EFFECTS OF SALINITY ON SEED GERMINATION AND SEEDLING DEVELOPMENT OF TOMATO

SYED TARIK MAHABUB

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA 1207

December, 2015

EFFECTS OF SALINITY ON SEED GERMINATION AND SEEDLING DEVELOPMENT OF TOMATO

BY

SYED TARIK MAHABUB

Registration No.: 09 – 03616
Semester: July- December, 2015

A Thesis

Submitted to the Institute of Seed Technology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
SEED TECHNOLOGY

APPROVED BY:

Prof Dr .A.K.M Ruhul Amin
Department of Agronomy
Sher-e-Bangla Agricultural University
Supervisor

Prof Dr.Md. Shahidul Islam
Department of Agronomy
Sher-e-Bangla Agricultural University
Co-Supervisor

Prof. Dr. Mohammed Ali
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled, *"EFFECTS OF SALINITY ON SEED GERMINATION AND SEEDLING DEVELOPMENT OF TOMATO"* submitted to the Institute of seed technology, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE IN SEED TECHNOLOGY,* embodies the result of a piece of research work carried out by *SYED TARIK MAHABUB* , Registration No. ***09-03616*** 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.

(*Prof. Dr A.K.M Ruhul Amin*)

Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Dated:December,2015

Place: Dhaka, Bangladesh

ACKNOWLEDGEMENTS

All praises are due to Almighty God, the Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully.

The author likes to express his deepest sense of gratitude to his respected supervisor ***Prof. Dr A.K .M Ruhul Amin** , Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing.*

*The author also expresses his gratefulness to his respected Co-Supervisor, **Prof Dr. Md. Shahidul Islam** Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimatable help, valuable suggestions throughout the research work and in preparation of the thesis.*

*The author expresses heartfelt thanks to **Prof. Dr. Mohammed Ali** , Director , Institute of Seed technology , SAU, for his valuable suggestions, instructions, cordial help and encouragement during the period of the study.*

The author expresses heartfelt thanks to all the teachers of the Institute of Seed Technology, SAU, for their valuable suggestions and instructions.

The author is also grateful to all his seniors and friends for their help, encouragement and moral support towards the completion of the degree.

Last but not least, the author expresses his heartfelt gratitude and indebtedness to his beloved father , mother, brothers and sisters for their inspiration, encouragement and blessings that enabled him to complete this research work.

EFFECTS OF SALINITY ON SEED GERMINATION AND SEEDLING DEVELOPMENT OF TOMATO

ABSTRACT

An experiment was conducted at the Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka in order to investigate the effects of different levels of NaCl concentrations on seed germination and seedling growth of six varieties of tomato. The two factor experiment was carried out using completely randomized design with three replications. Experimental treatments consisted of six varieties of tomato (Bahar , BARI Tomato-1, BARI Tomato-2, BARI Tomato-6, BARI Tomato-9, and BARI Tomato-12) and five levels of NaCl (0, 25, 50, 100 and 150 mM). At 10th days after sowing, the highest percentage of seed germination (94.67) was recorded in the variety BARI Tomato-12 and the lowest percentage of seed germination (61.33) was observed in the variety BARI Tomato-6. NaCl solutions significantly affected seed germination in tomato and seed germination, with the increase of NaCl solutions. At 11 days after sowing seeds, the highest percentage of seed germination (81.33) of tomato was recorded in case of control (0 mM NaCl) and the lowest percentage of seed germination (0.00) was observed in case of 150 mM NaCl salt solution. In case of combined effects of varieties and different levels of NaCl solutions on seed germination of tomato, the highest seed germination was recorded in the variety BARI Tomato-12 with control i.e. without any NaCl at 11 days after seed sowing. The germination percentage, germination coefficient, radicle and plumule length, seed vigor index, fresh weight of plumule and radicle, dry weight of plumule and radicle decreased with increasing NaCl salt solutions in the germination media compared to control. In the six varieties of tomato, BARI Tomato-12 , BARI Tomato-1 and BARI Tomato-2 were identifying that these varieties were relatively more salt tolerant than BARI Tomato-6, BARI Tomato-9 and Bahar, although control showed the best performance.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and is one of the most popular vegetable in the world. It is a monocarpic herbaceous plant originated in the western coastal plain of South America extending from Ecuador to Chile. It is cultivated in almost all home gardens and also in the field for its adaptability to wide range of soil and climate in Bangladesh. It is cultivated mainly as winter crop in Bangladesh. It is planted in October- November, and becomes ready to harvest and marketing in January-April. Tomato is also cultivated as summer. Its rank next to potato and sweet potato in respect of vegetable production in the world. Bangladesh produces 251 thousand metric tons of tomatoes from 65 thousand acres of land with an average yield of 3.86 metric tons/ha (BBS, Monthly Statistical Bulletin, December, 2013).

Tomato is the most popular fruit vegetable among millions of people in the world owing to its beautiful color, delicious taste and high nutrition. It is one of the most popular and extensively consumed vegetable crops worldwide. There is evidence that regular tomato consumption decreases the incidence of chronic degenerative diseases such as certain types of cancer and cardiovascular diseases. It contains lycopene, one of the most powerful natural antioxidants. Lycopene has been shown to improve the skin's ability to protect against harmful UV rays. It can protect against sunburn and help keeping the skin looking youthful. Its food value is also very high due to presence of vitamin A, B and C and minerals like calcium (Bose and Som, 1990). The chemical composition of tomato includes: total sugar 2.50-4.50%, vitamin C 15-20 mg/100g, calcium 0.25-0.50g/100g, magnesium 0.10-0.50g/100g, phosphorous 0.20-0.80g/100g, iron 40-500 ppm, zinc 10-50 ppm, lycopene 20-50g/100g (dry fruit weight basis) (Frusciante *et al.*, 2007).

Tomato is widely cultivated in tropical, sub-tropical and temperate climates and ranks third in terms of world vegetable production (FAO, 2006). The leading tomato producing countries are China, USA, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia (FAO, 2006).

In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahamed, 1995). The leading growing areas of tomato in Bangladesh include Chittagong, Comilla and Rajshahi. However, tomatoes are found growing extensively all over the country. The yield of tomato in Bangladesh depends on various factors such as irrigation and soil management are vital factors in increasing the production.

Salinity is a major environmental constraint to crop production throughout the arid and semi-arid regions of the world (Foolad and Lin, 1997). In the recent years, the sea level is gradually increasing and because of this, salinity is being increased in the soil of southern part of our country. One meter sea level rise will affect the vast coastal area and flood plain zone of Bangladesh (Sarwar, 2005). If the rising of the sea level is continued, some districts of our country like Barisal, khulna, Bagerhat, Noakhali, Faridpur, Madaripur, and Laksmipur may also be affected by salinity and in that condition the production of vegetables like tomato will be hampered.

On the other hand soil and water salinity in the arid regions are continuously increasing (Rus *et al*., 2002). Globally, more than 770,000 km^2 of the land is affected by secondary salinization, 20 % of the irrigated areas and about 2 % of the total agricultural land (FAO, 2002). Salinity is a major abiotic factor limiting plant growth and fruit yield (Parada *et al*., 2006). It induces osmotic and toxic effects leading to physiological, morphological and biochemical modifications; it causes growth inhibition, crop yield reduction, lower photosynthesis and respiration, nutritional deficiencies and inhibition of protein synthesis (Ashraf and Foolad, 2007). These phenomena have been observed in agricultural and horticultural crops, including tomato (Juan *et al*., 2005).

Salinity of soil and irrigation water is a continuing threat to economic crop production especially in arid and semiarid regions of the world (Kayani *et al.*, 1990). About 20% of the net cultivable land of Bangladesh in coastal region is affected by different degrees of salinity (Karim *et al*., 1990). The ability of seed to germinate in saline environments, the cotyledons to break through a soil crust, emerging and seedlings to survive in saline conditions are crucial for crop production in saline soils (Omami, 2005). The detrimental effect of salinity occurs because of osmotic stress and specific ion toxicity (Ungar, 1996).

Germination and seedling development are very important for early establishment of plants under stress. The response of plants to excess NaCl is complex and involves changes in their morphology, physiology and metabolism (Hilal *et al.,* 1998). Increased salinity caused a reduction in tomato germination percentage, germination rate, radicle and plumule length and fresh root and shoot weight (Jamil *et al*., 2006).

Seed germination is an important and vulnerable stage in the life cycle of terrestrial angiosperms and determines seedling establishment and plant growth (Grattan *et al*., 1999). Despite the importance of seed germination under salt stress, the mechanism of salt tolerance in seeds is relatively poorly understood, especially when compared with the amount of information currently available about salt tolerance physiology and biochemistry in vegetative stage of plants. In vegetative stage, salt stress causes reduced cell turgor and depressed rates of root and leaf elongation, suggesting that environmental salinity acts primarily on water uptake. Furthermore, high intracellular concentrations of both Na+ and Cl^- can inhibit the metabolism of dividing and expanding cells, retarding germination and even leading to seed death. The different results were detected from the effect of salinity stress on the quantitative and qualitative parameters. For instance, it was found that increasing of salinity stress decreased almost all the growth parameters in *Nigella sativa.* Ashraf and Khanam (1997) reported that salinity treatment led to reduction of growth and plant developments.

It is necessarily important to identify salt tolerant crop variety to increase crop production in saline prone areas of Bangladesh. Therefore, the present research work was undertaken with the following objectives:

- to study the salt tolerance of tomato varieties at seed germination and seedling development stage, and
- to assess the effects of different concentrations of NaCl on germination of tomato seed.

CHAPTER 2

REVIEW OF LITERATURE

Soil salinity is one of the major abiotic stresses for crops. It affects seed germination and seedling growth of plants. The effects of salinity on seed germination and seedling growth have been studied by different authors of the world. It is evident that sustainable global food security is partly dependent on the development of salt tolerant horticultural crops. Soil salinity is a common problem in southern regions of Bangladesh as a result of saline water flow from the Bay of Bengal in the coastal areas, low rainfall, high evapotranspiration, and poor quality of irrigation water. High soil salinity leads to poor germination, delays plant establishment, and reduces subsequent growth and yield of crops. Seed germination and seedling emergence are critical growth stages for successful crop establishment, which impacts ultimate crop yields. Anecdotal observations indicated that it is more difficult for tomato seeds to germinate and establish in saline soils compared with the least saline soils. Elevated soil salinity can further reduce seedling establishment.

Germination and seedling establishment are critical stages in the life cycle of plants especially under stress conditions. Different methodologies have been adopted by plant physiologists in different crops to alleviate salt stress. A brief review of literature related to present study has been presented in this chapter.

Baghbani *et al.* (2013) examined the salinity stress on germination and seedling growth in greenhouse cucumber cultivars. Salinity had an important role in reduction the growth and yield of cucumber especially in arid and semiarid regions. Salinity can affect physiological processes. In order to study the effects of salinity stress on parameters of cucumber germination, the experiment was carried out in a completely randomized design with factorial layout at the laboratory of Payame Noor University, Iran. The factors include salinity in 4 levels (0.5, 4.4, 6.5, 10 dS/m) and cucumber cultivars in 5 levels (Keyhan, Danito, Storm, Gohar and Kian) with three replications. After placing the seeds in Petri dishes and adding the saline water, then they were transferred to the germinator for 14 days with temperatures of 25 degrees and the humidity 30%. The result of analysis showed that there were significant differences between genotypes for all attributes. Also salinity significantly reduced the percentage and speed of germination, fresh and dry weights of root and shoot, root and shoots lengths, fresh and dry weights of seedling on all studied cultivars. The cultivars defined that Kian, Danito and Keyhan cultivars were the tolerant to salinity and Gohar and Storm is not resistant to salinity.

Ratnakar *et al.* (2013) carried out an experiment with *Triginella foenum-graecum*, commonly known as methi or fenugreek. The effect of different salinity levels on germination and early seedling growth of *Triginella foenum-graecum* were studied. Seeds were placed for germination and the seedlings were allowed to grow for seven days at different levels of NaCl salinity (0mM to 100mM). Though the lower concentrations of NaCl (up to 40mM) did not affect percentage germination, the germination was found to be delayed. At higher salinity levels, inhibitory effect on germination was recorded to an extent that seeds did not germinate at 80mM and above concentrations of NaCl. Gradual decrease in root length, shoot length, fresh weight and dry weight of the seedlings was observed with increasing concentrations of NaCl in the growth medium.

Moosavi *et al.* (2013) carried out an experiment to study the effect of the environmental stress such as salinity of soil or water in further areas of the world, especially arid and semiarid regions. In order to study salinity stress on *Nigella sativa* L. germination indices was carried out under controlled conditions (germinator) in Birjand Branch of Islamic Azad University, Iran in 2011. To create salinity stress, sodium chloride (NaCl) at five levels of 0 (as control), 2, 4, 6 and 8 dSm^{-1} were used. Effect of salt levels on investigated traits was significant. Mean comparison for these traits showed that the application of 8 dSm^{-1} salinity resulted in the loss of seedling length, seedling weight, germination percentage, germination rate and seed viability index of *Nigella sativa* L. seeds by 21, 33.3, 13.2, 32.7 and 31.3% respectively, as compared to control treatment. In total, it can be concluded that salinity stress significantly decreased germination and growth parameters of seedlings of *Nigella sativa* L.

Moradi *et al.* (2013) carried out an experiment in order to evaluate the effects of NaCl salinity on germination and early seedling growth of chickpea cultivars. The results indicate that effect of cultivar × salinity were not significant on germination percentage and seedling dry weight. Cultivars and salinity had significant effect on seed germination and seedling dry weight, separately. The highest root and shoot length and shoot dry weight were related to “Arman” and “Bevanij” cultivars, respectively. The highest and lowest value for the root dry weight represented from Hashem and Greet cultivars. It was concluded that genetic variation exists among them in terms of early seedling growth rate under stress condition. Among the cultivars, Arman showed higher resistance to increase of salinity.

Omran *et al.* (2013) studied the effect of salinity stress on seeds germination and plant growth of coriander (*Coriandrum sativum* L.). For this purpose, four treatments of different concentrations of NaCl were used, namely, 0, 1000, 2000, 3000, and 4000 ppm of NaCl. Seeds germination, roots number and length, plant strength, number of leaves, plant length, shoot tip necrosis, and the percentage of survivals were recorded. Results showed that all growth parameters were reduced by increasing the NaCl concentration except for the percentage of shoot tip necrosis which was increased with a significant difference among all treatments. Coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

Nasser *et al.* (2012) showed that plant growth and seed germination are severely affected by saline conditions. Local tomato cultivars could be better adapted to salt stress. For this reason, to test that, the effect of four levels of salinity (0, 50, 100 and 150 mM NaCl) on seed germination, plants growth (relative fresh and relative dry weight), K^+ and Na^+ content and photosynthetic rate of the three local cultivars (Heb, Mar, Ram and J1) and one commercial cultivar (Mar) was studied. Significant difference in G_{50} of Heb cultivar was seen at 50 and 100 mM NaCl when compared with the other four cultivars and the only one achieved 50% germination at 150 mM NaCl. Salt stress reduced plant growth of all cultivars, but Ram and Mar cultivars were characterized as the most tolerant and sensitive, respectively. No significant difference was seen in K^+/Na^+ ratio among four cultivars tested, but Ram showed the maximum value of 5.72 and 35.09 at 50 and 100 mM NaCl, respectively. Ram also showed better photosynthesis rate at 50 and 100 mM NaCl, respectively than the other four cultivars.

