and plant height.

The adverse effects of NaCl induced salt stress on growth attributes and endogenous levels of gibberellins (GA), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA) of soybean cv. Hwangkeumkong was investigated by Hamayun *et al.* (2010). Plant length, biomass, chlorophyll content, number of pods, 100 seed weight and yield significantly decreased in response to 70 mM and 140 mM concentrations of NaCl. Under salt stress, the endogenous GA and free SA content decreased, while a significant increase in the endogenous ABA and JA contents were observed. The results showed that salinity stress drastically reduce growth and yield components of soybean by affecting endogenous growth hormones.

Khan *et al.* (2009) conducted an experiment on the effect of seed priming with salicylic acid (SA) and acetylsalicylic acid (ASA) in improving seed vigour and salt tolerance of hot pepper. They found that hormonal priming, especially with acetylsalicylic acid, can be a good treatment for hot pepper to enhance uniformity of emergence and seedling establishment under normal as well as saline conditions.

In this experiment the effects of salicylic acid (SA) on resistance of pepper plants under salt stress (SS) and alkali stress (AS) were evaluated. Treatments include 0 and 150 mM of SS, 0, 50 and100 mM of AS and 0, 0.75 and 1.5 mM SA. Results showed that SS and AS imposed negative effects on pepper plant growth and productivity. Reduction in growth and yield in SS was higher than AS and maximum reduction occurred in high mixed stresses. SA application improved growth parameters and increased yield, relative water content (RWC) and chlorophyll of plants subjected to SS and AS and provided significant protection against stress compared to non-SA-treated plants. For most traits, 0.75 mM of SA was more effective than1.5 mM concentration. SA ameliorated the injury caused by SS and AS by increasing chlorophyll and RWC and inhibiting proline accumulation and leaf electrolyte leakage (EL). In general, results indicate that salinity and alkalinity have negative effects on growth and yield of pepper plants and these negative effects can be ameliorated by application of SA and conducted by Amirinejad *et al.* (2017).

Mahdavian *et al* (2008) Pepper (*Capsicum annuum* L.) plants were sprayed with salicylic acid (SA) and treated with ultraviolet radiation UV-A(320-390 nm), UV-B (312 nm), and UV-C (254 nm) of 6.1, 5.8, and 5.7 W m-2, respectively. UV significantly reduced contents of chlorophyll (Chl) a and b, and carotenoids (Car). SA treatment moderated Chl and Car reduction in plants treated with UV-B and UV-C. The quantity of antocyanins, flavonoids, rutin, and UV-absorbing compounds in plants that were treated with UV-B, UV-C, and SA were significantly increased. Foliar spray of SA counteracted the UV effects on pepper.

Fatma Abd and El-Lateef Gharib (2006). The response of sweet basil (*Ocimum basilicum* L.) and marjoram (*Majorana hortensis*) plants to foliar application of salicylic acid (SA) at 10–5, 10–4 and 10–3 M was determined in pot experiments conducted during 2004 - 2005. SA increased plant height, number of (branches, nodes & leaves) per plant, leaf area, fresh and dry weight of herbs, total carbohydrates, crude protein, total amino acids, free proline, photosynthetic pigments as well as microelement content and uptake up to 10–4 M relative to un-treated controls and decreased thereafter in both basil and marjoram. All SA treatments enhanced putrescine, spermidine as well as total polyamines contents, while reduced the level of spermine in both plants. Oil percentage and yield per plant for three cuttings also increased about two fold on a fresh weight basis with SA application at 10–4 M in case of basil land 10–3 M in marjoram relative to un-treated controls. GC/MS revealed that common components o (*Ocimum basilicum*) essential oil under all treatments were linalool (46.63 - 43.32%), methyl eugenol (13.83 - 5.68%), 1, 8 - cineol (13.20 -4.43%), eugenol (12.64-7.16%) and α-cadinol (9.59 - 4.46%). SA at 10–4 M increased the production of top quantity and quality of basil oil to the fragrance and food industries by increasing the percentage of eugenol and antioxidant activity in the herb. On the other hand, the marjoram essential oil contains cis-sabinene hydrate(37.50 - 14.27%), terpinen- 4-ol (24.33 -

13.99%), p-cymene (18.21 - 2.29%), sabinene (17.69 - 4.11%), γ-terpinene (10.64 - 4.77) in addition to α-terpineol (5.52 -3.96%), trans-sabinene hydrate (5.45 - 8.19%), α-terpinene (2.41 - 0.00%) and β-caryophyllene (3.82 - 1.76%). Moreover, SA at 10–5 M and 10–3 M improved oil quality by increasing the level of sabinene accompanied by a decrease in the proportion of cis-sabinene hydrate relative to controls. The data suggest that in both species, SA treatment especially at 10–4 M may have higher adaptive capacity to stress, originating from promoting polyamines synthesis and better osmotic adjustment.

Mohsen Kazemi (2014). This experiment was conducted to study the effect of salicylic acid and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. These factors included salicylic acid in 2 levels (0.5 and 0.75 $mmolL^{-1}$) and methyl jasmonate in 3levels (0.25, 0.5 and 0.75 $mmolL^{-1}$) applied on tomato. Results indicated that salicylic acid (0.5 $mmolL^{-1}$) and methyl jasmonate (0.25 $mmolL^{-1}$) either alone or in combination (0.5 $mmolL^{-1}$+ 0.25$mmolL^{-1}$) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 $mmolL^{-1}$) alone significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom end rot, but methyl jasmonate application alone or in combination had not significant effect on blossom end rot and leaves -NK content. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid and methyl jasmonate either alone or in combination(0.5 $mmolL^{-1}$SA+ 0.25$mmolL^{-1}$MJ). Application of salicylic acid with methyl jasmonate improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Mohsen Ali (2014).This study aimed at studying the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits. The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, while reduced blossom end rot. On the contrary, MJ (1 mM) application significantly decreased vegetative growth while increasing reproductive growth. The application of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content. In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato.

Rajkumar *et al.* (2008). Fluorescent pseudomonads (SE 21 and RD 41) and resistance inducers (chitin and salicylic acid) were examined for plant growth promotion and biological control of damping off of pepper caused by(*Rhizoctonia solani*). The antagonists SE21 and RD41 isolated from the rhizosphere of pepper were found to be effective in inhibiting the mycelial growth of (*Rhizoctonia solani*) in a dual culture assay and increasing the seedling vigour in a roll towel assay. Both antagonists were further characterized for biocontrol and plant growth promoting features. The addition of inducers (chitin alone) increased the antagonist's population in the culture medium. In a further study, seed treatment with antagonists showed an increase in plant growth and controlled the damping off under in vivo conditions. Amendment with inducers alone showed a moderate degree of plant protection against(*Rhizoctonia. solani*). However, there duction in disease was more pronounced when inducers were applied with antagonists. Amendment with chitin alone enhanced biocontrol efficiency of both SE 21 and RD 41. However, amendment with SA alone or in conjunction with chitin showed a moderate effect on biocontrol efficiency of the antagonists. These results show that the biocontrol efficiency of antagonists SE 21 and RD 41 may be stimulated by chitin resulting in a significant increase in their population density and antagonistic effect against(*Rhizoctonia solani*)

Coronado *et al.* (1998) a reported a significant increase in biomass of shoots and roots of soybean by SA application.

Foliar application of SA also increased stomatal conductance or resistance and reduced the transpiration in pepper seedlings Eris (1983).

The role of SA in defence mechanism shows promise in alleviating the adverse effects of salt stress on plants by Hamada and Al-Hakimi, (2001) and Gunes *et al*. (2007) .

Tari *et al*. (2002) observed that tomato plants tolerated 100 mM NaCl at low levels of SA concentration (10-7 to 10-4 M range) by a substantial increase in photosynthetic rate, transpiration rate and stomatal conductance.

The application of 2000 mg L^{-1} SA resulted in the highest fruit yield of mango (48.7 kg $tree^{-1}$), photosynthetic rate (8.2 μmol $m^{-2}s^{-1}$) and stomatal resistance (0.456 s cm^{-1}), with concurrent reduction in malformed panicles by 30% (Singh *et al.*, 2001).