According to Zhani *et al.* (2012) salinity affects germination and seedling growth and yield of several crop species, such as pepper. A study was carried out to evaluate the effects of NaCl on seed germination, seedling growth and ionic balance of three Tunisian chili pepper (*Capsicum frutescens*) cv: Tebourba, Korba and Awlad Haffouz. Results showed that different salinity stress levels had significant effect on germination percentage and germination time. In pot experiment, increasing NaCl concentration, for all cv, induced a significant decrease on plant height, root length, leaves number, leaf area and chlorophyll amount. The fresh and dry weights are also affected. In addition, salinity increased Na+ and Cl^- levels but decreased K+ level in roots and shoots. Awlad Haffouz cv had the highest K+/Na+ ratio compared to cv Korba and Tebourba and it has showed the best response under salt stress during germination and growth stage which lets it to be the most tolerant cv.

Kandil *et al.* (2012) carried out an experiment to study the effect of salinity on seed germination and seedling characters of some forage sorghum cultivars and founded that increasing salinity levels from 0 to 15 dSm^{-1} significantly decreased germination percentage, germination index, seedling vigor index, energy of germination, shoot and root lengths, shoot and root fresh weights, shoot and root dry weights and relative dry weight, the control treatment recorded the highest averages of these characters. Thus, the lowest averages of these characters were recorded with highest salinity levels i.e. 15 dSm^{-1}. Seedling height reduction percentage was increased significantly with increasing salinity levels from 0 to 15dSm^{-1}.

Ahmed *et al.* (2012) carried out an experiment on finding out impact of salinity on seed germination and early seedling growth of sorghum to investigate salinity stress on sorghum germination indices. In his experiment Seed germination percentage, seedling root dry weight and seedling shoot dry weight were measured and reported that low level of salinity (2 dSm^{-1}) increased seed germination percentage, while the high levels (4, 8 and 16 dSm^{-1}) inhibited the seed germination significantly. He also found that the strongest inhibition of germination occurred at the higher salt concentrations and growth of young seedlings was also reduced, especially at the higher salt concentrations.

Tabatabaei and Anagholi (2012) carried out an experiment to find out effects of salinity on some characteristics of forage sorghum and reported that germination rate of sorghum plant is not reduced up to 5 dSm^{-1} and it can tolerate the soil salinity up to 8.6 dSm^{-1} without any reduction to its yield. They also reported that each increase in salinity level above the salt tolerance threshold reduced the rate of germination by 1.64 percent. The highest length for root and shoot was observed for the control and 5 dSm^{-1}, respectively.

Singh *et al.* (2012) carried out an experiment on sorghum in order to investigate the potential for genetic salt tolerance during the germination and early vegetative growth and observed that all cultivars germinated in all salinities but at 10 and 12 EC level of salinity, the highest and lowest germination percentage was obtained for CSV-15 and PANT-1 cultivars respectively. It was also found that salt stress significantly decreased root length, shoot length, and seedling dry weight of sorghum cultivars. In the presence of high salt concentration (10 and 12 EC), CSV-15 and HC-171 cultivars showed the greatest shoot length, root length, and total dry weight. At the first development stage, the shoot growth of sorghum cultivar was more adversely affected compared to the root growth by salt stress.

Keshavarzi (2012) examined the effect soil salinity, one of the most important constraints that limit crop production in arid and semi-arid regions. Seed germination is a critical stage in the life of plants and salt tolerance during germination is crucial for the establishment of plants that grow in saline soils. The study was carried out in order to test the effects of different salinity levels on germination and early growth of lettuce (*Lactuca Sativa L.)*. Results showed that by increasing salinity, percentage and rate of germination decreased, so that, in the 150 mM of salinity level, germination reached to minimum (8.33%). Other measured parameters such as plumule length, radicle length, dry and wet weight decreased as well.

Ambede *et al.* (2012) studied the effects of NaCl salinity on seed germination, growth, physiology, and biochemistry of two bambara groundnut landraces (*Vigna subterranea* L) Kakamega (white seed coat) and Mumias (red seed coat), with the aim of establishing traits, which can provide a basis for breeding to salt tolerance in groundnuts. The study was carried out under laboratorial and greenhouse conditions. Bambara groundnut seeds and plants were subjected to five concentrations of NaCl solutions with several electrical conductivities: 0 (control), 6.96, 12.93, 19.89, and 25.86 dSm^{-1}. Germination percentage, growth, chlorophyll fluorescence, and leaf chlorophyll content were determined. Sodium chloride salinity significantly decreased germination and plant growth in both landraces. Mumias had significantly higher total chlorophyll, chlorophyll a and b content compared to Kakamega landrace. Overall, Mumias' landrace seeds seemed to be more salt-tolerant at higher salinity levels compared to Kakamega. A greater reduction in growth in Mumias than in Kakamega is a possible indicator for salt tolerance. The chlorophyll fluorescence parameters may not be used to identify salt sensitivity between the two landraces. The results indicated that leaf area and seed germination were suitable parameters for screening the two Bambara landraces for salt tolerance.

Pot experiments were carried out by Bagayoko (2012) at Niono Agronomic Research Station to determine soil alkalinity/salinity effects on seed germination and seedling growth of vegetable crops. Three types of soil with physical sign of salt effects were used for these experiments: salt affected black soil, salt affected white soil and soil presenting no physical sign of salinization. The test crops were 5 varieties of tomato, 5 varieties of cabbage, 5 varieties of onion, 5 varieties of okra and 2 varieties of red pepper. Three types of experiments were carried out: germination tests, seedling survival test and soil amendment test. The results of the study showed that the varieties of the different crop species generally are very sensitive to salt stress and none of them showed sign of resistance to salinity or alkalinity stress. While all species had high percent germination (95 to 98%) in the non-affected soil, none of them germinated in black or white salt soils indicating the seed quality was not a problem. Tomato, cabbage and onion are particularly sensitive to germination stage and seedling stage. Soil washing could mitigate salt effects on seedling growth but does not seem adequate for the total germination of seeds. Combination of organic amendments and soil washing reduced salt effects but did not ensure satisfactory plant growth conditions. It was concluded that in the high alkaline soil, tomato, cabbage, onion and red pepper crops are not suitable.

Keshavarzi *et al.* (2011) studied the effect of salt (NaCl) stress on germination and early seedling growth of spinach (*Spinacia oleracea L.*). Salinity is one of the major environmental factors that lead to a deterioration of agricultural land and reduction in crop productivity worldwide. The study was carried out in order to test the effects of different salinity levels on germination and early growth of Spinach seedlings. Experimental treatment includes 4 levels of NaCl concentration (0, 50, 100 and 150 mM). Result showed that the percentage and speed of germination, plumule length, radicle length and heaviest wet and dry seedling weights were higher in control treatment. At 150 mM and more concentration, germination decreased significantly. This reduction in germination indicates this plant’s extreme insensitivity to salinity, so it isn’t advisable to cultivate it in saline soil.

Yildirim *et al. (* 2011) conducted an experiment to evaluate the effect of NaCl salinity on germination and emergence of *Physalis ixocarpa* and *Physalis peruviana*. Seeds of

P. ixocarpa and *P. peruviana* were germinated by the use of 0, 30, 60, 90, 120 and 180 mM NaCl solutions in Petri dishes. Final germination percentage (FGP) decreased with the increase in NaCl concentration. Both species germinated at the ranges of salinity. *P. peruviana* gave the greater germination percentages under salt stress than *P. ixocarpa*. NaCl salinity at different concentrations adversely affected germination rates. For seedling growth, seeds of both species were sown at 10 mm depth in plastic trays filled with peat to determine final emergence percentage (FEP). The trays were irrigated manually to saturation every day with 0, 30, 60, 90, 120, 150 or 180 mM NaCl solutions to maintain the level of salinity. Salinity affected seed emergence and seedlings growth more than seed germination. The study showed that no emergence of *Physalis* was observed at 90, 120 and 180 mM NaCl salinity. Fresh and dry weights of normal seedlings were also evaluated. Salt stress significantly decreased the plant fresh and dry weight of both species. Based on the results of the experiment, it can be concluded that seedling emergence and growth is more sensitive to salt stress than seed germination in *Physalis*.

An experiment on seeds of four spinach cultivars including Green Gold, Larisa, Mikado and Ohio was conducted by Turhan *et al.* (2011) to investigate the effects of different NaCl concentrations (0, 50, 100, 150 and 200 mM) on their germination percentage, germination energy, 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 energy, germination index, and relative germination rate and germination time. Germination percentage and relative germination rate features of spinach cultivars were not influenced by 0–50 mM NaCl concentration, but germination energy values showed small decreases. In those features important decreases occurred by 100 mM concentration and the lowest values obtained at 200 mM. Despite the increase in germination time, germination index considerably decreased in accordance with the increasing salt concentrations. However, Green Gold cultivar demonstrated better performance than the other cultivars for most of measured parameters under different salinity levels.

The effects of NaCl and Na_2SO_4 on seed germination and seedling growth of 11 medicinal and aromatic crops was studied by Tsakalidi *et al.* (2011) under controlled conditions. For this, various aqueous solutions of NaCl (0.05, 0.5 and 1.5 mol) were used solely or combined as germination and growth substrates. These aqueous solutions of NaCl (0.5 and 1.5) negatively affected seed germination and seedlings growth of 11 medicinal and aromatic crops. One aqueous NaCl solution (0.5mol) impeded germination of rosemary, dill, lavender, and oregano seeds, whereas it did not affect germination of spearmint, coriander, parsley, sage, basil and cress. The highest seed germination was recorded in cress and basil and the lowest in mint and rosemary. The treatment with 0.5mol NaCl significantly increased the seedling length in mint, coriander, parsley, dill and lavender. The highest relative growth rate was observed mint, parsley, dill and lavender, and lowest in sage and cress. The result suggests that germination and seedling growth of the 11 species responded differently to low and moderate levels of NaCl.

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, dry matter percentage (DM), osmotic potential and proline contents 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. To evalute the role of ethylene and glutamine in seed germination and radicle growth under salt stress effect of 1-aminocyclopropane-1-carboxylic acid, Ethephon and glutamine on germination and radicle growth of cucumber (*Cucumis sativus* L.) seeds in the absence and presence of 200 mM NaCl were investigate by Chang *et al*. (2010). Seed germination was markedly inhibited by salt stress, and this effect was alleviating by ACC and Ethephon. In contrast to seed germination, aminocyclopropane-1-carboxylic acid and Ethephone had little effect on radicle growth under salt stress. These findings demonstrate that ethylene is associated with suppression of seed germination under salt stress and that L-glutamine interacts with ethylene in regulation of seed germination under salt stress.

Wambua *et al.* (2010) carried out an experiment on hydroponic screening of sorghum cultivars for salinity tolerance to evaluate the salinity tolerance of four selected Kenyan sorghum cultivars (Mtama-1, El-gadam, Seredo and Serena) obtained from KARI-Katumani and observed that *Sorghum bicolor* cultivars differ in their ability to grow under different levels of salinity during the early seedling growth stages. He also observed that root development (presence of root hairs and root length) was significantly inhibited at 10 and 15 dSm^{-1} for both Mtama-1 and El-gadam while Seredo and Serena were less affected.

Jouyban (2010) carried out an experiment to study the effect salinity in arid and salt-affected soils where salinity was caused by poor quality of irrigation water. Saline soil induces physiological and metabolic disturbances in plants, affecting development, growth, yield, and quality of plants. Plants affects adversely as a result of salinity, seed germination, survival percentage, morphological characteristics, development and yield and its components. In general, salt stress decreases the photosynthesis and respiration rate of plants. The salinity tolerance depends on the interaction between salinity and other environmental factors.

According to Bybordi (2010) NaCl salinity affected germination, vegetative growth, elements, concentration and proline accumulation in 5 canola cultivars. The results showed that different salinity stress levels had significant effect on germination percentage, germination speed, shoot and root length.

Ahmed (2009) reported that salinization of soil was one of the major factors limiting crop production particularly in arid and semi-arid regions of the world.

Kaymakanova (2009) studied the response of three bean cultivars (*Phaseolus vulgaris* L.) to equimolar NaCl and Na_2SO_4 salinity to study the germination and early seedling growth. Seeds were germinated and grown in Petri plate on filter paper with solution of the respective treatment and incubated at 25°C in a thermostat. Each treatment was replicated three times. The seedlings were harvested and their growths, as well as their germination and respiration rates were measured. All treated cultivars registered decrease in the percentage of germination, seedlings growth and respiration rate.

Six different NaCl levels (0, 5, 10, 20 , 30 and 40 dS/m) and two seed types (hulled and dehulled) of sunflower seeds of opal, shelly and pactol (oily) were tested by Kaya (2009) to determine the effects of the hull on salinity tolerance during germination, germination percentage, mean germination time (day), root and shoot length were investigated. Kernel type seeds exhibited higher germination percentage, longer root and shoot length and lower mean germination time compared to the achene type seeds at all NaCl levels. Hull was responsible for delaying germination and water uptake by seeds while it had no role in lowering the toxic effects of NaCl during germination.

A laboratory study was carried out by Mohammadi (2009) to investigate the effect of NaCl priming on seed germination and seedling growth of onion. Onion seeds primed with 1% NaCl solution for 24 hours at 20^{o}C. Then primed and non primed seeds irrigated with 7 different saline solutions consisted of 0 (control), 0.25, 0.50, 0.70, 1.00, 1.25 and 1.50% concentrations of NaCl. Results indicated that NaCl priming increased germination percentage, germination rate and seedling dry wt. 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 level of 1.25% salinity, the reduction for germination percentage, germination rate and seedling dry wt. 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 % 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 onion.

Noreen and Ashraf (2008) carried out an experiment on alleviation of adverse effects of salt stress on sunflower and reported that salt stress perturbed a multitude of physiological processes.

Sivritepe (2007) carried out an experiment where seeds of onion cultivars 'Valencia' and 'TEG-502' were primed for 3 days at 15 C^0 with NaCl solution (EC: 18 dSm^{-1}) to examine the response of the seedlings to salinity. Non-primed (NP) and primed (P) seeds were sown in plastic trays containing Sphagnum peat and sand. The plastic trays were placed in a heated greenhouse and watered with the NaCl solution at four salinity levels (0.3, 4.5, 9.0 and 13.5 dSm^{-1}) 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.

A field experiment was carried out 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).

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.

Robina and Sheela (2006) carried out an experiment to investigate the effect of sodium chloride (NaCl) on germination, early seedling growth and ion uptake of seeds of two genotypes of onion. Salinity decreased the percentage of germination, germination speed, emergence index, and roots and shoot length, fresh and dry weight, vigour index and salt tolerance index of seedlings. The highest percentage of germination was obtained at 0 and 100 mM NaCl and a further increase in salinity resulted in a gradual decrease in germination. Fresh and dry weight of seedlings was highest in non-saline (control) condition. Salinity reduced overall growth of the seedlings which was highly significant at higher salinity levels, the highest being at 150 mM NaCl. The vigor index was the lowest at 150 mM NaCl. On the contrary a gradual and progressive accumulation of Na^+ and Cl^- ions in both shoot and root was observed. Overall, cluster bean is a moderately salt tolerant crop whose response to salinity was associated with maintenance of high Na^+/Cl^- ratios in both shoots and roots.

Jamil *et al.* (2006) studied on four vegetables species 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, and root and shoot lengths and fresh root and shoot weights.

The effects of sea water salinity (1500, 2500 and 3500 ppm) on the growth of tomato cultivars were 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. Seedling 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 solution.

Saline soil is characterized by the presence of toxic levels of sodium and its chlorides and sulphates. Over 800 million hectares of land throughout the world (6% of total cultivated land area) is salt affected either by salinity (397 million ha) or the associated condition of sodocity (434 million ha) (FAO, 2005).

Ghassan Al-Lahham (2005) reported that increased salinity level in growth medium caused harmful effects on germination percentage, root, shoot, and plant length for the tested sorghum genotypes, due to significant decreases in water uptake by root, relative water content, increase in water saturation deficit, reduced leaf area / plant, leaf area ratio (LAR), relative growth rate (RGR), net assimilation rate (NAR), total chlorophyll (a+b) content, root and shoot dry matter accumulation. All these, were accompanied with high accumulation of Na^{+} ions, a decrease in K^{+} ions, and a decrease in selectivity ratio of K^{+} / Na^{+}.

Chang and Randle (2005) carried out an experiment to investigate how sequentially exposing of plants to sodium chloride (NaCl) would affect growth and the flavor quality of onion (*Allium cepa* L). The performance of seven onion (*Allium cepa*) genotypes ('Pusa White Flat', 'Agri Dark Red', 'PBR 5', 'Amrawati', 'Pusa White Round', 'Phule Safed' and 'Agri Light Red') was evaluated by Sharma *et al*. (2000) during rabi season 1995 and 1996 both under alkaline (pH 9.20, 9.45 and 9.70) and salinity (ECe 3.5 and 5.2 dS/m) stresses besides a non-stress control.

An experiment was carried out by Muhammad *et al.* (2005) to investigate the salinity tolerance of onion during germination and early seedling growth in four treatments of salinity including 0.0 (control), 4.7, 9.4 and 14.1 dSm^{-1} NaCl. The results showed that different treatments of salinity had considerable effect on the germination, germination rate, shoot and root length, shoot and root fresh weight, leaf area and number of leaves of onion. Germination percentage of these three species showed considerable decrease with increasing salinity up to 14.1dSm^{-1} NaCl. The required time for germination also increased with increasing levels of salinity. The seedling growth of three species was significantly inhibited by all salinity levels. Particularly at 14.1 dSm^{-1} NaCl root and shoot length of all species were considerably reduced. Shoots growth of all these three plant species were more affected as compared to root growth at all salinity levels. Fresh shoot and root weight, leaf area and number of leaves were also severely affected at all salinity treatments.

According to Omami (2005) good plant stands are difficult to obtain in saline environments due to poor germination and seedling emergence. The response of germination to salinity stress varies with species and variety, salt type, salt concentration and environmental conditions. Salinity tolerance during germination and early seedling growth was examined for six genotypes of amaranth namely

In Amaranthus tricolor, Accession '83, *A. dubius, A. hypochondriacus, A. cruentusand A. hybridus*. Ten salt treatments, 0, 25, 50, 100, and 200 mM NaCl or Na_2SO_4 were applied and germination experimented was carried out in Petri dishes at 27^{0}C for 10 days. Enhancement of germination was observed at 25 mM NaCl in *A. tricolor*, *A. hypochondriacus*, *A. cruentus*, and at 25 mM Na_2SO_4 in *A. hybridus and A. dubius*. The strongest inhibition of germination occurred at the highest salt concentration (200 mM), where only 17% of *A. tricolor* and 24% of Accession '83 seeds were able to germinate in NaCl. No genotype germinated at 200 mM Na_2SO_4. Accession '83 had the highest final germination while *A. hybrids* showed the least. A seedling emergence and growth experiment was carried out in a greenhouse, in plastic pots containing sand. Four genotypes (*A tricolor*, Accession '83, *A. cruentusand A. hypochondriacus*) were exposed to NaCl and Na_2SO_4 at concentrations of 0, 25, 50, 100 mM. Emergence and seedling survival were reduced by increasing salt concentrations. There was no emergence at 100 mM Na_2SO_4. Stem and root lengths as well as shoot fresh mass were reduced by increasing salt stress. *A. tricolor* was the most sensitive genotype, with the seedlings surviving only in the control and 25 mM Na_2SO_4 treatments, while *A. hypochondriacus* was the most tolerant with 100% and 95% survival at 25 and 50 mM Na_2SO_4 respectively.

Salinity tolerance during early during germination and early seedling growth was evaluated by Jamil *et al.* (2005) for *Brassica sp*. such as cabbage, cauliflower and canola using four treatments of salinity including 0.0 (control), 4.7, 9.4 and 14.1 ds/m NaCl. The results showed that different treatments of salinity had considerable effects on the germination, germination rate, root and shoot length, shoot and root fresh weight, leaf area and number of leaves of canola, cabbage and cauliflower. Germination percentage in all three species showed considerable decrease with increasing salinity upto 14.1 ds/m NaCl. This reduction was more in cauliflower as compared to cabbage and canola. The required time for germination also increased with increasing levels of salinity. The seedling growth of three species was significantly inhibited by all salinity levels particularly at 14.1 ds/m NaCl, root and shoot length of all species were considerably reduced. Shoots growth of all three plant species was more affected as compared to root growth at all salinity levels. Fresh root and shoot wt., leaf area and number of leaves were also severely affected at all salinity treatments.

A laboratory study was carried out by Maiti *et al.* (2004) to evaluate the germination and seedling growth of different vegetable species under different salinity conditions. The species showed significant variation in their tolerance of salinity. Celery showed the highest level of tolerance at the germination stage followed by cabbage, beet, green tomato and lettuce. Small gourd, calabaza [squash], onion, spinach, pea and carrot were sensitive to salinity. Coriander was highly sensitive to salinity.

According to Yilmiz *et al.* (2004) NaCl affected the growth and development of pepper varieties for germination and seedling growth. The parameters measured were germination rate, radical length, hypocotyl length, radical fresh weight etc. It was found that high NaCl had a negative effect on plant growth and development. In the seedling stage, the negative effects were on relative growth rate for root and shoot length, relative growth rate for fresh and dry wt. of roots, shoots and whole plants, fresh and dry wt. of shoot to root indices, relative growth rate for leaf number and area. The results of the research of demonstrated different NaCl tolerances for the varieties tested.

Lee *et al.* (2003) carried out an experiment on effect of NaCl stress on germination characteristics of onion in China, reported that germination energy, germination percentage, germination index , viability index and seedling growth decreased with increasing NaCl concentration, but the germination energy and germination percentage of some cultivars were higher than the control. Radicle growth was inhibited with salt stress.

Mutawa *et al.* (2003) studied the effect of irrigation water salinities on germination and seedling growth of chickpea. Germination and seedling growth responses of 30 genotypes of chickpea were determined at a range of irrigation water salinities. All genotypes showed salt tolerance either at germination or seedling growth stage at low level of salinity (4 dSm^{-1}). Genotypes C10, C14, C16, C17, C19 and C29 also showed tolerance to medium level of salinity (6 dSm^{-1}). Only two salt tolerant genotypes out of those tested proved to be C28 and C29 which perform well both at germination and seedling stage under all salt levels. There were also significant genotypic differences in seedling growth on acid washed sandy soil with increasing NaCl, $CaCl_2$ and $MgSO_4$ over the same range of salinity as used to test germination.

Garratt *et al.* (2002) and Mittova *et al.* (2003) reported increased activities of the anti oxidative enzymes in plants under salt stress. They found a correlation between these enzyme levels and salt tolerance. Many changes have been detected in the activities of antioxidant enzymes in plants exposed to salinity.

Demidchik, Davenport and Tester (2002) reported that in Bangladesh, 2.85 million hectars of land are saline affected and there is a great possibility to bring these areas under cultivation with salt tolerant crop varieties and proper reclamation and management.

Yildrim *et al.* (2002) stated that the seed germinability changed depending on species and was affected by the salinity of applied water. The germination percentage decreased linearly as salinity increased. At different salt and temperature levels, garden cress had the highest germination percentage. Celery and parsley did not germinate at any salt and temperature levels. Generally, the higher the temperature and salt level the greater the reduction of the germination percentages. Interactions between NaCl concentrations and temperatures were significant at P=0.001 in all vegetable species except for onion.

Schmidhalter and Oertli (2001) examined the effects of salinity and moisture stress and their interaction on seed germination and seedling growth of carrot. Variable soil matric and osmotic potentials were either obtained by equilibrating soil salinized to different degrees on a 0.5 Pa ceramic plate soil moisture extractor or by adding different amounts of salt. Germination decreased significantly in the investigated silty soil at soil moisture potential higher than -0.01 Mpa, whereas osmotic potentials as low as -0.5 Mpa did not influence germination. It is concluded that germination and seedling growth are differently affected by comparable matric and osmotic stress and that water stress exerts a more negative effect than salt stress.

The performance of seven onion (*Allium cepa*) genotypes ('Pusa White Flat', 'Agri Dark Red', 'PBR 5', 'Amrawati', 'Pusa White Round', 'Phule Safed' and 'Agri Light Red') was evaluated by Sharma *et al*. (2000) during rabi season 1995 and 1996 both under alkaline (pH 9.20, 9.45 and 9.70) and salinity (ECe 3.5 and 5.2 dS/m) stresses besides a non-stress control.

Cuartero and Ferna Andez (1999) studied the effects of salinity on growth and fruit production of tomato to develop the cultural techniques. Salinity reduced 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 $8dSm^{-1}$. Seeds primed with 1M NaCl for 36 hrs seems advisable to established a crop by direct sowing in saline soils and seeding conditioning either by exposure to moderately saline water exposure or by withholding watering until seedlings wilt for 20±24 hrs can be recommended for crops that are to be established by transplanting. 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.

According to Carvajal *et al.* (1998); Yeo (1998); Grattan and Grieve (1999) the direct effects of salts on plant growth may be divided into three broad categories: (i) a reduction in the osmotic potential of the soil solution that reduces plant available water, (ii) a deterioration in physical structure of the soil such that water permeability and soil aeration are diminished, and (iii) increased in concentration of certain ions that have an inhibitory effect on plant metabolism. The relative contribution of osmotic effects and specific ion toxicities on yield are difficult to quantify.

The activity of antioxidant enzymes was reported to increase under salinity in shoot cultures of rice, wheat (Meneguzzo and Navarilzzo, 1999) and pea (Hernandez *et al.*, 1999), but decreased wheat roots (Meneguzzo and Navarilzzo, 1999) or was unaffected as in the case of SOD in cucumber. The differences in these results may be for the fact that salinity effects depend on a number of factors. The mechanism of salinity affects the antioxidant responses is not yet clear. Meneguzzo and Navarilzzo (1999), however, proposed that it might be either via (i) the effect of CC toxicity on photo system or (ii) the change in membrane integrity caused by a high Na^+ to CW ratio.

Katembe *et al.* (1998) carried out an experiment to study the effect of salinity, one of the environmental factors that have a critical influence on the germination of halophyte seeds and plant establishment. Salinity affects imbibition, germination and root elongation. However, the way in which NaCl exerts its influence on these vital processes, whether it is through an osmotic effect or a specic ion toxicity, is still not resolved. Dimorphic seeds of the halophytes *Atriplex prostrata* and *A. patula* were treated with various isoosmotic solutions of NaCl and polyethylene glycol (PEG). For each treatment, imbibition, germination rate, percent germination, germination recovery and nuclear area of root tip cells were compared. Higher concentrations of NaCl were inhibitorier to imbibition, germination and seedling root elongation than iso-osmotic PEG solutions. All seeds recovered from a pre-treatment with NaCl and PEG solutions, except large seeds of *A. prostrata* which failed to germinate following transfer from NaCl. NaCl caused a greater increase in nuclear volume than iso-osmotic PEG solutions. These data suggest that the influence of NaCl is a combination of an osmotic effect and a specic ion effect.

The effectiveness of directional phenotype selection to improve tomato (*Lycopersicon esculentum* Mill.) seed germination under salt-stress was investigated by Foolad (1996). Seed of F_2 and F_3 progeny of F_1 hybrids between in a salt tolerant (PI174263) and a salt-sensitive (UCT5) tomato cultivar were evaluated for germination response at three stress levels of 100 (low), 150 (intermediate), and 200 mM (high) synthetic sea salt (SSS). At each salt-stress level, the most tolerant individuals, as determined by the germination of seed were selected. Selected individuals (F_2 or F_3s) were grown to maturity and self-pollinated to produce F_3 and F_4 progeny families. The selected progenies from each experiment were evaluated for germination at four treatment levels of 0 (non-stress), 100, 150, and 200 mM SSS and were compared with unselected populations. The results indicated that similar or identical genes with additive genetic effects contributed to rapid germination response of tomato seeds at different salt-stress levels. Thus, selection at one stress level resulted in progeny with improved germination at diverse salt-stress levels.

According to Dubey (1994) salt causes both ionic and osmotic effects on plants and most of the known responses of plants to salinity are linked to these effects. High soil salinity and low soil water combining had an adverse effect on plant growth but the biomass production was appreciably high (57 to 75% of control) even under high soil salinity (EC 10 dsm^{-1}) when sufficient water was available. (Gupt *et al.*, 1986).

The differences in crops growth may be for the fact that salinity effects depend on a number of factors. Salt type, concentration, plant genotype, growth stage and environment (Shannon *et al.*, 1994).

According to Greenway and Mons (1980), salt sensitivity in non-halophytes may result from either (i) inability of osmotic regulation, which may result from either an insufficient uptake of salt ions or a lack of synthesis of organic solutes being used as osmotica, or (ii) injury caused by inorganic ions, is absorbed by the cell and not compartmentalized.

From the above review we can assert that high levels of soil salinity can significantly inhibit seed germination and seedling growth due to the combined effects of high osmotic potential and specific ion toxicity. This environmental factor has a critical effect on the germination of halophytic seeds and plant establishment also affects imbibition and root elongation of plants.

CHAPTER 3

MATERIALS AND METHODS

The present chapter deals with the materials used and methodology followed in conducting the experiment, the location of experiment, experimental materials, methodology, and design of experiment, data collection and statistical analysis of collected data. The experiment was conducted at Agronomy Laboratory, Sher-e-Bangla Agricultural University (SAU), Dhaka. Effect of different concentrations of NaCl on seed germination and subsequent seedling growth of six varieties of tomato were investigated. Details of different materials and methodologies followed in conducting the experiment are presented below.

3.1 Experimental site

The present research work was conducted at the Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from January to March, 2015. The temperature was maintained at 25±1 C^0 in incubator during the winter season.

3.2 Treatments of the experiment

Variety: Six varieties of tomato seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Insect and disease free healthy seeds were used for the experiment. The varieties were as follows:

V_1 = Bahar

V_2=BARI Tomato -1 (Manik)

V_3=BARI Tomato -2 (Ratan)

V_4=BARI Tomato -6 (Choti)

V_5=BARI Tomato -9 (Lalima)

V_6= BARI Tomato -12 (Shidur)

Salt: Sodium chloride (NaCl, MW 58.44 g/mol) was used for this experiment.

Different level of salinity was considered as experimental treatment. The salinity was expressed in milli mole (mM).

S_0= Distilled water (Control)
S_1 = 25 mM

S_2 = 50 mM

S_3 = 100 mM

S_4 = 150 mM

3.3 Experimental design

The two factor experiment was conducted following Completely Randomized Design (CRD) with three replications. Twenty five seeds of each variety represented one replication.