Sibgha *et al*. (2008) conducted an experiment to assess whether exogenously applied SA as a foliar spray could ameliorate the adverse effects of salt stress on sunflower plants. Two lines of sunflower (Hisun-33 and SF-187) were grown under normal or saline (120 mM NaCl) conditions. Different levels of salicylic acid (0, 100, 200, 300 mg L^{-1}) were applied as a foliar spray. Salt stress reduced the growth of both lines, but both cultivars were equally responsive to the stress and application of 200 mg L^{-1} of SA caused an increase in biomass and photosynthetic rate of both cultivars under control and saline conditions, particularly in line SF-187.

An experiment was conducted by Mohsina *et al.* (2008) to study the effect of salicylic acid seed priming on growth and some biochemical attributes in wheat (*Triticum aestivum* L.) grown under saline conditions. Wheat seeds of cv. Inqlab and S-24 were soaked in water and 100 mg /L salicylic acid solution for 24 hours and sown in sand salinized with 0, 50 or 100 mM NaCl. Salt stress significantly reduced all growth parameters (shoot and root length, and shoot and root dry weights) and salicylic acid treatment alleviated the adverse effect of salinity on growth. Salinity decreased the chlorophyll a and b content and chlorophyll a/b ratio in both the lines, but reduction in chlorophyll a/b ratio was lower in salt tolerant wheat line S-24, which could be a useful marker for selection of salt tolerant wheat.

Salicylic acid was reported to induce salinity tolerance and increased biomass of Torreya grandis as a result of enhanced chlorophyll content and the activity of antioxidant enzymes that eventually activated the photosynthetic process and alleviated oxidative stress (Li *et al*., 2014).

Ali *et al*. (2007) have reported an increase in anti-oxidative potential in Panaxginsenge roots by the application of 200 μM SA.

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

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in the experiment. It includes short description of location of the experimental plot, characteristic of soil, climate, materials of the experiment, raising of seedlings, treatments, layout and design pot preparation, manuring and fertilizing, transplanting, intercultural operations, harvesting, collection of data and statistical analysis which are given below.

3.1 Location

The research work was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2016 to April, 2017. The location of the site was 23°71′ N Latitude and 90°33′ E Longitude with the elevation of 8.2 meter from the sea level (Anon, 1989).

3.2 Soil

The experimental plot belongs to the Modhupur Tract which was under the Agro Ecological Zone-28. The analytical data of the soil, collected from the experimental area were determined in SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and presented in Appendix II.

3.3 Climate

The experimental site is situated in subtropical zone, the macro climate is characterized by heavy rainfall during the months from April to September (Kharif season) and scantly rainfall during the rest month of the year (Rabi season). Information regarding average monthly the maximum and minimum temperature, rainfall and relative humidity and sunshine hour as recorded by the weather yard, Bangladesh Meteorological Department, Agargaon, during the period of study has been presented in Appendix I.

3.4 Plant materials used

The variety of chilli used in the experiment was F_1 Hybrid Seed. Seed was collected from Kalash seed company pvt. Ltd.

3.5 Raising of seedlings

Chilli seedlings were raised in the seedbed of 3 m x 1 m size. The soil was well prepared and converted into loose friable condition to obtain good tilth. All weeds, stubbles and dead root were removed. Twenty grams of seeds were sown in two seed bed. The seeds were sown in the seed bed on 19 November 2016. Seeds were then covered with finished light soil and shading was provided by coconut leafs to protect the young seedlings from scorching sunshine and rainfall. Light watering weeding and mulching were done as and when necessary to provide seedlings of a good condition for growth.

3.6 Treatments of the experiment

The experiment consisted of two factors:

Factor A: Different level of salt

S_0: 0 dSm^{-1} (Control)

S_1: 4 dSm^{-1}

S_2 :8 dSm^{-1}

S_3:12 dSm^{-1}

S_4:16 dSm^{-1}

Factor B: It consisted of three levels of salicylic acid

A_0 : 0 mM (control)

A_1 : 0.5 mM

A_2 : 1.0 mM

There were 15 treatments combination used in each block.

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, S_3A_2, S_4A_0, S_4A_1, S_4A_2

3.7 Layout and design of the experiment

The two factors experiment was laid out in Completely Randomized Design (CRD) with five levels of salinity and three levels of salicylic acid. Four replications were maintained in this experiment. The total number of unit pots was 60 (15×4). Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height.

3.8 Pot preparation

A ratio of 1:3 well rotten cow dung and soil were mixed and pots were filled 15 days before transplanting. Silt Loam soils were used for pot preparation. All 60 pots were filled on 20 November 2016. Weeds and stubbles were completely removed from the soil.

3.9 Uprooting and 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 20 December 2016 maintaining two seedlings in each pot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage of roots with ensuring maximum retention of roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from the hot sun and removed after seedlings were established

3.10 Application of the treatments

Chilli plants were treated with 0, 4, 8, 12 and 16 dsm^{-1} salinity levels which were maintained by adding 0, 15.36, 30.72, 46.08 and 61.44 g of sodium chloride (NaCl), respectively per pot containing 10 kg soil. These total amounts of salts were applied through irrigation water in three splits at 30, 50 and 70 DAT. As a

Na+ stress mitigation agent salicylic acid was used at 0, 0.5 and 1.0 mM concentration with irrigation water at 30, 50 and 70 DAT.

3.11 Intercultural operations

3.11.1 Irrigation

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

3.11.2 Staking

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

3.11.3 Weeding

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

3.11.4 Plant protection measures

Insect attack was serious problem at the time of establishment of the seedling. Mole cricket, field cricket and cut warm attacked the young transplanted seedlings. Bashudin was applied for controlling the soil born insects. Cut worms were controlled both mechanically and spraying by Dursban 20 EC @ 3%. Some of the plants were attacked by aphids and were controlled by spraying Diazinon 60.

3.12 Harvesting

The crop was harvested during the period from 20 March, 2017 to 20 April, 2017 when the chilli was completely mature. Harvesting was done pot wise after testing the maturity of the chilli by thumb.

3.13 Data collection

When the fruit were well mature, the fruits were harvested at random from each pot. Data were recorded according to the characters were studied. Plant height was taken 40, 60 and harvest days after transplanting whereas the rest parameters were recorded at the time of harvest.

3.13.1 Plant height

Plant height was taken to the length between the base of the plant and the shoot tip. The plant height was recorded at 40, 60 and 90 days after transplanting (DAT).

3.13.2 Number of branches per plant

The number of branch per plant was manually counted at 90 days after transplanting from tagged plants.

3.13.3 Canopy of plant

The canopy of plant was manually counted at 90 days after transplanting from tagged plants.

3.13.4 Plant breadth

The stem diameter of plant was manually measured at 90 days after transplanting from tagged plants and express in milimeter.

3.13.5 Days to flower initiation

The number of days from the date of transplanting to the date of first flower opening was recorded.

3.13.6 Number of flowers per plant

The number of flowers per plant was counted and recorded.

3.13.7 Number of fruits per plant

The total number of fruits produced in a plant was counted and recorded.

3.13.8 Length of fruit

The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 5 randomly selected marketable fruits from each pot and expressed in cm.

3.13.9 Fruit breadth

Diameter of fruit was measured at the middle portion of 10 randomly selected marketable fruit from each pot with a digital calipers-515 (DC-515) and average was taken and expressed in cm.

3.13.10 Individual fruit weight

The weight of individual fruit was measured with a digital weighing machine from 5 randomly selected marketable fruits from each pot.

3. 13.11 Yield per plant

Yield per plant was calculated by the taking weight of total number of fruit per plant and express in gram.

3.13.12 Chlorophyll - SPAD content

Leaf chlorophyll content was measured using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). At each evaluation the content was measure from five leaves at different positions plant^{-1} and the average was used for analysis.

3.14 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for salt and salicylic acid on yield and yield contributing characters of chilli. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Least Significant Different Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER VI

RESULTS AND DISCUSSION

The results obtained with different levels of salinity and salicylic acid (SA) and their combinations are presented and discussed in this chapter. Data about morpho-physiological parameters, yield contributing characters of chilli have been presented in both tables and figures.