Petri dishes for main sample = 5 (salinity levels) x 6 (Varieties) x 3 (replications) = 90

Petri dishes for destructive sample = 5 (salinity levels) x 6 (Varieties) x 3 (replications) =

So, total numbers of Petri dishes for both sample= 90 + 90 = 180

3.4 Preparation of the solutions

Required amount of commercial salt (NaCl) was estimated and added to distilled water to make the required solution of NaCl. Amount of salt (NaCl), used in the preparation of different salt solution is given into the following table:

Table 1. Preparation of salt solution for making various experimental treatments

Treatments	Salinity level (mM)	Amount of NaCl gL^{-1} in distilled water
T_1	0 (control)	0.0
T_2	25	1.46
T_3	50	2.92
T_4	100	5.84
T_5	150	8.76

3.5 Procedure of seed germination

Germination is the emergence of seedling which was conducted using Petri dish method.Twenty five seeds of each of tomato varieties were germinated in clean sand placed in Petri dishes (9 cm diameter). Each treatment was replicated three times. Different salt solutions with different mM were used for particular treatment of seeds and distilled water was used in control. Each Petri dish was moistened with 5 ml of different salt concentrations. The moisture level and salt solution were assessed daily and respected solutions were applied time to time as per requirement. The Petri dishes were kept at under constant incubator temperature set at 25± 1^{o}C for 12 days in the laboratory.

3.6 Methods of data collection

Data regarding germination percentage, coefficient of germination (CG), radicle length, plumule length, radicle fresh weight, plumule fresh weight, plumule dry weight, radicle dry weight, and seedling vigor index were recorded at 4 days interval up to 11 days after sowing (DAS).

3.6.1 Germination percentage

The Petri dishes were menitored every day and the numbers of germinated seeds were recorded at 10:30 a.m. After 4 days of seed setting in Petri dishes, few of the seeds were germinated. Within 11 days of seed setting in Petri dishes the maximum number of seeds were germinated. A seed was considered to be germinated as seed coat ruptured, plumule and radicle came out and were >2 mm long. Germination is expressed in percentage. The germination percentage was calculated using the following formula-

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds set for test}} \times 100$$

3.6.2 Coefficient of germination

Co- efficient of germination (CG) was calculated using the following formula (Copeland, 1976).

$$\text{Coefficient of germination} = \frac{(A_1 + A_2 + \ldots\ldots\ldots\ldots + A_x)}{(A_1 T_1 + A_2 T_2 \ldots\ldots\ldots + A_x T_x)} \times 100$$

Where,

CG= Coefficient of germination (%)

A= Number of seeds germinated

T= Time corresponding to A

x= Number of days to final count

3.6.3 Destructive sample

Destructive sample were set for collecting data on various parameters without destroying the main sample

3.6.4 Radicle length

Randomly selected four seedlings were taken from each Petri dish to measure radicle length. Radicle length of seedlings was measured after 5 days of seed setting. Radicle lengths were expressed in centimeter (cm) with the help of a measuring scale.

3.6.5 Plumule length

Randomly selected four seedlings were taken from each Petri dish to measure radicle length. After separating the plumule, length was expressed in centimeters (cm) with the help of a measuring scale. Plumule length of seedlings was measured after 5 days of seed setting.

3.6.6 Seed vigor index

For determination of seedling vigor index, five seedlings were selected randomly from each Petri dish and their individual plumule and radicle length were measured. The vigor of the seedlings was determined by following formula of Abdul-Baki and Anderson (1973).

Vigor index= [Mean of root length (cm) + Mean of shoot length (cm)] X Percentage of seed germination

3.6.7 Radicle fresh weight

Radicles of four seedlings from Petri dish were cut and their fresh weights were expressed in milligram (mg). Weights were taken in four successive periods at 5, 7, 9 and 11 DAS with the help of digital balance.

3.6.8 Plumule fresh weight

Plumule fresh weights were recorded from 5 DAS at 2 days an interval which was continued up to 11 DAS. Plumules of four seedlings from Petri dish were cut and their fresh weights were taken in milligram (mg) with the help of digital balance. Plumule weights were taken in four successive periods at 5, 7, 9 and 11 DAS.

3.6.9 Radicle dry weight

For dry radical weight, four radicles were taken randomly from the Petri dishes and dried in an oven at 70^0C for 48 hours till the weight become constant. The radicle dry weights were measured with the help of digital balance and expressed in milligram (mg) and the mean value was calculated.

3.7 Plumule dry weight

For dry plumule weight, four plumules were taken randomly from the Petri dishes and dried in an oven at 70 C^0 for 48 hours till the weight become constant. The plumule dry weights were measured with the help of digital balance and expressed in milligram (mg) and the mean value was calculated.

3.8 Statistical analysis

Data collected during experimental period were tabulated and analyzed following MSTAT-C computer package program. The data were statistically analyzed in respect of seed germination and seedling characters to investigate the statistical significance of the experimental results. The means for all the treatments were calculated and analysis of variance for all the characters under consideration was performed by T variance test. Mean separation was performed by Least Significant Difference (LSD) test (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The present study was conducted to investigate the effects of different levels of NaCl on germination and seedling vigor of six tomato varieties. The results on seed germination percentage, germination coefficient, and seedling vigor were influenced by varieties and salt concentrations are presented in this chapter. The analysis of variances for these characters obtained from the present investigation has been presented in Appendix I-VIII

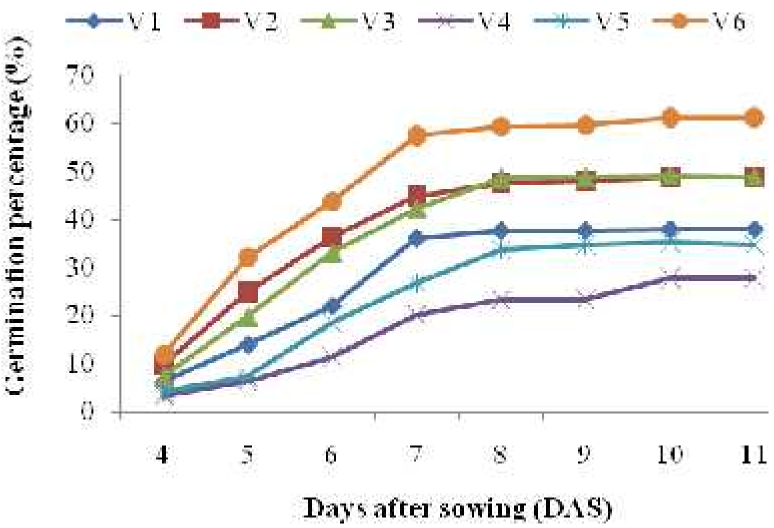
4.1 Seed germination percentage

4.1.1 Effect of variety

Effect of tomato varieties on seed germination at different days after sowing (DAS) have been presented in Figure 1. Germination started in all the varieties after three days of seed sowing. Result showed that the percentage of seed germination varied differently among the different varieties of tomato at 11 DAS, the maximum germination (61.07%) was observed in BARI Tomato-12 and the minimum (27.73%) was observed in BARI Tomato-6 at 10 DAS (Figure 1). BARI Tomato-1 was statistically identical with BARI Tomato-2 in case of seed germination at 11 DAS.

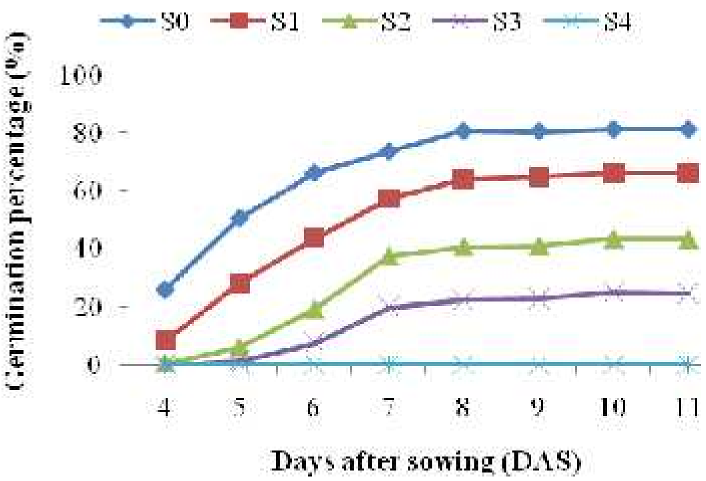
4.1.2 Effect of NaCl concentration

Germination percentage of seed was decreased with the increasing levels of NaCl concentration (Figure 2). The maximum germination percentage of seed (81.33%) was observed with the control (0 mM) concentration and the minimum germination percentage (0.00%) was observed with 150 mM salt concentration at 11 DAS (Figure 2). Significant differences were found in control (0 mM), 25mM 50mM , 100 mM and 150 mM in case of seed germination at 11 DAS.



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 1. Effect of varieties on the germination of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.35, 0.66, 1.11, 1.51, 1.67, 1.81, 1.94 and 1.93 at 4, 5, 6, 7, 8, 9, 10 and 11 DAS, respectively)



S_0=Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 2. Effect of NaCl concentration on the germination of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.32, 0.60, 1.01, 1.38, 1.52, 1.65, 1.77 and 1.76 at 4, 5, 6, 7, 8, 9, 10 and 11 DAS, respectively)

Table 2. Combined effect of varieties and NaCl concentration on germination of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Germination (%)							
		4 DAS	5 DAS	6 DAS	7 DAS	8 DAS	9 DAS	10 DAS	11 DAS
Bahar (V_1)	0 (S_0)	22.67 c	53.33 d	62.67 f	73.33 e	74.69 e	74.67 fg	74.67 f	74.67 f
	25 (S_1)	8.00 g	11.68 j	28.00 j	57.33 h	62.67 g	62.67 i	62.67 gh	62.67 gh
	50 (S_2)	0.00 j	4.00 l	16.00 l	33.33 k	34.67 k	34.67 l	34.67 m	34.67 l
	100 (S_3)	0.00 j	0.00 m	2.670 o	16.00 o	16.00 n	16.00 n	17.33 o	17.33 n
	150 (S_4)	0.0 0 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
BARI Tomato-1 (V_2)	0 (S_0)	34.67 b	73.33 b	82.67 b	90.67 b	92.00 a	92.00 ab	92.00 ab	92.00 ab
	25 (S_1)	13.33 e	46.67 f	66.67 e	78.47 d	82.67 c	82.67 de	82.67 de	82.67 de
	50 (S_2)	0.0 j	4.00 l	22.60 k	34.67 k	42.67 j	42.67 k	42.65 kl	42.67 jk
	100 (S_3)	0.0 j	0.00 m	9.33 mn	20.00 n	20.00 m	22.67 m	26.67 n	26.67 m
	150 (S_4)	0.00 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
BARI Tomato-2 (V_3)	0 (S_0)	22.67 c	50.67 e	74.67 d	73.33 e	86.69 b	86.67 cd	86.67 cd	86.67 cd
	25 (S_1)	13.33 e	28.00 g	48.00 h	57.44 h	66.65 f	66.67 hi	66.67 g	66.67 g
	50 (S_2)	0.00 j	16.00 i	34.67 i	50.67 i	54.67 h	55.34 j	57.33 ij	56.33 i
	100 (S_3)	0.00 j	4.00 l	8.00 n	29.33 l	34.67 k	34.67 l	34.67 m	34.67 l
	150 (S_4)	0.00 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
BARI Tomato-6 (V_4)	0 (S_0)	13.33 e	22.67 h	36.00 i	48.00 i	57.33 h	57.33 j	61.33 hi	61.33 h
	25 (S_1)	2.67 i	8.00 k	16.00 l	28.00 l	34.67 k	34.67 l	41.33 l	41.33 k
	50 (S_2)	0.00 j	0.00 m	4.0 o	16.00 o	16.00 n	16.00 n	25.33 n	25.33 m
	100 (S_3)	0.00 j	0.00 m	0.00 p	8.00 p	8.00 p	8.0 o	10.67 p	10.67 o
	150 (S_4)	0.00 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
BARI Tomato-9 (V_5)	0 (S_0)	16.00 d	24.00 h	50.67 g	62.67 g	78.67 d	78.70 ef	78.67 ef	78.67 ef
	25 (S_1)	4.00 h	12.00 j	26.67 j	38.67 j	50.67 i	55.34 j	56.00 j	56.00 i
	50 (S_2)	0.00 j	0.00 m	10.67 m	24.00 m	26.67 l	26.67 m	26.67 n	26.67 m
	100 (S_3)	0.00 j	0.00 m	4.0 o	8.00 p	12.00 o	12.00 no	14.67 op	12.00 o
	150 (S_4)	0.00 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
BARI Tomato-12 (V_6)	0 (S_0)	46.67 a	81.33 a	90.67 a	94.67 a	94.67 a	94.60 a	94.67 a	94.67 a
	25 (S_1)	9.33 f	62.67 c	78.67 c	86.67 c	88.00 b	88.00 bc	89.33 bc	89.34 bc
	50 (S_2)	2.66 i	12.00 j	28.00 j	66.67 f	69.33 f	70.67 gh	74.67 f	74.65 f
	100 (S_3)	0.0 0 j	4.00 l	21.33 k	38.67 j	44.0 j	44.0 k	46.67 k	46.67 j
	150 (S_4)	0.00 j	0.00 m	0.00 p	0.00 q	0.00 q	0.00 p	0.00 q	0.00 p
$LSD_{(0.05)}$		0.78	1.48	2.47	3.37	3.73	4.05	4.34	4.32
CV (%)		6.86	5.25	5.52	5.46	5.49	5.91	6.13	6.13

4.1.3 Combined effect of varieties and NaCl concentrations

The maximum seed germination (94.67 %) was found in the combination of variety BARI Tomato-12 with the control salt concentration (0 mM) and the minimum germination (0 %) was recorded by the combination of all varieties with 150 mM NaCl concentration (Table 2). V_1S_0 is statistically similar with V_6S_2; V_1S_2 is statistically similar with V_3S_3; V_3S_2 is statistically similar with V_5S_1; V_4S_3 was statistically similar with V_5S_3 ; V_2S_3 is statistically similar with V_4S_2 and V_5S_2 was at 11 days after sowing. The combined effect between variety and NaCl concentration were found significant in case of seed germination percentage of tomato (Appendix I)

4.2. Germination coefficient

4.2.1 Effect of variety

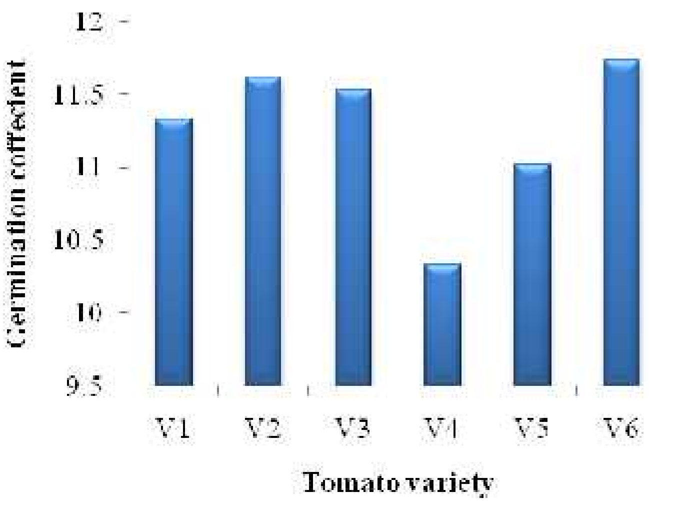
The maximum germination coefficient (11.73%) was found in the variety BARI Tomato-12 and the minimum (10.33%) was observed in BARI Tomato-6 (Figure 3). Significant differences in germination coefficient were found in the varieties BARI tomato-6 ,BARI Tomato-9 and Bahar. No significant differences in germination coefficient were found in the varieties BARI Tomato-1, BARI Tomato-2, and BARI Tomato-12 at 11 DAS (Appendix VIII).