4.1 Plant height

The plant height varied significantly due to the effect of salinity stresses observed at 40, 60 days after transplanting (DAT) and at harvest (Appendix III). At 40 , 60 DAT and at harvest, the highest plant height (13.83, 32.89 and 52.26 cm) was found from S_0 or control whereas the lowest value (11.51, 22.36 and 43.58 cm) respectively was observed with S_4 salinity level (Fig. 1). The results of this study showed that salinity significantly reduced the plant height of chilli at different DAT and the reduction was quite incremental with the increase of NaCl concentrations. Salinity generally provides a slow growth and development of cells which is confirmed by Munns (2002) who reported that salinity reduces plant growth through lessening or stopping the leaf expansion.

Salicylic acid had significant effect on plant height of chilli at 40, 60 DAT and at harvest (Appendix III). At 40, 60 DAT and at harvest, the tallest plant height (13.19, 28.28 and 49.15 cm) was recorded from A_2 or 1.0 mM salicylic acid (SA) whereas the shortest 11.89 cm, 26.48 cm and 47.0 cm, respectively was observed with A_0 or control (Figure 2) . This result agreed with Qados (2015) who reported that SA treatment improved the plant height at all levels of salt stress and also control plants, it is therefore acting as growth stimulants.

Interaction effect of salinity and salicylic acid showed significant variation on plant height of chilli at 40, 60 DAT and harvest (Appendix III). At 40, 60 DAT and harvest, the highest plant height (15.23, 33.69 and 53.13 cm) respectively was observed from the S_0A_2 treatment and the lowest (10.90, 22.0 and 41.00 cm) respectively plant height was observed from S_4A_0 treatment combination (Table 1). The positive effect of foliar application with SA on the growth parameters and water status has also been reported under stress conditions (Khodary, 2004; Hussein et al., 2007; Erdal et al., 2011).

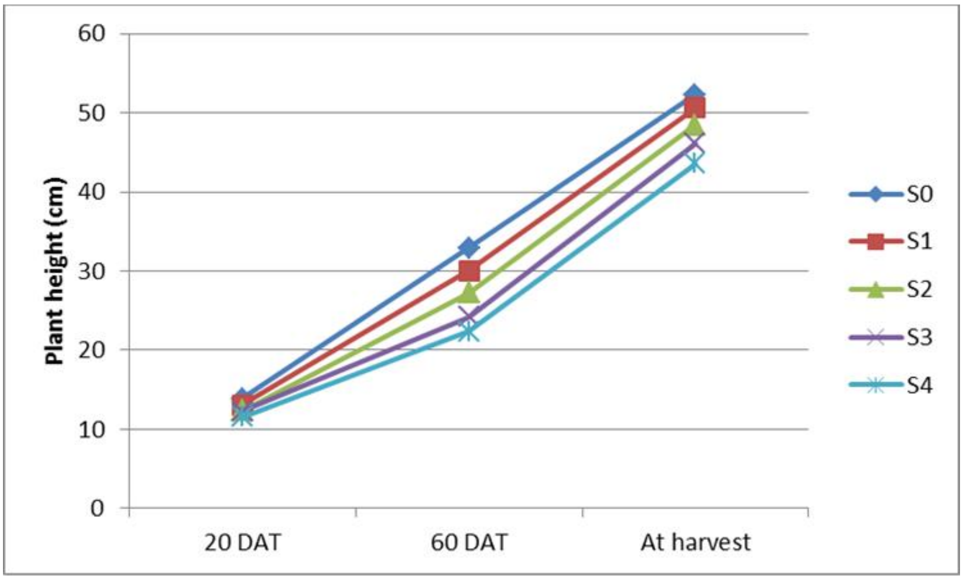

Fig. 1. Effect of salinity level on the plant height of chilli

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

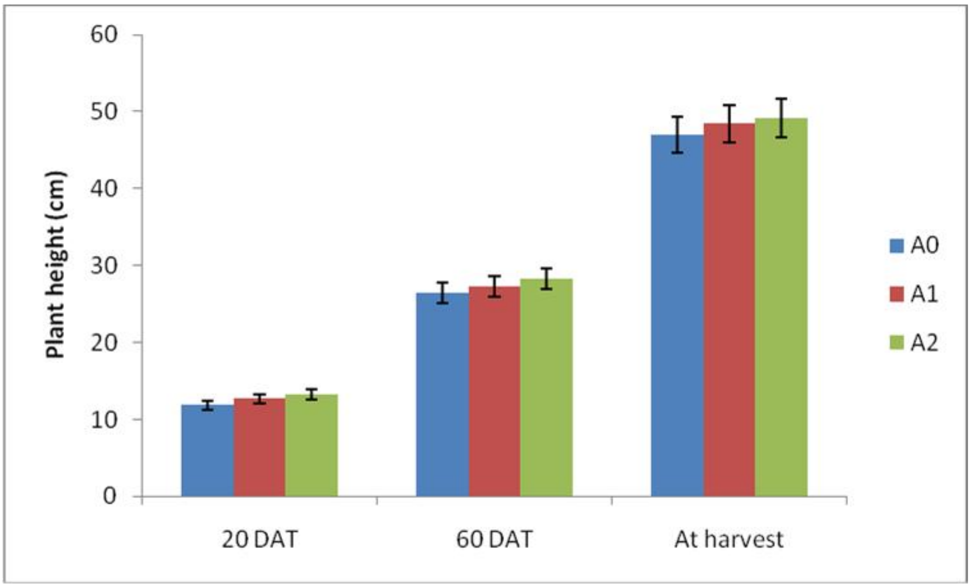

Fig. 2. Effect of salicylic acid on the plant height of chilli

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

Table 1. Interaction effect of salinity level and salicylic acid on the plant height of chilli

Treatment	Plant height (cm)		
	40 DAT	60 DAT	At harvest
S_0A_0	15.03 bc	32.00 a-c	51.09 ab
S_0A_1	14.20 b	32.99 ab	52.55 a
S_0A_2	12.07 de	33.69 a	53.13 a
S_1A_0	12.10 de	29.13 cd	50.00 a-c
S_1A_1	13.50 bc	30.02 b-d	50.85 ab
S_1A_2	13.50 bc	31.00 a-d	51.00 ab
S_2A_0	12.00 de	26.00 f-i	47.67 b-e
S_2A_1	12.05 de	27.13 e-h	48.10 b-e
S_2A_2	12.98 cd	28.50 de	49.56 a-d
S_3A_0	12.38 de	23.25 ij	45.25 e
S_3A_1	12.02 de	24.25 hi	46.13 de
S_3A_2	12.27 de	25.19 g-j	47.05 c-e
S_4A_0	10.9 ef	22.00 j	41.00 f
S_4A_1	11.63 ef	22.08 j	44.72 e
S_4A_2	12.00 de	23.00 ij	45.00 e
$LSD_{(0.05)}$	1.01	3.05	3.20

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt ; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

4.2 Leaf area

Leaf area was significantly affected by different salinity levels. (Appendix IV). The maximum leaf area (19.53 cm^2) was recorded from control, S_0 (without salt) treated plant and the minimum leaf area (12.4 cm^2) was found from S_4 (16 dSm^{-1}) (Figure 3). Similar result was also reported by Saberi *et al*. (2011) and Munns and Tester (2008). According to Hernandez *et al*. (2003) salt stress inhibited the cell division and cell expansion, consequently leaf expansion and as a result leaf area was reduced.

Different levels of salicylic acid affected significantly on leaf area (Appendix IV). The highest leaf area (16.26 cm^2) was found from A_2 where the lower leaf area (15.55 cm^2) was recorded fromA_0 (Fig. 4).

The combined effect of salt and salicylic acid played a significant effect on the leaf area (Appendix IV). The maximum leaf area (20.13 cm^2) was recorded from S_0A_2 which was statistically similar (19.90) to S_0A_1 and (18.58) to S_0A_0 and minimum leaf area (11.58 cm^2) was found from S_4A_0 (Table 2).The leaf area was found higher with 1.0 mM concentration of salicylic acid in different level salinity stress. From the results it can be concluded that the salicylic acid has important role in mitigating salt stress.