4.2.2 Effect of NaCl concentration

The maximum germination coefficient (15.31%) was found with the control (0 mM) concentration and the minimum germination coefficient (0.00%) was noticed with 150 mM salt concentration (Figure 4). Significant differences in germination coefficient were found with 0, 25, 50, 100 and 100 mM salt concentrations at 11 DAS (Appendix VIII).

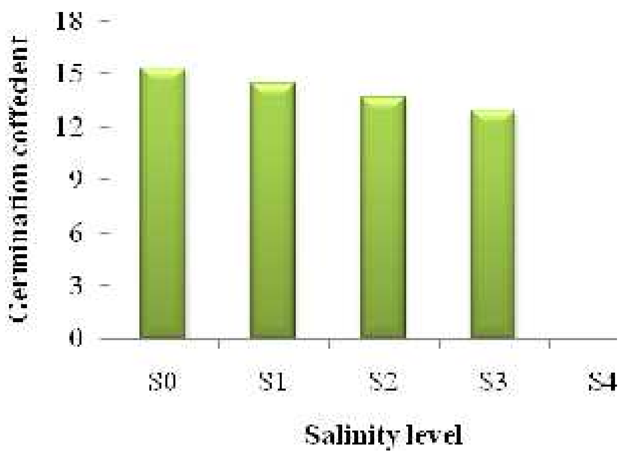
4.2.3 Combined effect of varieties and NaCl concentrations

The maximum germination coefficient (16.00%) was found in the combination of variety BARI Tomato-12 with the control salt concentration (0 mM) and the minimum germination coefficient (0.00%) was recorded by the combination of all varieties with 150 mM NaCl concentration (Table 3). V_4S_1 is statistically similar with V_6S_3; V_3S_0 is statistically similar with V_6S_1 ; V_1S_3 is statistically similar with V_2S_3, V_3S_3 and V_5S_2; V_2S_0 is statistically similar with V_6S_0 ; V_1S_2 is statistically similar with V_2S_2 , V_5S_1 and V_6S_2 at 11 days after sowing. The combined effect between variety and NaCl concentration in case of germination coefficient was found highly significant (Appendix VIII).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 3. Effect of varieties on the germination coefficient of tomato seeds ($LSD_{0.05}$=0.43)



S_0= Distilled water (Control), S1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 4. Effect of NaCl concentration on the germination coefficient of tomato seeds ($LSD_{0.05}$=0.40)

Table 3. Combined effect of varieties and NaCl concentration on germination coefficient and vigority index of tomato seeds

Variety	NaCl conc.	Germination coefficient	Vigority index
Bahar (V_1)	0 (S_0)	15.53 ab	865.4 d
	25 (S_1)	14.13 d-h	588.6 f
	50 (S_2)	13.77 e-h	288.6 hi
	100 (S_3)	13.23 g-i	101.4 m
	150 (S_4)	0.00 k	0.00 o
BARI Tomato-1 (V_2)	0 (S_0)	15.91 a	1233 a
	25 (S_1)	15.07 a-d	991.1 c
	50 (S_2)	13.77 e-h	471.5 g
	100 (S_3)	13.33 g-i	167.9 l
	150 (S_4)	0.00 k	0.00 o
BARI Tomato-2 (V_3)	0 (S_0)	15.31 a-c	983.7 c
	25 (S_1)	14.70 b-e	621.8 f
	50 (S_2)	14.16 d-g	430.5 g
	100 (S_3)	13.49 ghi	184.0 kl
	150 (S_4)	0.00 k	0.00 o
BARI Tomato-6 (V_4)	0 (S_0)	14.57 bcdef	630.7 f
	25 (S_1)	13.69 fghi	322.9 h
	50 (S_2)	12.74 i	169.1 l
	100 (S_3)	10.66 j	42.76 no
	150 (S_4)	0.00 k	0.00 o
BARI Tomato-9 (V_5)	0 (S_0)	14.55 cdef	841.0 d
	25 (S_1)	13.82 efgh	595.7 f
	50 (S_2)	13.55 ghi	228.7 jk
	100 (S_3)	13.18 hi	52.96 n
	150 (S_4)	0.00 k	0.00 o
BARI Tomato-12 (V_6)	0 (S_0)	16.00 a	1266 a
	25 (S_1)	15.23 a-c	1050 b
	50 (S_2)	13.80 e-h	730.1 e
	100 (S_3)	13.62 f-i	258.1 ij
	150 (S_4)	0.0 0 k	0.00 o
$LSD_{(0.05)}$		0.97	45.02
CV (%)		5.26	6.3

4.3 Seed vigor

4.3.1 Effect of variety

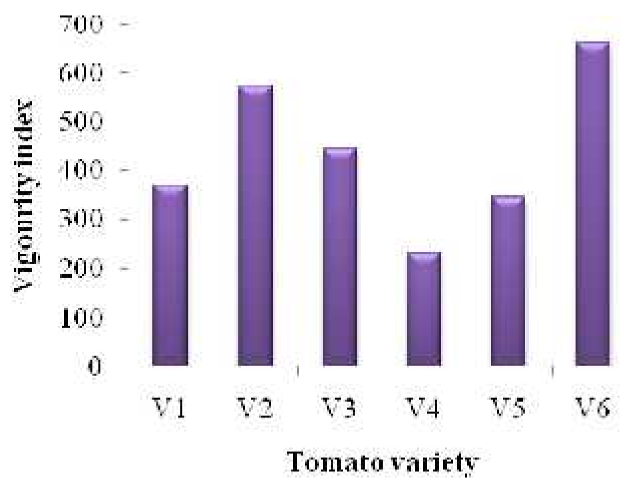
The maximum seed vigor was found in the variety Bahar and the minimum was observed in BARI Tomato-6 (Figure 5). No significant similarities in seed vigor were found among the varieties (Appendix VIII).

4.3.2 Effect of NaCl concentration

The maximum seed vigor was found with 0 mM concentration and the minimum seed vigor was noticed with 150 mM salt concentration (Figure 6). Significant differences in seed vigor were found to control with 25, 50 , 100 and 150 mM salt concentrations (Appendix VIII).

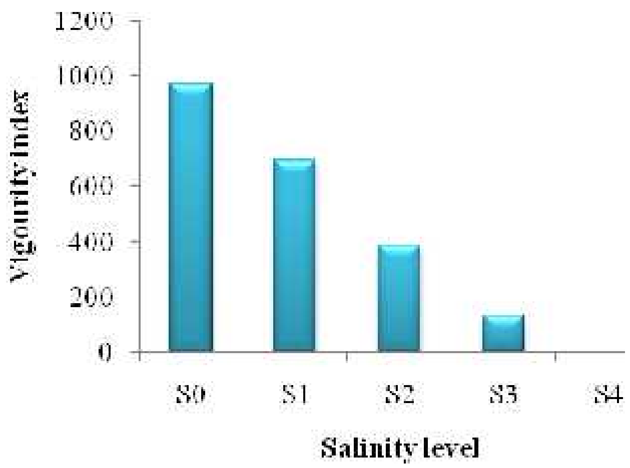
4.3.3 Combined effect of varieties and NaCl concentrations

The maximum seed vigor was found in the combination of variety BARI Tomato-1 with the control salt concentration (0 mM) and the minimum seed vigor (0.00 %) was recorded by the combination of all varieties with 150mM NaCl concentration (Table 3). V_1S_0 was statistically similar with V_5S_0; V_2S_0 is statistically similar with V_6S_0; V_2S_1 is statistically similar with V_3S_0; V_2S_3 is statistically similar with V_4S_2; V_2S_2 is statistically similar with V_3S_2; V_1S_1 was statistically similar with V_4S_0, V_3S_1, and V_5S_1 at 11 days after sowing (Appendix VIII).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 5. Effect of varieties on the vigority index of tomato seeds ($LSD_{0.05}$= 20.13)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 6. Effect of NaCl concentration on the radicle length of tomato seeds ($LSD_{0.05}$=18.38)

4.4 Radicle length

4.4.1 Effect of variety

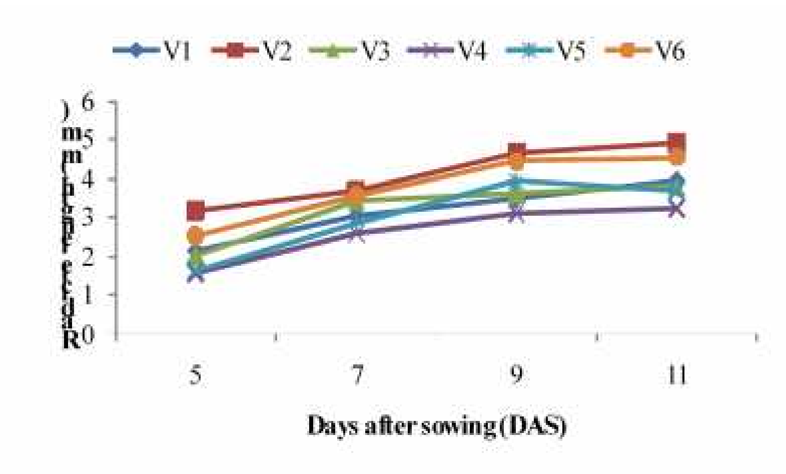
The radicle length was significantly influenced due to varieties of tomato (Figure-7).The maximum radicle length (4.92 cm) was found in the variety BARI Tomato-1 and the minimum (3.24 cm) was observed in BARI Tomato-6 at 11 DAS. No Significant differences in radicle growth were found between BARI Tomato-2 & BARI Tomato-9 at 11 DAS . Significant differences in radicle growth were observed among Bahar , BARI Tomato-1, BARI Tomato-6 and BARI Tomato-12 at 11 DAS.

4.4.2 Effect of NaCl concentrations

The radicle length was significantly influenced with the increasing levels of NaCl concentration (Figure-8). The maximum radicle length of seedling (6.56 cm) was found with the control (0 mM) concentration and the minimum radicle length (0.00 cm) was noticed with 150 mM salt concentration at 11 DAS.Significant differences in radicle growth were found among five different salt concentrations (Appendix II).

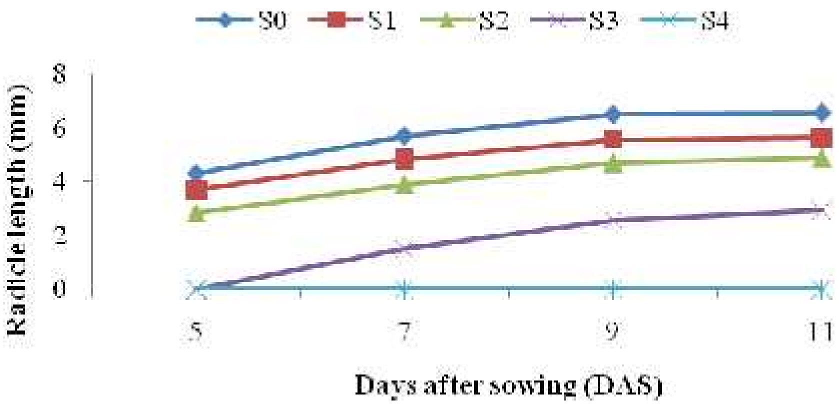
4.4.3 Combined effect of varieties and NaCl concentrations

The interaction effect of variety and NaCl concentration had significant effect on the radicle length of tomato (Appendix II). The maximum radicle length (7.78 cm) was found in combination of the variety BARI Tomato-1 with the control salt concentration (0 mM). The minimum radicle length (0 cm) was recorded with the combination of all varieties of tomato seed with 150 mM NaCl concentration at 11 DAS (Table 4). V_2S_0 was statistically similar with V_6S_0; V_4S_3 was statistically similar with V_5S_3; V_2S_3 was statistically similar with V_4S_2 ; V_1S_3 is statistically similar with V_6S_3 and V_3S_3 ; V_1S_1 was statistically similar with V_3S_1 , V_5S_1 and V_6S_2 at 11 days after sowing (Table 4).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 7. Effect of varieties on the radicle length of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.08, 0.11, 0.13 and 0.13 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 8. Effect of NaCl concentration on the radicle length of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.08, 0.10, 0.12 and 0.12 at 5, 7, 9 and 11 DAS, respectively

Table 4. Combined effect of varieties and NaCl concentration on radical length of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Radicle length (mm)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	4.13 ef	5.47 cd	6.05 c	6.21 c-e
	25 (S_1)	3.50 g	4.48 e	5.03 de	5.40 f
	50 (S_2)	3.00 hi	3.70 gh	4.23 f	4.87 g
	100 (S_3)	0.00 l	1.53 j	2.20 jk	3.21 k
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m
BARI Tomato-1 (V_2)	0 (S_0)	6.10 a	6.83 a	7.73 a	7.78 a
	25 (S_1)	5.33 b	5.54 c	6.56 b	6.81 b
	50 (S_2)	4.50 d	4.29 e	5.93 c	6.02 de
	100 (S_3)	0.00 l	1.74 ij	3.10 h	3.98 j
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m
BARI Tomato-2 (V_3)	0 (S_0)	4.01 f	6.23 b	6.07 c	6.30 cd
	25 (S_1)	3.51 g	5.37 cd	5.07 de	5.27 f
	50 (S_2)	2.50 j	4.00 f	4.20 fg	4.39 i
	100 (S_3)	0.00 l	1.67 ij	2.80 i	3.01 k
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m
BARI Tomato-6 (V_4)	0 (S_0)	3.13 h	4.37 e	5.08 d	5.50 f
	25 (S_1)	2.83 i	3.91 fg	4.43 f	4.58 hi
	50 (S_2)	1.85 k	3.48 h	3.94 g	3.99 j
	100 (S_3)	0.00 l	1.12 k	2.05 k	2.11 l
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m
BARI Tomato-9 (V_5)	0 (S_0)	3.49 g	5.23 d	6.57 b	5.99 e
	25 (S_1)	2.86 i	4.46 e	5.93 c	5.33 f
	50 (S_2)	1.85 k	3.51 h	4.79 e	4.69 gh
	100 (S_3)	0.00 l	1.19 k	2.36 j	2.38 l
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m
BARI Tomato-12 (V_6)	0 (S_0)	5.11 c	6.20 b	7.51 a	7.61 a
	25 (S_1)	4.23 e	5.35 cd	6.40 b	6.50 c
	50 (S_2)	3.36 g	4.50 e	5.25 d	5.54 f
	100 (S_3)	0.00 l	1.82 i	3.06 hi	3.11 k
	150 (S_4)	0.00 l	0.00 l	0.00 l	0.00 m

LSD $_{(0.05)}$	0.19	0.25	0.29	0.29
CV (%)	5.28	4.79	4.51	4.48

4.5 Plumule length

4.5.1 Effect of variety

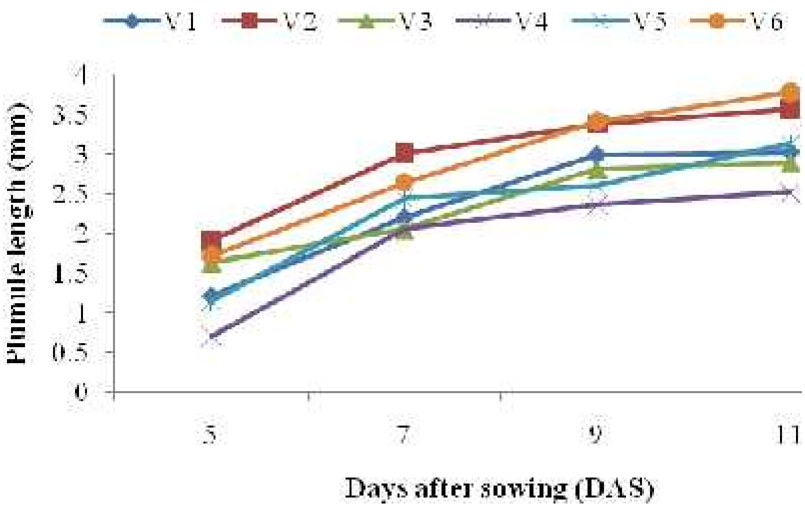
The plumule length was significantly influenced due to different varieties of tomato (Figure-9).The maximum plumule length (3.79 cm) was found in the variety BARI Tomato-12 and the minimum (2.52 cm) was observed in BARI Tomato-6. Significant differences in plumule growth were found between BARI Tomato-1, BARI Tomato-2, BARI Tomato-6 & BARI Tomato-12 at 11 DAS. No significant differences in plumule growth were observed among Bahar and BARI Tomato-9 at 11 DAS (Appendix 3).

4.5.2 Effect of NaCl concentration

The plumule length was significantly influenced due increasing levels of NaCl concentration (Figure-10). The maximum plumule length of seedling (5.31 cm) was found with the 0 mM concentration and the minimum plumule length (0.00 cm) was observed with 150 cm salt concentration. Significant differences were found amoung five different salt concentrations at 11 DAS (Appendix III).

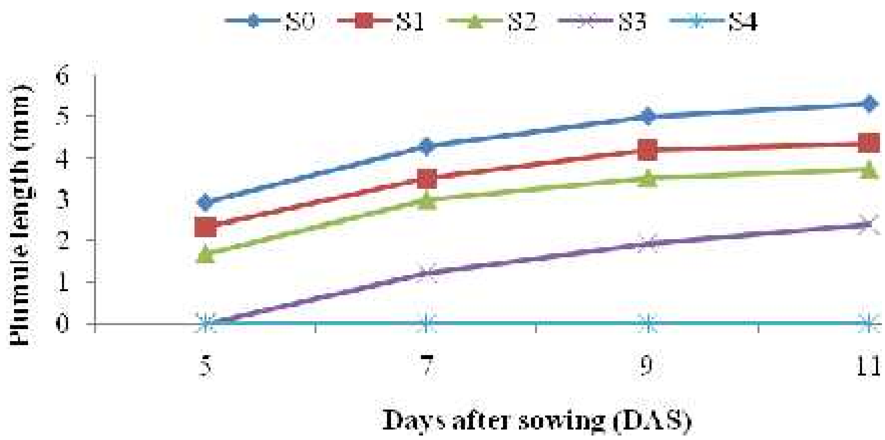
4.5.3 Combined effect of varieties and NaCl concentrations

The maximum plumule length (5.82 cm) was found in the combination of the variety BARI Tomato-1 with the control salt concentration (0mM) at 11 DAS (Table 5). The minimum plumule length (0 cm) was recorded with the combination of all varieties of tomato seed with 150 mM NaCl concentration at 11 DAS. V_1S_0 was statistically similar with V_2S_1; V_1S_1 was statistically similar with V_3S_1; V_1S_3 was statistically similar with V_2S_3 and V_4S_2 ; V_2S_0 was statistically similar with V_6S_0; V_3S_0 was statistically similar with V_6S_2; V_3S_2 was statistically similar with V_6S_3 ; V_4S_3 was statistically similar with V_5S_3 at 11 days after sowing (Appendix III).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 9. Effect of varieties on the plumule length of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.06, 0.08, 0.09 and 0.12 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 10. Effect of NaCl concentration on the plumule length of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.06, 0.08, 0.08 and 0.11 at 5, 7, 9 and 11 DAS, respectively)

Table 5. Combined effect of varieties and NaCl concentration on plumule length of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Plumule length (mm)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	2.70 e	3.92 de	5.07 c	5.12 bc
	25 (S_1)	1.90 i	3.13 g	4.15 e	3.98 fg
	50 (S_2)	1.50 j	2.72 h	3.84 fg	3.43 h
	100 (S_3)	0.00 n	1.25 j	1.91 k	2.63 j
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
BARI Tomato-1 (V_2)	0 (S_0)	3.80 a	4.99 a	5.73 a	5.82 a
	25 (S_1)	3.20 c	4.65 b	5.05 c	5.25 bc
	50 (S_2)	2.55 f	4.02 d	4.10 e	4.24 ef
	100 (S_3)	0.00 n	1.40 j	2.07 jk	2.58 j
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
BARI Tomato-2 (V_3)	0 (S_0)	3.12 c	3.84 de	4.94 c	5.05 cd
	25 (S_1)	2.85 d	3.14 g	4.02 ef	4.05 fg
	50 (S_2)	2.25 g	2.29 i	3.06 h	3.12 i
	100 (S_3)	0.00 n	1.01 k	2.07 jk	2.30 k
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
BARI Tomato-6 (V_4)	0 (S_0)	1.82 i	3.83 e	4.43 d	4.79 d
	25 (S_1)	1.06 l	2.76 h	3.14 h	3.23 hi
	50 (S_2)	0.63 m	2.70 h	2.59 i	2.69 j
	100 (S_3)	0.00 n	1.01 k	1.67 l	1.90 l
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
BARI Tomato-9 (V_5)	0 (S_0)	2.50 f	4.36 c	4.53 d	5.37 b
	25 (S_1)	2.10 h	3.43 f	3.70 g	4.39 e
	50 (S_2)	1.20 k	3.11 g	2.94 h	3.89 g
	100 (S_3)	0.00 n	1.30 j	1.88 k	2.03 l
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
BARI Tomato-12 (V_6)	0 (S_0)	3.60 b	4.75 b	5.34 b	5.71 a
	25 (S_1)	2.91 d	4.01 de	5.00 c	5.18 bc
	50 (S_2)	2.06 h	3.11 g	4.63 d	5.03 cd
	100 (S_3)	0.00 n	1.35 j	2.13 j	3.01 i
	150 (S_4)	0.00 n	0.00 l	0.00 m	0.00 m
LSD $_{(0.05)}$		0.14	0.19	0.21	0.27
CV (%)		6.2	4.81	4.36	5.15

4.6 Radicle fresh weight

4.6.1 Main effect of variety

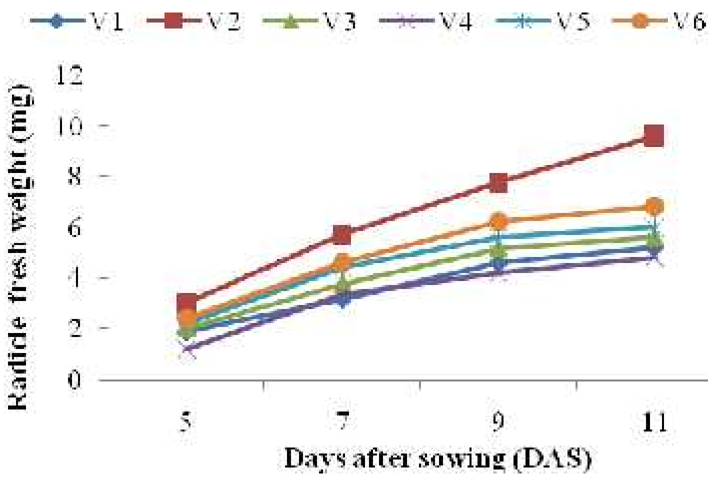
The radicle fresh weight was significantly influenced due to different varieties of tomato. The maximum radicle fresh weight (9.64 mg) was found in the variety BARI Tomato-1 and the minimum (4.82 mg) was observed in BARI Tomato-6 at 11 DAS. Significant differences were found among Bahar, BARI Tomato-1 , BARI Tomato-2 , BARI Tomato-6, BARI Tomato-9 and BARI Tomato-12 in case of radicle fresh weight at 11 DAS (Figure-11)

4.6.2 Effect of NaCl concentrations

The radicle fresh weight was significantly influenced with the increasing levels of NaCl concentration (Figure-12). The maximum radicle fresh weight of seedling (10.17 mg) was found with the control (0mM) concentration and the minimum radicle fresh weight (0.00 mg) was noticed with 150 mM salt concentration at 11 DAS (Appendix IV). Significant differences in radicle growth were found with 0, 25,50, 100 and 150 mM at 11 DAS.

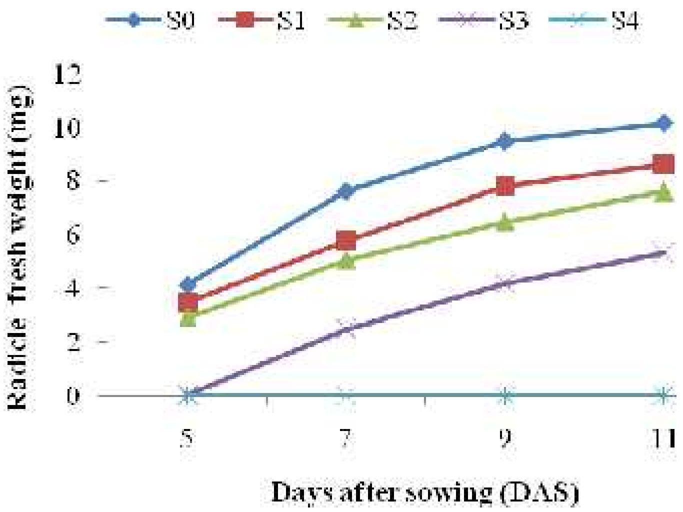
4.6.3 Combined effect of varieties and NaCl concentrations

The maximum radicle fresh weight (14.82 mg) was found in the combination of variety BARI Tomato-1 with the control salt concentration 0 mM and the minimum radicle fresh weight (0.00 mg) was recorded by the combination of all varieties with 150 mM NaCl concentration (Table 6). V_1S_0 was statistically similar with V_4S_0 ,V_6S_1 and V_6S_2 ; V_1S_1 was statistically similar with V_2S_3, V_3S_1 , V_3S_2 and V_5S_2 ; V_1S_2 was statistically similar with V_6S_3 ; V_1S_3 was statistically similar with V_5S_3 ; V2S0 was statistically similar with V_2S_1 ; V_2S_2 was statistically similar with V_6S_0 ; V_3S_0 was statistically similar with V_5S_0 and V_5S_1 at 11 days after sowing (Appendix IV).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 11. Effect of varieties on the radicle fresh wight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.09, 0.14, 0.26 and 0.30 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 12. Effect of NaCl concentration on the radicle fresh weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.08, 0.13, 0.23 and 0.28 at 5, 7, 9 and 11 DAS, respectively)

Table 6. Combined effect of varieties and NaCl concentration on radicle fresh weight of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Radicle fresh weight (mg)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	4.00 c	6.97 c	7.98 e	8.05 d
	25 (S_1)	3.00 d	3.93 f	6.01 g	7.02 e
	50 (S_2)	2.50 e	3.03 g	5.01 h	6.03 fg
	100 (S_3)	0.00 g	1.99 h	4.00 i	5.03 i
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
BARI Tomato-1 (V_2)	0 (S_0)	6.00 a	9.97 a	12.97 a	14.82 a
	25 (S_1)	5.00 b	8.83 b	12.00 b	14.38 a
	50 (S_2)	4.00 c	7.05 c	8.98 d	12.01 b
	100 (S_3)	0.00 g	2.90 g	5.01 h	6.97 e
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
BARI Tomato-2 (V_3)	0 (S_0)	4.02 c	6.87 c	8.95 d	9.03 c
	25 (S_1)	3.00 d	5.07 e	7.00 f	6.99 e
	50 (S_2)	3.00 d	5.10 e	5.99 g	7.03 e
	100 (S_3)	0.00 g	1.90 h	3.99 i	5.09 hi
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
BARI Tomato-6 (V_4)	0 (S_0)	1.90 f	6.00 d	7.10 f	8.05 d
	25 (S_1)	1.88 f	4.90 e	6.00 g	6.50 ef
	50 (S_2)	2.00 f	4.03 f	5.00 h	5.74 gh
	100 (S_3)	0.00 g	1.90 h	2.99 j	3.82 j
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
BARI Tomato-9 (V_5)	0 (S_0)	4.00 c	7.10 c	8.95 d	9.00 c
	25 (S_1)	3.93 c	5.87 d	8.00 e	9.00 c
	50 (S_2)	2.94 d	6.03 d	6.99 f	7.03 e
	100 (S_3)	0.00 g	3.03 g	4.01 i	5.01 i
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
BARI Tomato-12 (V_6)	0 (S_0)	4.90 b	8.86 b	11.01 c	12.05 b
	25 (S_1)	4.00 c	5.97 d	8.00 e	8.00 d
	50 (S_2)	3.00 d	5.10 e	6.99 f	8.04 d
	100 (S_3)	0.00 g	3.06 g	5.01 h	6.03 fg
	150 (S_4)	0.00 g	0.00 i	0.00 k	0.00 k
$LSD_{(0.05)}$		0.19	0.31	0.58	0.68
CV (%)		5.53	4.6	6.29	6.53

4.7 Radicle dry weight

4.7.1 Effect of variety

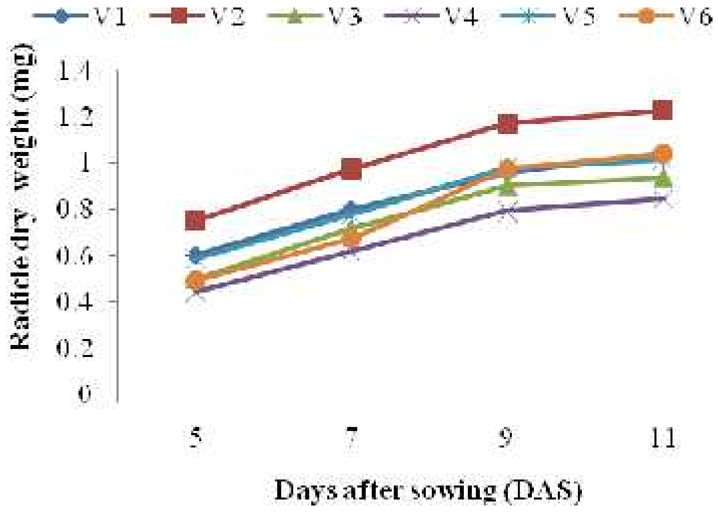
The maximum radicle dry weight (1.226 mg) was found in the variety BARI Tomato-1 and the minimum (0.84 mg) was observed in BARI Tomato-6 at 11 DAS. Significant differences in radicle dry weight were found in Bahar ,BARI Tomato-1, BARI Tomato-2, BARI Tomato-6, BARI Tomato-9 and BARI Tomato-12 at 11 DAS (Figure-13).

4.7.2 Effect of NaCl concentration

The radicle dry weight was significantly influenced with the increasing levels of NaCl concentration (Figure-14). The maximum radicle dry weight of seedling (1.76 mg) was found with the control (0mM) concentration and the minimum radicle dry weight (0.00 mg) was noticed with 150 mM salt concentration at 11 DAS. Significant differences were found amoung five different salinity concentration in case of radicle dry weight.