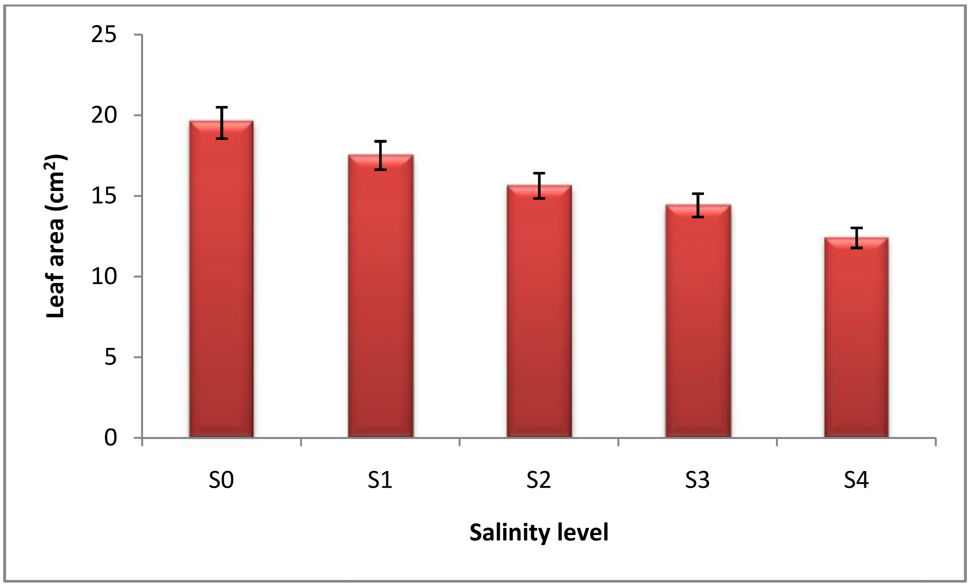

Fig. 3. Effect of salinity level on the leaf area of chilli.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

4.3 Number of branches per plant

Number of branches per plant of chilli was significantly affected by the different levels of salinity at harvest DAT (Appendix IV). The highest number of branches $plant^{-1}$ (18.42) was found from S_0. The lowest value (12.25) was recorded from S_4 (Fig. 5). Uddin *et al*. (2005) also found that number of branch decreased with the increased salinity in (*Brassica sp*).

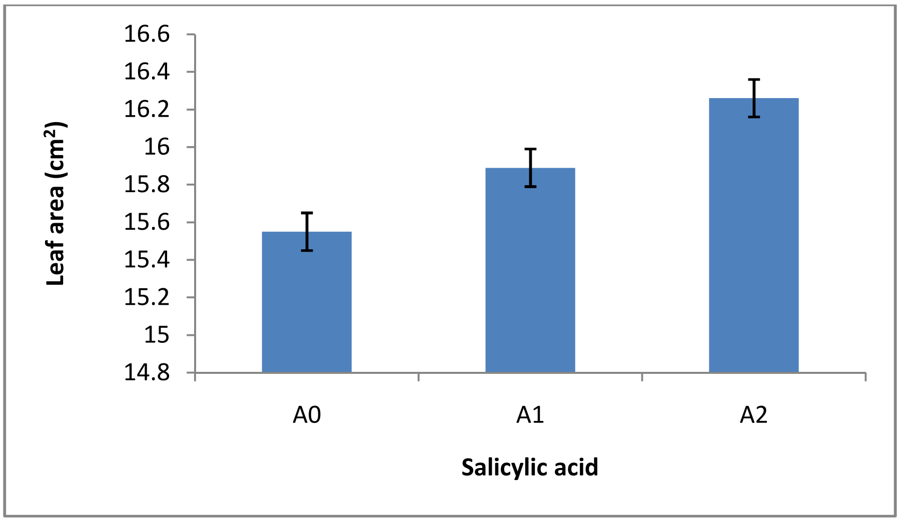

Fig. 4. Effect of salicylic acid on the leaf area of chilli.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

A significant effect of salicylic acid was found on the number of branches per plant of chilli at harvest DAT (Appendix IV). The highest number of branches plant^{-1} (15.8) was found from A_2 and the lowest value (14.55) was recorded from A_0 (Fig. 6).

The combined effect of salinity and salicylic acid on number of branches per plant of chilli showed a significant effect (Appendix IV). The highest number of branches per plant (19.75) was found from S_0A_2 and the lowest value (11.75) was found from S_4A_0 (Table 2).

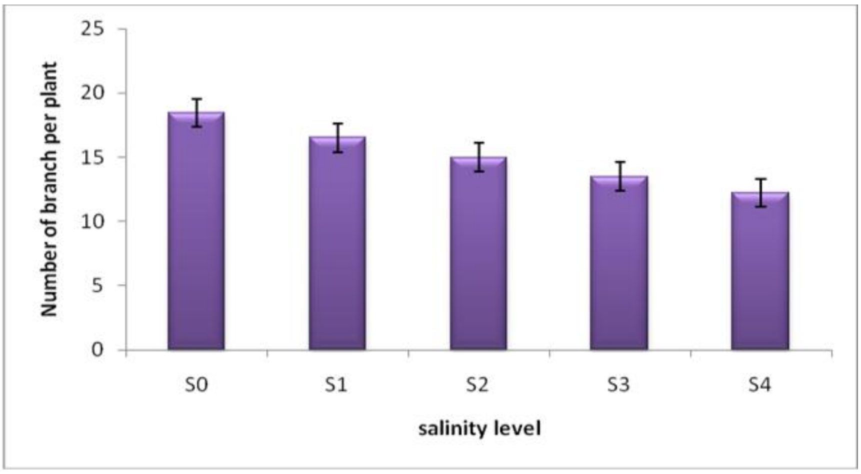

Fig. 5. Effect of salinity level on the number of branch per plant of chilli

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

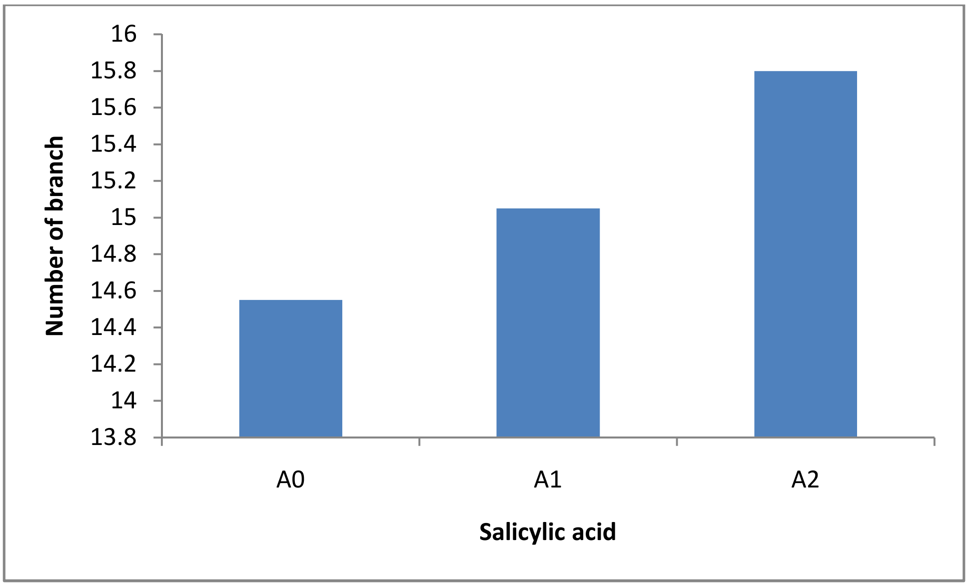

Fig. 6. Effect of salicylic acid on the number of branch per plant of chilli.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

4.4 Root length

Length of root of chilli was significantly affected by the different levels of salinity at harvest DAT (Appendix IV). The highest root length (16.69 cm) was found from S_0. The lowest value (11.99 cm) was recorded from S_4 (Fig. 7).

A significant effect of salicylic acid was found on the length of root per plant of chilli at harvest DAT (Appendix IV). The highest length of root per plant (14.88 cm) was found from A_2 and the lowest value (13.85 cm) was recorded from A_0 (Fig. 8). Salicylic acid level was proportional with the root length of chilli.