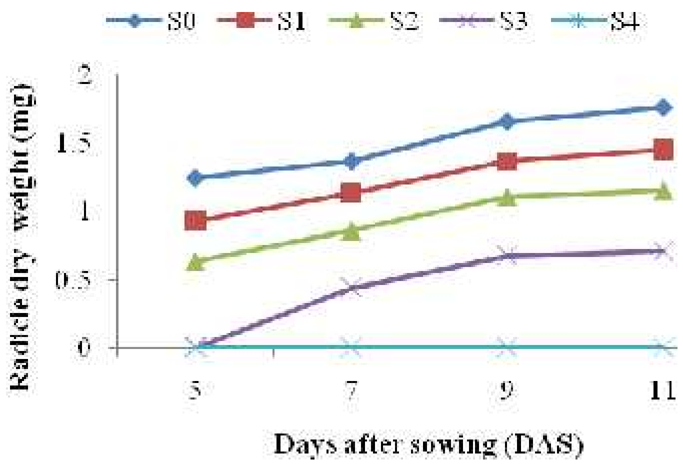
4.7.3 Combined effect of varieties and NaCl concentrations

The maximum radicle dry weight (2.10 mg) was found in the combination of variety BARI Tomato-1 with the control salt concentration (0mM) and the minimum radicle dry weight (0.00 mg) was recorded by the combination of all varieties with 150 mM NaCl concentration at 11 DAS (Table 8). V_1S_0 was statistically similar with V_2S_1 ; V_1S_2 was statistically similar V_4S_1 ; V_1S_3 was statistically similar V_2S_3; V_4S_0 is statistically similar V_6S_0 ; V_5S_1 was statistically similar V_6S_1 at 11 days after sowing (Appendix V).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 13. Effect of varieties on the radicle dry weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.02, 0.03, 0.03 and 0.04 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 14. Effect of NaCl concentration on the radicle dry weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.02, 0.03, 0.03 and 0.04 at 5, 7, 9 and 11 DAS, respectively)

Table 7. Combined effect of varieties and NaCl concentration on radicle dry weight of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Radicle dry weight (mg)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	1.25 c	1.37 b	1.57 c	1.80 b
	25 (S_1)	1.00 e	1.19 c	1.32 f	1.40 fg
	50 (S_2)	0.75 f	1.07 ef	1.17 g	1.21 i
	100 (S_3)	0.00 i	0.37 j	0.72 j	0.79 mn
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
BARI Tomato-1 (V_2)	0 (S_0)	1.50 a	1.71 a	1.98 a	2.10 a
	25 (S_1)	1.25 c	1.44 b	1.72 b	1.80 b
	50 (S_2)	1.00 e	1.21 c	1.42 e	1.44 ef
	100 (S_3)	0.00 i	0.50 i	0.72 j	0.79 mn
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
BARI Tomato-2 (V_3)	0 (S_0)	1.25 c	1.44 b	1.68 b	1.69 cd
	25 (S_1)	0.75 f	1.00 fg	1.22 g	1.32 gh
	50 (S_2)	0.50 h	0.74 h	0.98 h	1.01 k
	100 (S_3)	0.00 i	0.41 j	0.62 k	0.65 o
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
BARI Tomato-6 (V_4)	0 (S_0)	1.00 e	1.10 de	1.49 de	1.61 d
	25 (S_1)	0.75 f	0.93 g	1.19 g	1.22 i
	50 (S_2)	0.45 h	0.70 h	0.80 i	0.89 l
	100 (S_3)	0.00 i	0.35 j	0.48 l	0.50 p
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
BARI Tomato-9 (V_5)	0 (S_0)	1.33 b	1.44 b	1.72 b	1.73 bc
	25 (S_1)	0.99 e	1.21 c	1.43 de	1.50 e
	50 (S_2)	0.60 g	0.74 h	1.02 h	1.11 j
	100 (S_3)	0.00 i	0.50 i	0.72 j	0.72 no
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
BARI Tomato-12 (V_6)	0 (S_0)	1.16 d	1.15 cd	1.50 d	1.63 d
	25 (S_1)	0.80 f	1.03 ef	1.32 f	1.50 e
	50 (S_2)	0.50 h	0.69 h	1.24 g	1.24 hi
	100 (S_3)	0.00 i	0.51 i	0.80 i	0.82 lm
	150 (S_4)	0.00 i	0.00 k	0.00 m	0.00 q
$LSD_{(0.05)}$		0.05	0.07	0.07	0.09
CV (%)		6.62	5.35	4.16	5.05

4.8 Plumule fresh weight

4.8.1Effect of variety

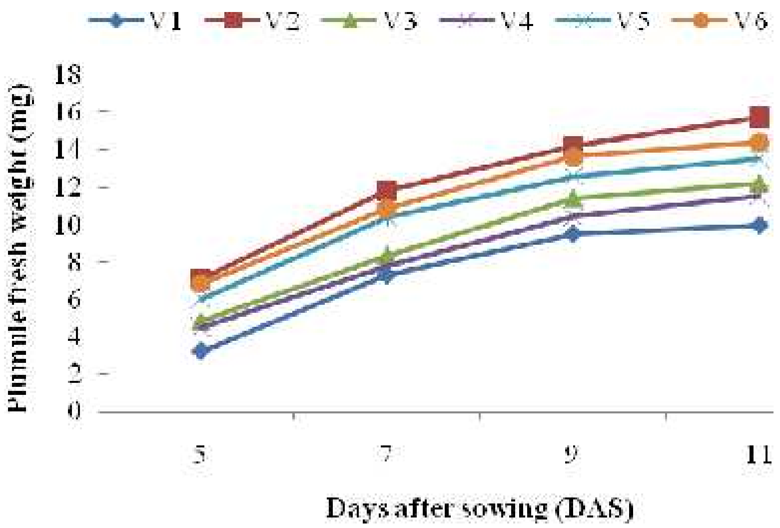
The maximum plumule fresh weight (15.75 mg) was found in the variety BARI Tomato-1 and the minimum (9.96 mg) was observed in Bahar at 11 DAS (Figure-15) . Significant differences were found amoung six different varieties in case of plumule fresh weight at 11 DAS.

4.8.2 Effect of NaCl concentration

The maximum plumule fresh weight of seedling (20.26 mg) was found with the control (0mM) concentration and the minimum plumule fresh weight (0.00 mg) was noticed with 150 mM salt concentration at 11 DAS. Significant differences were found in all salt concentrations in case of plumule fresh weight (Figure-16).

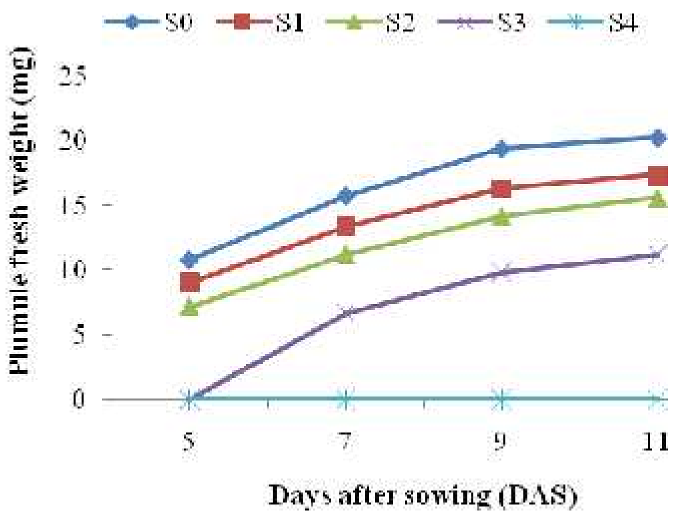
4.8.3 Combined effect of varieties and NaCl concentrations

The maximum plumule fresh weight (24.69 mg) was found in the combination of variety BARI Tomato-1 with the control salt concentration (0 mM) and the minimum plumule fresh weight (0.00 mg) was recorded by the combination of all varieties with 150 mM NaCl concentration at 11 DAS (Table 8). V_1S_0 was statistically similar with V_3S_0 , V_4S_1, V_4S_2 and V_5S_1 ; V_2S_0 was statistically similar with V_6S_0 : V_3S_1 was statistically similar with V_4S_0 and V_6S_2 ; V_2S_2 was statistically similar with V_5S_1 and V_6S_1 at 11 days after sowing (Appendix VI).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 15. Effect of varieties on the plumule fresh weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.21, 0.33, 0.43 and 0.55 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 16. . Effect of NaCl concentration on the plumule fresh weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.19, 0.30, 0.39 and 0.51 at 5, 7, 9 and 11 DAS, respectively)

Table 8. Combined effect of varieties and NaCl concentration on plumule fresh weight of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Plumule fresh weight (mg)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	7.00 h	12.83 hi	15.50 f	15.00 f
	25 (S_1)	5.00 j	10.73 k	12.99 h	13.33 gh
	50 (S_2)	3.97 k	7.92 m	11.01 j	12.50 hi
	100 (S_3)	0.00 l	4.93 o	7.98 m	8.97 l
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
BARI Tomato-1 (V_2)	0 (S_0)	14.23 a	18.80 a	23.01 a	24.69 a
	25 (S_1)	12.00 b	17.03 c	18.99 c	21.00 c
	50 (S_2)	9.00 e	15.07 d	17.01 e	19.06 d
	100 (S_3)	0.00 l	8.10 m	12.01 i	14.01 fg
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
BARI Tomato-2 (V_3)	0 (S_0)	9.00 e	13.80 fg	17.01 e	17.96 de
	25 (S_1)	8.00 g	11.93 j	16.03 f	16.97 e
	50 (S_2)	6.97 h	10.07 k	14.02 g	15.06 f
	100 (S_3)	0.00 l	5.83 n	10.01 k	11.05 jk
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
BARI Tomato-6 (V_4)	0 (S_0)	8.50 f	14.27 ef	15.99 f	17.31 e
	25 (S_1)	7.83 g	10.60 k	13.95 gh	15.04 f
	50 (S_2)	5.97 i	9.00 l	13.03 h	15.07 f
	100 (S_3)	0.00 l	5.02 o	9.00 l	10.20 kl
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
BARI Tomato-9 (V_5)	0 (S_0)	12.00 b	16.87 c	21.99 b	22.64 b
	25 (S_1)	10.00 d	14.98 de	18.01 d	19.02 d
	50 (S_2)	8.00 g	12.10 ij	14.01 g	15.00 f
	100 (S_3)	0.00 l	8.07 m	8.99 l	11.00 jk
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
BARI Tomato-12 (V_6)	0 (S_0)	14.03 a	17.97 b	22.99 a	23.95 a
	25 (S_1)	11.10 c	15.07 d	18.02 d	19.01 d
	50 (S_2)	8.98 e	13.10 gh	15.99 f	16.97 e
	100 (S_3)	0.00 l	8.10 m	11.01 j	11.99 ij
	150 (S_4)	0.00 l	0.00 p	0.00 n	0.00 m
$LSD_{(0.05)}$		0.47	0.73	0.96	1.24
CV (%)		5.32	4.76	4.94	5.89

4.9 Plumule dry weight of tomato

4.9.1 Effect of variety

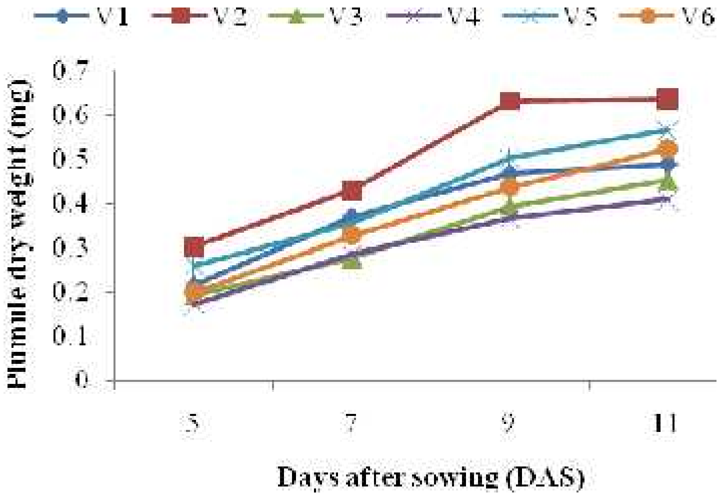
The plumule dry weight was significantly influenced due to different varieties of tomato (Appendix VII). The maximum plumule dry weight (0.64 mg) was found in the variety BARI Tomato-1 and the minimum (0.41 mg) was observed in BARI Tomato-6 (Figure-17). Significant differences in plumule dry weight were found in Bahar, BARI Tomato-1 , and BARI Tomato-2 , BARI Tomato-6 , BARI Tomato-9 and BARI Tomato-12 at 11 DAS.

4.9.2 Effect of NaCl concentration

The maximum plumule dry weight of seedling (1.00 mg) was found with the control (0 mM) concentration and the minimum plumule dry weight (0.00 mg) was noticed with 150 mM salt concentration (Figure-18). Significant differences were found in control (0 mM) , 25mM , 50mM ,100mM and 150mM in case of plumule dry weight at 11 DAS.

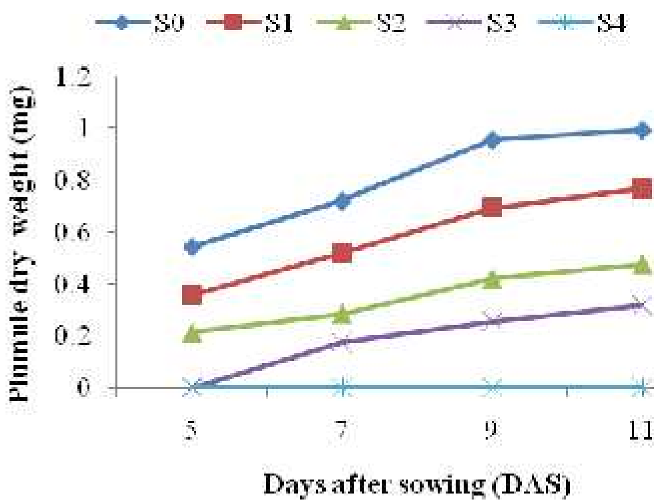
4.9.3 Combined effect of varieties and NaCl concentrations

The maximum plumule dry weight (1.2 mg) was found in the combination of variety BARI Tomato-1 with the control salt concentration (0 mM) and the minimum plumule dry weight (0.00 mg) was recorded by the combination of all varieties with 150 mM NaCl concentration (Table-9). V_2S_2 was statistically similar with V_4S_1; V_4S_0 was statistically similar with V_5S_1 and V_6S_1; V_1S_3 was statistically similar with V_2S_3 ,V_3S_3 ,V_4S_2 and V_6S_3; V_1S_2 was statistically similar with V_3S_2 , V_5S_3 and V_6S_2 ; V_1S_0 is statistically similar with V_5S_0 , V_2S_1 and V_6S_0 at 11 days after sowing (Appendix VII).