The combined effect of salinity and salicylic acid on length of root of chilli showed a significant effect (Appendix IV). The highest length of root (17.25 cm) was found from S_0A_2 which was statistically similar with S_0A_1 and S_0A_0. The lowest value (11.03 cm) was found from S_4A_0, which was also statistically similar with S_4A_1 (Table 2).

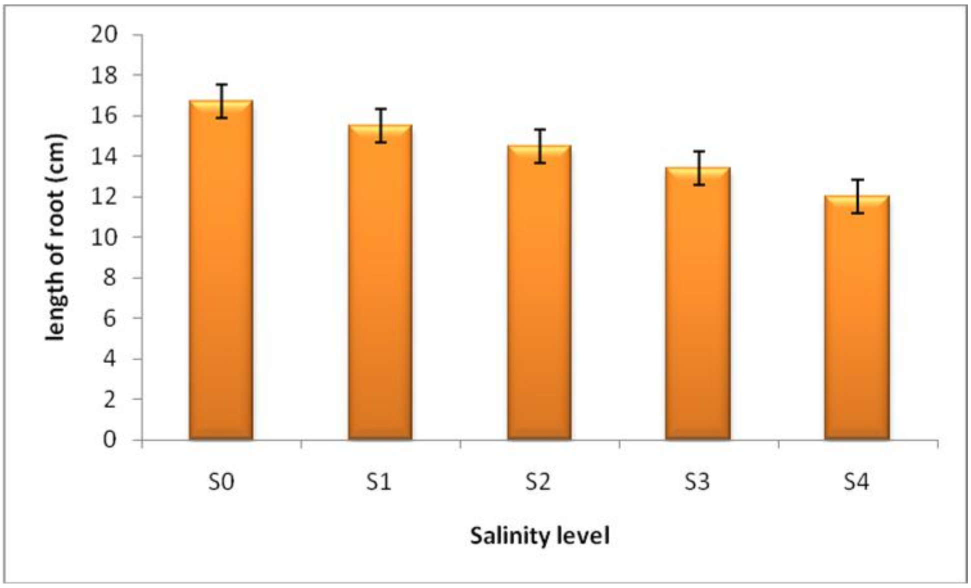

Fig. 7. Effect of salinity level on the length of root of chilli.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

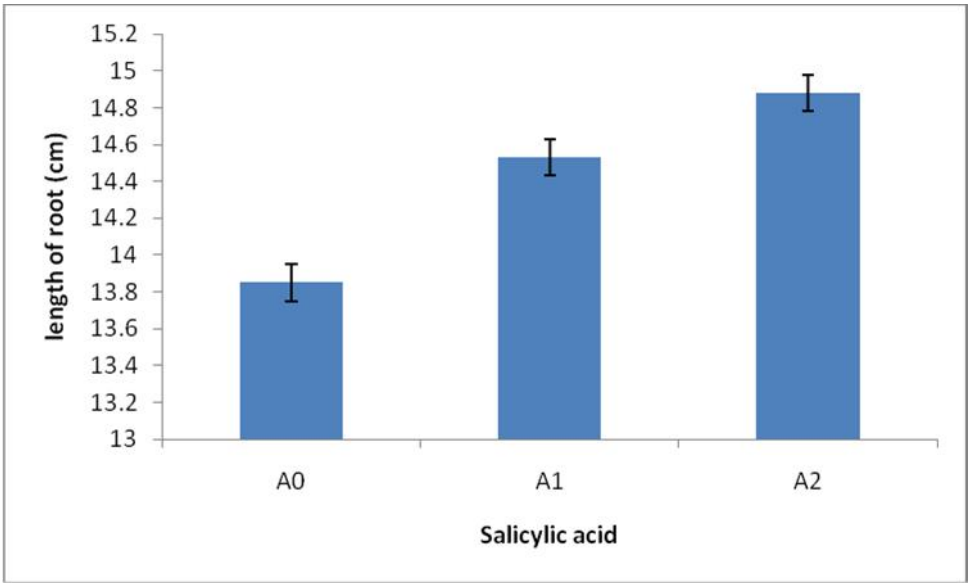

Fig.8. Effect of salicylic acid on the length of root of chilli.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

Table 2. Interaction effect of salinity level and salicylic acid on the leaf area, number of branch and root length of chilli

Treatment	leaf area (cm^2)	No. of branch/plant	Root length (cm)
S_0A_0	18.58 ab	17.50 bc	16.02 a-c
S_0A_1	19.90 a	18.00 b	16.80 ab
S_0A_2	20.13 a	19.75 a	17.25 a
S_1A_0	16.63 c-e	16.00 d-f	15.15 c-f
S_1A_1	17.85 b-d	16.50 c-e	15.58 b-e
S_1A_2	18.05 bc	17.00 b-d	15.78 a-d
S_2A_0	14.98 ef	14.50 g-i	14.03 e-h
S_2A_1	15.85 e	15.00 f-h	14.40 d-h
S_2A_2	16.08 de	15.50 e-g	15.05 c-f
S_3A_0	15.98 de	13.00 j-l	12.99 hi
S_3A_1	13.27 fg	13.50 i-k	13.52 gi
S_3A_2	14.00 fg	14.00 hi	13.71 f-j
S_4A_0	11.58 h	11.75 l	11.03 k
S_4A_1	12.55 gh	12.25 kl	12.35 jk
S_4A_2	13.07 gh	12.75 jk	12.60 ij
$LSD_{(0.05)}$	1.74	1.31	1.41
CV(%)	7.68	6.07	6.88

In a column,means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1}Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

4.5 Plant diameter

Different levels of salinity application showed significant effect on plant diameter of chilli plant (Appendix V). The largest plant diameter (1.91 mm) was recorded from S_0 application. In comparison, the smallest plant diameter (1.08 mm) was observed from S_4 treatment of salinity (Table 3). Salinity reduced the total plant diameter which was also supported by Netondo *et al*. (2004).

Plant diameter of chilli plant was insignificantly influenced by different levels of salicylic acid application (Appendix V). The largest plant diameter (1.71 mm) was recorded from A_2 application. In comparison, the smallest plant diameter (1. 55 mm) was observed in A_0 treatment (Table 4).

Interaction of salinity and salicylic acid significantly affected the plant base diameter of chilli (Appendix V). The longest plant base diameter (1.90 cm) was recorded from the combination of S_0A_2 treatment. In comparison, the shortest plant base diameter (0.75 cm) was observed in treatment combination of S_4A_0 (Table 5).

4.6 Leaf chlorophyll content

There was a clear significant effect of salinity on the leaf chlorophyll content of chilli plant at harvest DAT (Appendix V). The chlorophyll content (SPAD reading) in leaves of chilli decreased with increasing salinity levels. The highest chlorophyll content (48.33 SPAD units) was recorded from S_0. The lowest value (41.83 SPAD units) was found from S_4 (Table 3). From these results, it was found that the highest levels of salinity (16 dSm^{-1}) induced a significant decrease in the total chlorophyll content as compared to control plants. The total chlorophyll content of the leaves of chilli plant exhibits a little increase when grown at 4 and 8 dSm^{-1}. Chlorophyll content was significantly reduced at 16 dSm^{-1}, these results were also supported by Nahar (2014).

Insignificant effect of salicylic acid on leaf chlorophyll content of chilli plant was found at 90 DAT (Appendix V). The highest value (45.85 SPAD units) was found from A_2 and that was statistically similar with A_1. The lowest value (44.55 SPAD units) was recorded from A_0 (Table 4). Thus, salicylic acid reduced the toxic effect on leaf chlorophyll content which was supported by Howladar and Rady (2012). This study suggests that, exogenous salicylic acid supply improves the total chlorophyll content in plant which was strongly related to the fruits weight of plant as well as to yield of chilli.

The interaction effect between salinity and salicylic acid levels on leaf chlorophyll content of chilli plant was statistically significant at 90 DAT (Appendix V). The highest leaf chlorophyll content (49.0 SPAD units) was found from S_0A_2. The lowest value (41.00 SPAD units) was found from S_4A_0 which was statistically identical (28.83 SPAD units) to S_3A_0 (Table 5).

4.7 Canopy size

Different levels of salinity application showed significant effect on canopy size of chilli plant (Appendix V). The largest canopy size (47.08 cm) was recorded from S_0 application. In comparison, the smallest canopy size (41.58 cm) was observed in S_4 treatment of salinity (Table 3).

Canopy size of chilli plant was insignificantly influenced by different levels of salicylic acid application (Appendix V). The largest canopy size (45.05 cm) was recorded from A_2 application. In comparison, the smallest canopy size (43.90 cm) was observed in A_0 treatment of salicylic acid (Table 4).

The interaction effect of salinity and salicylic acid showed significant interaction effect on canopy size of chilli (Appendix V). The maximum canopy size (47.50 cm) was recorded from the combination of (S_0A_2). In comparison, the minimum canopy size (40.50 cm) was observed in treatment combination (S_4A_0) (Table 5).

Table 3. Effect of salinity level on plant diameter, leaf chlorophyll content and canopy size of chilli

Treatment	Plant diameter (mm)	Leaf chlorophyll content	Canopy size (cm)
S_0	1.91 a	48.33 a	47.08 a
S_1	1.80 a	46.50 b	45.58 b
S_2	1.73 ab	45.58 c	44.58 bc
S_3	1.65 ab	44.00 d	43.50 c
S_4	1.08 b	41.83 e	41.58 d
$LSD_{(0.05)}$	0.69	0.79	1.29
CV(%)	5.70	4.91	5.36

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

Table 4 . Effect of salicylic acid on plant diameter, leaf chlorophyll content and canopy size of chilli

Treatment	Plant diameter (mm)	Leaf chlorophyll content	Canopy size (cm)
A_0	1.55	44.55	43.90
A_1	1.64	45.35	44.45
A_2	1.71	45.85	45.05
$LSD_{(0.05)}$	0.78	0.76	1.46
CV(%)	5.70	4.91	5.36

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

Table 5. Interaction effect of salinity level and salicylic acid on plant diameter , leaf chlorophyll content and canopy size of chilli

Treatment	Plant diameter (mm)	Leaf chlorophyll content	Canopy size (cm)
S_0A_0	1.90 a	47.50 a-c	46.50 ab
S_0A_1	1.90 a	48.50 ab	47.25 a
S_0A_2	1.92 a	49.00 a	47.50 a
S_1A_0	1.79 ab	46.00 a-d	45.25 ab
S_1A_1	1.81 ab	46.25 a-d	45.50 ab
S_1A_2	1.81 ab	47.25 a-c	46.00 ab
S_2A_0	1.71 b-d	45.00 b-f	44.25 a-d
S_2A_1	1.72 b-d	45.75 a-e	44.50 a-c
S_2A_2	1.78 ab	46.00 a-e	45.00 a-c
S_3A_0	1.6 1 d	43.25 d-f	43.00 b-d
S_3A_1	1.64 cd	44.25 c-g	43.50 a-d
S_3A_2	1.69 bc	44.50 c-g	44.00 a-d
S_4A_0	0.75 g	41.00 g	40.50 d
S_4A_1	1.15 f	42.00 fg	41.50 cd
S_4A_2	1.35 e	42.50 ef	42.75 b-d
LSD $_{(0.05)}$	0.14	3.16	3.4
CV(%)	5.70	4.91	5.35

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1}Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

4.8 Number of flower per plant

Number of flowers per plant of chilli showed significant differences with different levels of salinity (Appendix VI). The highest number of flowers per plant (39.00) was observed from S_0, where the lowest number (33.83) was recorded from S_4. Number of flowers plant gradually reduced with the increased levels of salinity through dropping of flowers and also consistent with flowers cluster (Table 6).

Significant variation was recorded for the number of flowers per plant of chilli for different doses of salicylic acid (Appendix VI). The maximum number of flowers per plant (36.85) was found from A_2. Again the lowest number (35.90) was obtained from A_0 (Table 7). Application of salicylic acid increased the number of flowers plant^{-1}.

Interaction effect of salinity level with salicylic acid showed significant variation in terms of number of flowers plant^{-1} (Appendix VI).The highest number of flowers plant^{-1} (39.25) was observed in S_0A_2 and the lowest number (33.0) was recorded from S_4A_0 (Table 8).

4.9 Drop of flower per plant

Drop of flowers plant^{-1} of chilli showed significant differences with different levels of salinity (Appendix VI). The highest drop of flowers per plant (9.00) was observed from S_4, where the lowest number (4.5) was recorded from S_0 (Table 6). Drop of flowers plant^{-1} gradually increased with the increased levels of salinity.

Significant variation was recorded for the drop of flowers plant^{-1} of chilli for different doses of salicylic acid (Appendix VI). The maximum number of flowers drop plant^{-1} (7.20) was found from A_0 which was statistically similar with A_1. Again the lowest number (6.35) was obtained from A_2. Application of salicylic acid decreased the number of flowers drop per plant (Table 7).

Interaction effect of salinity level with salicylic acid showed significant variation in terms of number of flowers drop plant^{-1} (Appendix VI).The highest number of flowers drop plant^{-1}(9.50) was observed in S_4A_0 that was also statistically similar with S_4A_1 and S_4A_2. And the lowest number (4.0) was recorded from S_4A_2 (Table 8 and).

4.10 Number of fruits per plant

Number of fruits per plant of chilli showed significant differences in response to different levels of salinity (Appendix VI). The highest number of fruits per plant (32.58) was recorded from S_0 (control) that was also statistically similar with S_1 and the lowest number (21.0) was observed from S_4 (16 dSm^{-1}) that are similar to S_3 (Table 6). Salinity reduced the number of fruits per plant which was also consistent with the number of flowers per plant and ultimately reduced the fruit yield which is also supported by Hamayun *et al*. (2010).

Statistically significant variation was recorded for number of fruits $plant^{-1}$ of chilli after the application of different levels of salicylic acid (Appendix VI). The highest number of fruits $plant^{-1}$ (28.55) was observed from A_2 and the lowest value (25.10) from A_0 (Table 7). Number of fruits $plant^{-1}$ increased with the increased levels of salicylic acid. This trend was also related with the number of flowers $plant^{-1}$.

Number of fruits $plant^{-1}$ varied significantly for the interaction effect of different salinity and salicylic acid levels (Appendix VI). The highest number of fruits $plant^{-1}$ (34.21) was recorded from S_0A_2 and the lowest (19.00) was obtained from S_4A_2 that was statistically similar with S_4A_1 (Table 8).

Table 6. Effect of salinity level on number of flower, drop of flower, number of fruit per plant of chilli

Treatment	No. of flower	Drop of flower/plant	No. of fruit/plant
S_0	39.00 a	4.50 e	32.58 a
S_1	37.75 b	5.92 d	31.25 a
S_2	36.50 c	6.92 c	27.17 b
S_3	35.00 d	7.67 b	23.50 c
S_4	33.83 e	9.00 a	21.00 c
$LSD_{(0.05)}$	0.97	0.31	3.49
CV(%)	5.73	10.74	6.87

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

Table 7. Effect of salicylic acid on number of flower, Drop of flower, number of fruit per plant of chilli

Treatment	No. of flower	Drop of flower/plant	No. of fruit/plant
A_0	35.90 b	7.20 a	25.10 b
A_1	36.50 ab	6.85 a	27.65 ab
A_2	36.85 a	6.35 b	28.55 a
$LSD_{(0.05)}$	0.62	0.37	2.99
CV(%)	5.73	10.74	6.87

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

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Table 8. Interaction effect of salinity level and salicylic acid on number of flower, drop of flower, number of fruit per plant of chilli

Treatment	No. of flower	Drop of flower/plant	No. of fruit/plant
S_0A_0	38.75 ab	5.00 h-j	30.25 b-d
S_0A_1	39.00 ab	4.50 ij	33.25 a
S_0A_2	39.25 a	4.00 j	34.25 a
S_1A_0	37.25 a-e	6.25 e-g	29.25 c-e
S_1A_1	37.75 a-d	6.00 f-h	32.00 a-c
S_1A_2	38.25 a-c	5.50 g-i	32.50 ab
S_2A_0	35.75 b-f	7.25 de	26.00 fg
S_2A_1	36.75 a-e	7.00 d-f	27.00 e-g
S_2A_2	37.00 a-e	6.50 e-g	28.50 d-f
S_3A_0	34.75 de	8.00 b-d	21.00 ij
S_3A_1	35.00 c-f	7.75 cd	24.50 gh
S_3A_2	35.25 c-f	7.25 de	25.00 gh
S_4A_0	33.00 f	9.50 a	19.00 j
S_4A_1	34.00 ef	9.00 ab	21.50 ij
S_4A_2	34.50 d-f	8.50 a-c	22.50 hi
$LSD_{(0.05)}$	2.97	1.04	2.65
CV(%)	5.73	10.74	6.87

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

4.11 Fruit length

Different salinity levels exhibited significant variation in fruit length (cm) of individual fruit (Appendix VII).The maximum fruit length (15.52 cm) was found from control (S_0) whereas the minimum (10.84 cm) was obtained from S_4 (16 dSm^-

^{1}) (Table 9). It was observed in almost all cases that relative large size fruits were obtained from control plants and gradually small size fruits were obtained from increased salinity levels due to its inhibitory effect on cell expansion.

Salicylic acid had insignificant effect on the fruit length (Appendix VII). The highest fruit length (13.85 cm) was produced from A_2 and the shortest fruit length (12.84 cm) was produced from A_0 (Table 10). The higher the salicylic acid, the higher the fruit length.

There were significant interaction effects between different salinity levels and salicylic acid levels in case of fruit length of chilli (Appendix VII). The maximum fruit length (16.20 cm) was found from the treatment combination of S_0A_2. The minimum fruit length (10.08 cm) was obtained from S_4A_0 (Table 11).

4.12 Fruit diameter

Diameter of individual chilli fruit varied significantly for the different levels of salinity (Appendix VII). The highest fruit diameter (1.89 mm) was recorded from control (S_0) whereas the lowest fruit diameter (0.83 mm) was found from S_4 (Table 9). Salinity decreased the fruit size.

Statistically insignificant difference was observed for fruit diameter of chilli due to the application of different levels of salicylic acid (Appendix VII).The highest fruit diameter (1.53 mm) was recorded from A_2. Again the lowest value (1.33 mm) was observed from A_0 (Table 10).

Salinity and salicylic acid levels significantly affected fruit diameter of chilli (Appendix VII). The highest fruit diameter of fruit (2.03 mm) was recorded from S_0 A_2 whereas the lowest fruit diameter (0.65 mm) was found from S_4A_0 (Table 11) .

4.13 Individual fruit weight

Individual fruit weight of chilli per plant varied significantly due to influence of the different levels of salinity (Appendix VII). The highest individual fruit weight per plant of chilli (4.55 g) was found from S_0 (control). The lowest weight (2.94 g) was obtained from S_4 (Table 9). The results obtained from this experiment showed that salinity stress caused a significant reduction in fruit weight.

Application of different levels of salicylic acid showed statistically insignificant differences for the fruit weight per plant of chilli (Appendix VII). The highest fruit weight (3.72 g) was recorded from A_2 and the lowest yield (3.00 g) was obtained from A_0 (Table 10). Salicylic acid insignificantly increase the fruit weight mostly at 1mM.

The interaction effect of salinity and salicylic acid for the yield of chilli per plant showed significant difference (Appendix VII). The highest fruit weight (5.45 g) was recorded from S_0A_2 whereas the lowest value (2.32 g) was found from the S_4A_0 (Table 11).

4.14 Fruit yield/plant

Fruit yield of chilli per plant varied significantly due to influence of the different levels of salinity (Appendix VII). The highest fruit yield per plant (59.25 g) was found from S_0 (control). The lowest yield (50.0 g) was obtained from S_4 (Table 9). The results obtained from this experiment showed that salinity stress caused a significant reduction in fruit yield which was also reported by Lolaei et al. (2012). This also responsible for the reduction of fruit yield plant^{-1}. Salinity reduced the fruit yield by inhibiting the cell division and rate of fruit expansion due to the lower water potential in the plant which reduced the water flow into the fruit.

Application of different levels of salicylic acid showed statistically insignificant differences for the fruit yield per plant of chilli (Appendix VII). The highest fruit yield (55.90 g) was recorded from A_2 and the lowest yield (54.05 g) was obtained from A_0 (Table 10). Salicylic acid insignificantly increase the fruit yield mostly at 1mM. The interaction effect of salinity and salicylic acid for the yield of chilli per plant showed significant difference (Appendix VII). The highest yield (60.0 g) was recorded from S_0A_2 whereas the lowest value (8.25 g) was found from the S_4A_0 (Table 11).

Table 9. Effect of salinity level on yield and yield contributing character of chilli

Treatment	Fruit length (cm)	Fruit diameter (mm)	Individual fruit weight (g)	Yield/plant (g)
S_0	15.52 a	1.89 a	4.55 c	59.25 a
S_1	14.21 b	1.68 b	3.59 b	57.50 b
S_2	13.47 b	1.48 c	3.25 c	55.25 c
S_3	12.41 c	1.32 b	3.13 c	53.25 d
S_4	10.84 d	0.84 d	2.94 c	50.00 e
$LSD_{(0.05)}$	1.05	0.19	1.45	1.65
CV(%)	8.54	5.31	6.45	4.46

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

Table 10. Effect of salicylic acid on yield and yield contributing characters of chilli.

Treatment	Fruit length (cm)	Fruit diameter (mm)	Individual fruit weight (g)	Yield/plant (g)
A_0	12.84	1.33	3.00	54.05
A_1	13.18	1.45	3.28	55.20
A_2	13.85	1.53	3.72	55.90
$LSD_{(0.05)}$	1.31	0.27	1.21	2.55
CV(%)	8.54	5.31	4.35	4.46

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.
A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

Table 11. Interaction effect of salinity level and salicylic acid on yield and yield contributing character of chilli

Treatment	Fruit length (cm)	Fruit diameter (mm)	Individual fruit weight (g)	Yield/plant (g)
S_0A_0	15.00 ab	1.79 bc	4.85 ab	58.25 ab
S_0A_1	15.35 ab	1.84 b	4.95 ab	59.50 a
S_0A_2	16.20 a	2.03 a	5.45 a	60.00 a
S_1A_0	14.00 b-d	1.60 de	3.25 a-d	57.00 a-c
S_1A_1	14.18 bc	1.68 cd	3. 35 bc	57.50 ab
S_1A_2	14.45 a-c	1.77 bc	3.45 a-c	58.00 ab
S_2A_0	13.07 c-f	1.41 fg	3.19 b-e	54.50 b-e
S_2A_1	13.52 b-f	1.49 ef	3.22 b-d	55.25 b-d
S_2A_2	13.80 b-e	1.53 e	3. 29 a-d	56.00 a-d
S_3A_0	12.02 c-f	1.22 h	3.11 a-c	52.25 de
S_3A_1	12.23 d-g	1.35 g	3.19 a-b	53.25 c-f
S_3A_2	12.98 c-f	1.40 fg	3.29 a-c	54.25 b-f
S_4A_0	10.08 h j	0.65 j	2.32 g	8.25 g
S_4A_1	10.63 gh	0.88 i	2.45 h	10.50 fg
S_4A_2	11.82 fg	0.95 i	2.64 i	11.25 e-g
$LSD_{(0.05)}$	1.62	0.11	2.05	3.50
CV(%)	8.54	5.31	3.25	4.46

In a column, means with similar letter(s) are not significantly different by LSD at 5% level of significance.

S_0: Control; S_1: 4 dSm^{-1} Salt; S_2: 8 dSm^{-1} Salt; S_3: 12 dSm^{-1} Salt; S_4: 16 dSm^{-1} Salt.

A_0: Control; A_1: 0.5 mM Salicylic Acid; A_2: 1.0 mM Salicylic Acid.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to April 2017 to investigate mitigation of salt stress in chilli with salicylic acid. In this experiment, the treatments consisted of five different salinity levels viz. S_0: 0 dSm^{-1} salt (control), S_1: 4 dSm^{-1}, S_2: 8 dSm^{-1}, S_3: 12 dSm^{-1}, S_4: 16 dSm^{-1} and three different levels of salicylic acid viz. A_0: 0 mM, A_1: 0.5 mM and A_2: 1.0 mM. The experiment was laid out in two factors Completely Randomized Design (CRD) with four replications. Data on different growth parameters, physiological parameters and yield with yield contributing characters of chilli were recorded. The collected data were statistically analyzed for evaluation of the treatment effect.

There was significant variation among the influence of different levels of salinity in case of almost all the parameters. In this experiment, chilli plants were subjected to salinity by applying saline water at four different days in the life cycle of chilli plant to keep the soil in saline condition. Plant grown on normal soil (control treatment) showed the maximum height more or less over the growth period whereas the lowest height was recorded from more saline soil treated plants. At 40, 60 DAT and at harvest, the highest plant height was 13.83, 32.89 and 52.26 cm, respectively under a controlled condition whereas the lowest value 11.51, 22.36 and 43.58 cm, respectively was observed with S_4 salinity level. Maximum number of branches $plant^{-1}$ was (18.2) at harvest under controlled treatment condition whereas the lowest was 12.25. The maximum plant breadth and root length of plant 1.91 mm and 16.69 cm was observed from controlled treatment whereas the lowest 1.08 mm and 11.99 cm was found from S_4 treatment. The leaf chlorophyll content was reduced with the increase of salinity whereas the maximum chlorophyll content was recorded from no salt with minimum from 16 dSm^{-1}. The maximum number of leaf area, canopy size and drop of flower per plant was identify from S_0 (control treatment) and lower number was found from S_4 treatment. The maximum flower number per plant (39.00), number of fruit per plant (32.28), fruits breadth (1.89), individual fruit length (15.52 cm), fruit weight plant^{-1} (59.25 g) was recorded from control with favored the higher yield and the lowest value of all these parameters were found from S_4.Higher salinity level was responsible for maximum number of dropped flowers plant^{-1} (9.0) whereas the lowest (4.5) was recorded from 0 dSm^{-1}.

Plant height showed significant difference in response of foliar application of salicylic acid. At 40, 60 DAT and at harvest, the highest plant height was 13.19, 28.28 and 49.15 cm, respectively under A_2 condition whereas the lowest value 11.89, 26.48 and 47.0 cm, respectively was observed with A_0 (control condition). Maximum number of branches plant^{-1} was 15.8, at harvest under A_2 treatment and the minimum was 14.55 from A_0 condition. The maximum plant diameter and root length plant^{-1} (1.71 mm) and 14.88 cm was observed from A_2 treatment whereas the lowest 1.55 mm and 13.85 cm was found from A_0 treatment. The leaf chlorophyll content was increase with the increasing of salicylic acid whereas the maximum chlorophyll content was recorded from A_2 and minimum chlorophyll content was observed from A_0. The maximum of leaf area, canopy size and no. of flower per plant was recorded from A_2 treatment and lower number was found from A_0 (control) treatment. The maximum flower number plant^{-1} (36.85), number of fruit plant^{-1} (28.55), fruits breadth (1.53), individual fruit length (13.85 cm), fruit weight plant^{-1} (55.90) was recorded from A_2 and the lowest value of all these parameters were found from A_0 (control) treatment. A_0 level was responsible for maximum number of dropped flowers plant^{-1} (7.20) otherwise the lowest (6.35) was recorded from A_2.

The combinations of salinity and salicylic acid levels had significant effect of all parameters. The tallest plant height 15.23, 33.69 and 53.13 cm at 40, 60 DAT and harvest, respectively was found in S_0A_2 treatment combination and the shortest plant height 10.90, 22.0 and 41.00 cm at 40, 60 DAT and harvest, respectively was produced with the S_4A_0. The maximum of leaf area (20.13), number of branch (19.75), root length (17.25) were recorded from S_0A_2 treatment whereas minimum of leaf area (11.58), number of branch plant (11.75), root length (11.03) were observed from S_4A_0 treatment. The SPAD value content was statistically influenced by the different levels salinity and salicylic acid. But numerically the highest SPAD value 49.00 was observed from S_0A_2 otherwise the lowest SPAD value 41.0 was observed from S_4A_0. The highest number of flower per plant (39.25), number of fruit per plant (34. 25), fruit length (16.20 cm), fruit diameter (2.03 mm) fruit weight (60.0 g), were found from S_2A_2 treatment while the lowest number of flower per plant (33.0), number of fruit plant^{-1} (19.0), fruit length (10.08 cm), fruit diameter (0.65 mm) fruit weight (48.25 g), were recorded from S_4A_0 treatment.

Conclusion

The results revealed that, the yield of chilli was gradually decreased by the increase of salinity levels. Among the salicylic acid levels, almost 1.0 mM SA showed the highest result in growth, physiology and yield parameters. Therefore, the present experimental results suggested that 1.0 mM salicylic acid application is suitable to mitigate salt stress and produced higher yield of chilli.

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APPENDICES

Appendix I. Monthly average record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 2016 to April 2017

Month	Air temperature (ºc)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2016	31.6	22.8	78	171.3	5.2
November, 2016	29.7	19.2	78	34.4	5.3
December, 2016	26.4	14.1	69	12.8	5.5
January, 2017	25.5	12.1	68	8.7	5.5
February, 2017	28.1	15.5	65	28.9	4.5
March, 2017	31.5	22.4	64	65.8	5.2
April, 2017	33.7	23.6	69	165.3	4.9

Source: Bangladesh Meteorological Department (Climate & Weather Division) Agargaon, Dhaka.

Appendix II. Physical characteristics and chemical composition of soil of the experimental pot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
pH	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix III. Analysis of variance of the data on plant height of chilli as influence salinity and salicylic acid level

Source	Degrees of freedom	Mean square		
		Plant height (cm)		
		40 DAT	60 DAT	at harvest
Factor A (Salt)	4	9.332*	218.004*	143.91*
Factor B (Salicylic Acid)	2	8.64*	16.227*	23.8999*
Interaction (A× B)	8	1.72*	0.335*	2.16*
Error	45	0.5010	4.59	5.005

*Significant at 5% level of probability

Appendix VI . Analysis of variance of the data on leaf area, number of branch and root length of chilli as influenced by salinity level and salicylic acid

Source	Degrees of freedom	Mean square		
		leaf area	No. of branch	Root length (cm)
Factor A (Salt)	4	90.893*	70.94*	39.72*
Factor B (Salicylic Acid)	2	2.60*	7.992*	5.51*
Interaction (A ×B)	8	3.52*	0.42*	0.223*
Error	45	1.349	0.84	0.98

*Significant at 5% level of probability

Appendix V. Analysis of variance of the data on plant breadth, leaf chlorophyll and canopy size of chili as influenced by salinity level and salicylic acid.

Source	Degrees of freedom	Mean square		
		Plant diameter (mm)	Leaf chlorophyll	Canopy size (cm)
Factor A (Salt)	4	1.025*	73.25*	52.007*
Factor B (Salicylic Acid)	2	0.12^{NS}	8.160*	6.62^{NS}
Interaction (A ×B)	8	0.007*	0.16*	0.43*
Error	45	0.01	4.931	5.692

***S**ignificant at 5% level of probability; NS- Non significant

Appendix VI. Analysis of variance of the data on number of flower, Drop of flower, number of fruit per plant of chilli as influenced by salinity level and salicylic acid

Source	Degrees of freedom	Mean square		
		No. of flower	Drop of flower	No. of fruit/plant
Factor A (Salt)	4	51.42*	35.03*	292.039*
Factor B (Salicylic Acid)	2	4.062*	3.65*	64.05*
Interaction (A ×B)	8	0.24*	0.03*	0.197*
Error	45	4.351	0.5301	3.047

*Significant at 5% level of probability

Appendix VII. Analysis of variance of the data on yield and yield contributing character of chilli as influenced by salinity level and salicylic acid

Source	Degrees of freedom	Mean square			
		Fruit breadth (mm)	Fruit length (cm)	Individual fruit weight (g)	Yield/plant (g)
Factor A (Salt)	4	1.95^{*}	37.79^{*}	157.03^{*}	14.67^{*}
Factor B (salicylic acid)	2	0.20^{NS}	5.33^{NS}	17.14^{NS}	7.32^{NS}
Interaction (A×B)	8	0.01^{*}	0.23^{*}	0.70^{*}	0.10^{*}
Error	45	0.01	1.29	6.03	1.87

*Significant at 5% level of probability ; NS- Non significant