V_1=Bahar,V_2=BARI Tomato-1,V_3=BARI Tomato-2, V_4=BARI Tomato-6, V_5=BARI Tomato -9 and V_6=BARI Tomato-12

Figure 17. Effect of varieties on the plumule dry weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.02, 0.02, 0.02 and 0.02 at 5, 7, 9 and 11 DAS, respectively)



S_0= Distilled water (Control), S_1=25 mM , S_2=50 mM, S_3=100 mM, S_4=150 mM

Figure 18. Effect of NaCl concentration on the plumule dry weight of tomato seeds at different days after sowing ($LSD_{0.05}$= 0.02, 0.02, 0.02 and 0.02 at 5, 7, 9 and 11 DAS, respectively)

Table 9. Combined effect of varieties and NaCl concentration on plumule dry weight of tomato seeds at different days after sowing (DAS)

Variety	NaCl conc.	Plumule dry weight (mg)			
		5 DAS	7 DAS	9 DAS	11 DAS
Bahar (V_1)	0 (S_0)	0.50 c	0.75 b	1.02 b	1.02 b
	25 (S_1)	0.33 e	0.65 d	0.64 ef	0.68 e
	50 (S_2)	0.25 fg	0.31 g	0.41 h	0.43 g
	100 (S_3)	0.00 i	0.14 i	0.26 jk	0.31 h
	150 (S_4)	0.00 i	0.00 j	0.00 m	0.0 j
BARI Tomato-1 (V_2)	0 (S_0)	0.75 a	0.81 a	1.17 a	1.20 a
	25 (S_1)	0.51 c	0.67 cd	1.02 b	1.02 b
	50 (S_2)	0.25 fg	0.44 f	0.64 ef	0.64 ef
	100 (S_3)	0.00 i	0.23 h	0.32 i	0.32 h
	150 (S_4)	0.00 i	0.0 j	0.00 m	0.00 j
BARI Tomato-2 (V_3)	0 (S_0)	0.50 c	0.72 bc	0.92 c	0.93 c
	25 (S_1)	0.26 f	0.32 g	0.50 g	0.61 f
	50 (S_2)	0.20 g	0.20 h	0.32 i	0.42 g
	100 (S_3)	0.00 i	0.14 i	0.23 kl	0.31 h
	150 (S_4)	0.00 i	0.00 j	0.00 m	0.00 j
BARI Tomato-6 (V_4)	0 (S_0)	0.40 d	0.62 d	0.71 d	0.81 d
	25 (S_1)	0.31 e	0.48 ef	0.61 f	0.65 ef
	50 (S_2)	0.14 h	0.21 h	0.31 ij	0.33 h
	100 (S_3)	0.00 i	0.11 i	0.20 l	0.25 i
	150 (S_4)	0.00 i	0.00 j	0.00 m	0.00 j
BARI Tomato-9 (V_5)	0 (S_0)	0.65 b	0.75 b	1.01 b	0.99 b
	25 (S_1)	0.40 d	0.50 e	0.73 d	0.81 d
	50 (S_2)	0.24 fg	0.31 g	0.51 g	0.61 f
	100 (S_3)	0.00 i	0.21 h	0.26 jk	0.41 g
	150 (S_4)	0.00 i	0.00 j	0.00 m	0.00 j
BARI Tomato-12 (V_6)	0 (S_0)	0.47 c	0.67 cd	0.91 c	1.02 b
	25 (S_1)	0.33 e	0.51 e	0.68 de	0.85 d
	50 (S_2)	0.20 g	0.24 h	0.33 i	0.43 g
	100 (S_3)	0.00 i	0.22 h	0.20 jk	0.31 h
	150 (S_4)	0.00 i	0.00 j	0.00 m	0.00 j
LSD $_{(0.05)}$		0.05	0.05	0.05	0.05
CV (%)		8.15	5.95	4.49	4.77

CHAPTER 5

SUMMARY

The present study was carried out at Agronomy Laboratory, Sher-e-Bangla Agricultural University (SAU), Dhaka in order to investigate the effects of different salinity levels on germination percentage, plumule length, radicle length, plumule fresh weight, radicle fresh weight; plumule dry weight and radicle dry weight of different varieties of tomato seedlings. This experiment was carried out using a completely randomized design with three replications per treatment in 2015 at Sher-e-Bangla Agricultural University, Dhaka. Treatments included five levels of NaCl concentrations (0, 25, 50, 100 and 150 mM). Six varieties of tomato seeds named Bahar, BARI Tomato-1 ,BARI Tomato-2 BARI Tomato-6, BARI Tomato-9, BARI Tomato-12 seeds were used in petridish to investigate the effects of salt stress on seed germination and seedling growth in laboratory conditions. The response of tomato seed germination and seedling growth to salinity stress is dependent on the genotype, salt concentration, and the parameter measured.

The presence of genotypic differences in salinity tolerance during germination was demonstrated. Increasing salt concentrations resulted in a delay and reduction in germination. High percentage and rate of germination are attributes that identify tolerant cultivars at the germination stage.

The results demonstrated that the variety BARI Tomato-12, BARI Tomato-1 and BARI Tomato-2 are relatively salt tolerant than BARI Tomato-6, BARI Tomato-9 and Bahar are salt susceptible. Plumule length was highest in BARI Tomato-1 followed by BARI Tomato-12 and BARI Tomato-9. It was intermediate in Bahar, BARI Tomato-2 and lowest in BARI Tomato-6. Responses to radicle lengths of these varieties were also similar at salt levels. Significant differences were also found in plumule and radicle fresh and dry weight in the variety and salinity level.

Increasing salinity stress reduced seedling emergence and early growth of seedlings as indicated by plumule and radicle elongation. It was observed that radicle elongation was more sensitive to salinity stress than plumule elongation. It may be concluded that the rate of germination and emergence, percentage of germination, radicle and plumule lengths may be used as potential selection criteria for salinity stress tolerance at the establishment stage. The results are useful to breeders for future development of salinity tolerant cultivars and to agronomists to predict sowing rates depending upon expected salinity levels.

CHAPTER 6

CONCLUSION

In petridish condition, six varieties of tomato were evaluated against five salinity levels. The germination of seed was varied significantly with the variety and salt concentrations. The results showed that the performance of BARI Tomato-12 was comparatively better in salt concentration. In case of the combined effect of variety and salt concentration, BARI Tomato-1, BARI Tomato-12, BARI Tomato-9 showed better performance than the other varieties. The results demonstrated that the variety BARI Tomato-12, BARI Tomato-1 and BARI Tomato-2 are relatively salt tolerant than BARI Tomato-6, BARI Tomato-9 and Bahar are salt susceptible.

It was observed that seed germination, radical and plumule length, radical and plumule fresh weight and dry weight gradually decreased in 100 mM and 150 mM as compared to control, 25 mM and 50 mM NaCl solution. Seed germination was first started at 4 DAS in BARI Tomato-12 and then the other varieties sequentially. Different varieties of tomato responded differently to the different concentration of salt. BARI Tomato-12, BARI Tomato-1 and BARI Tomato-2 are relatively salt tolerant than BARI Tomato-6, BARI Tomato-9 and Bahar are salt susceptible.

From the results of the experiment it might be concluded that

- Germination and seedling growth decreased with the increasing levels of NaCl concentration
- The studied tomato cultivars can tolerate salinity below 150 mM regarding to all germination and seedling growth parameters.

REFERENCES

Abbruzzese, G., Beritognolo, I., Muleob, R., Piazzaia, M., Sabattia, M., Mugnozza, G. S. and Kuzminsky, E. (2009). Leaf morphological plasticity and stomatal conductance in three *Populus alba* L genotypes subjected to salt stress. *Environ. Expt. Bot.* **66**: 381-388.

Abdul-Baki, A. and Anderson, J. D. (1973). Vigor determination of soybean seed by multiple criteria. *Crop Sci.* **3**: 360-633.

Ahamad, K. (1995). Phul Phal O Shak-Sabjee, 5th Edn. 414, Senpara, Parbata, Mirpur, Dhaka. p. 440.

Ahmed, S. (2009). Effect of soil salinity on the yield and yield components of Mungbean. *Pakistan J. Bot.* **4**(1): 263-268.

Ahmed , M. E., Naim, E., Khawla, M. A and Elshiekh, I. N. (2012). Impact of salinity on seed germination and early seedling growth of three sorghum (*Sorghum biolor* L) cultivars. *Sci. Technol.***2**(2): 16-20.

Ambede, G. J., Netondo, G. W., Mwai, G. N. and Musyimi, D. M. (2012). NaCl salinity affects germination growth physiology and biochemistry of bambara groundnut. *Brazil J. Plant Physiol.* **24**(3):151-160.

Ashraf, M. (2001). Relationships between growth and gas exchange characteristics in some salt-tolerant amphidiploid *Brassica* species in relation to their diploid parents. *Environ. Expt. Bot.* **45**: 155-163.

Ashraf, M. and Foolad, M. R. (2007). Roles of glycine betaine and proline in improving salt tolerance plant. *Environ. Expt. Bot.* **59**: 206-216.

Ashraf, A. and Khanam, A. (1997). Relationship between ion accumulation and growth in two-spring wheat line differing in salt tolerance at different growth stages. *J. Agron. Crop Sci.* **178**: 39-51.

Ashraf, M. and Sharif, R. (1997). Does salt tolerance vary in a potential oil-seed crop *Brassica carinata* at different growth stages*? J. Agron.Crop Sci*. **181**: 103-

115.

Azami, M. A., Torabi, M. and Shekari, F. (2010). Response of some tomato cultivars to sodium chloride stress under in vitro culture condition. *African J. Agril. Res.* **5**(18): 2589-2592.

Bagayoko, M. (2012). Soil salinity alkalinity effects on germination and seedling growth of vegetable crops in the Office du Niger zone. *J. Res. Environ. Sci. Toxicol.* **1**(12): 328-337.

Baghbani, A., Forghani, A. H. Kadkhodaie, A. (2013). Study of Salinity Stress on Germination and Seedling Growth in Greenhouse Cucumber Cultivars. *J. Basic Appl. Sci. Res.* **3**(3): 1137-1140.

BBS (2013). *Monthly Statistical Bulletin,* 2013: Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. p. 72.

Bewley, D. J. and Black, M. (1994). Seeds Physiology of de ä elopement and germination. New York: *Plenum Press*.

Bose, T. K. and Som, M. G. (1990). *Vegetable Crops in India* Published by B Mitra and Naya Prokash, 206 Bidhan Sarani, Calcutta, India. p. 249

Bybordi, A. (2010). The influence of salt stress on seed germination growth and yield of canola cultivars. *Notulae Botanicae Horti AgrobotaniciCluj-Napoca* **38**(1): 128-133.

Carvajal, M., Amor, D., Fernandez, B., Martinez, V. and Cerda, A. (1998). Time course of solute accumulation and water relations in muskmelon plants exposed to salt during different growth stages. *Plant Sci.* **138**: 103-112.

Chang, P. T. and Randle, W. M. (2004). Sodium chloride in nutrient solutions can affect onion growth and flavor development. *Hort. Sci. USA.* **39**(6):1416-1420.

Copeland, L. (1976). *Principle of Seed Science and Technology*. Burgess Publishing Company, Minneapolis, Mannishly. pp. 164-165.

Cuartero, J. and Fernandez, R. (1999). Tomato and salinity. *Scientia Horticulturae.* **78**: 83-125.

Demidchik, V. R. J. and Davenport, M. T. (2002). Nonselective cation channels in plants. *Ann. Rev. Plant Biol.* **53**: 67-107.

Dubey, R. S. (1994). Protein synthesis by plants under stressful conditions. Handbook of plant and crop stress. (Pessarakli M ed.) New York, USA: Marcel Dekker Inc. pp. 277-299.

Fadzilla, N. M., Finch, R. P. and Roy, H. B. (1997). Salinity oxidative stress and antioxidant responses in shoot cultures of rice. *J. Expt. Bot.* **48**: 325-331.

FAO (2006). FAO Production Yearbook, 1996: Basic data unit statistics division, FAO, Rome, Italy. **55**:125-127.

FAO (2005). Productive Yearbook. Food and Agriculture Organization of the United Nations, Rome, Italy. **57**: 153.

Foolad, M. R. (1996). Genetic analysis of salt tolerance during vegetative growth in tomato.

Lycopersican esculentum Mill. *Plant Breed.* **115**(4): 245-250.

Frusciante, L., Carli, P., Ercolano, M. R., Pernice, R. Matteo , A. D. (2007). Antioxidant nutritional quality of tomato. *Mol. Nutr. Food Res.* **51**: 609-617.

Garratt, L. C., Janagoundar, B. S., Lowe, K. C., Anthony, P., Power, J. B. and Davey, M. R. (2002). Salinity tolerance and antioxidant status in cotton cultures. *Free Radical Biol. Med.* **33**: 502-511.

Ghassan, A. (2005). Study the effect of salt stress mechanism on sorghum [*sorghum bicolor* (l.) moench] and its tolerant types. Damascus University, Faculty of Agriculture p.1.

Ghoulam, C. and Foursy, F. K. (2002). Effects of salt stress on growth inorganic ions and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars. *Environ. Expt. Bot*. **47**: 39-50.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical Procedure for Agricultural Research 2nd (edn.)* John Willey and Sons, New York. pp. 28-192.

Grattan ,S. R. and Grieve, C. M. (1999). Salinity-mineral nutrient relations in horticultural crops. *J. Hort. Sci.* **78**: 127-157.

Greenway, H., Munns, R. (1980). Mechanisms of salt tolerance in non-halophytes. *Ann. Rev. Plant Physiol.* **31**: 149-190.

Hajer, A. S., Malibari, A. A., Al-Zahrani, H. S. and Almaghrabi, O. A. (2006). Responses of three tomato cultivars to sea water salinity 1 Effect of salinity on the seedling growth. *African J. Biotechnol.* **5**(10): 855-861.

Hernandez, J. A., Olmos, E., Corpas, F., Sevilla, J. F. and Rio, D. (1999). Salt induced oxidative stress in chloroplasts of pea plants. *Plant Sci.* **105**:151-167.

Hilal, M. A. M., Zenoff, G., Ponessa, H. and Moreno, E. D. (1998). Saline stress alters the temporal patterns of xylem differentiation and alternative oxidative expression in developing soybean roots. *Plant Physiol.* **11**: 695-701.

Jamil, M., Jung, L. D. B., Ashraf, K. Y., Lee. S. C. and Rha, S. E. (2006). Effect of salt (NaCl) stress on germination and early seedling growth of four vegetable species. *J. Cent. European Agric.* **7**(2): 273-282.

Jamil, M., Lee, C. C., Rehman, S. U., Lee, D. B. and Ashraf, M. (2005). Salinity (NaCl) tolerance of *Brassica* species at germination and early seedling growth Electron. *J. Environ. Agric. Food Chem.* **4**: 970-976.

Jouyban, Z. (2012). Effects of Salt stress on plant growth. *TJEAS J.* pp.2-1.

Juan, M., Rosa, M., Rivero, M. R., Romero, L. and Ruiz, J. M. (2005). Evaluation of some nutritional and biochemical indicators in selecting salt-resistant tomato cultivars. *Environ. Expt. Bot.* **54**:193-201.

Kandil, A. A., Sharief, E., Abido, W. A. E. and Ibrahim, M. M. (2012). Effect of salinity on seed germination and seedling characters of some forage sorghum cultivars. *Int. J. Agric. Sci.* **4**(7): 306-311.

Karim, Z., Hussain, S. G. and Ahmed, M. (1990). *Salinity Problems and Crop Intensification in the Coastal Regions of Bangladesh.* Soils Publication No.33, Soils and Irrigation Division BARC, Farmgate, Dhaka, Bangladesh. pp. 1-20.

Kasukabe, Y., Nada, K., Misawa, S., Ihara, I. and Tachibana, S. (2006). Overexpression of spermidine synthase enhances tolerance to multiple environmental stresses and upregulates the expression of various stress-regulated genes in transgenic Arabidopsis thaliana. *Plant Cell Physiol.* **45**: 712-22.

Katembe, W. J., Unga, I. and Michell, J. P. (1998). Effect of Salinity on Germination and Seedling Growth of two *Atriplex* species (Chenopodiaceae). *Ann. Bot.***82**: 167-175.

Kaya, M. D. (2009). The role of hull in germination and salinity tolerance in some sunflower cultivar. *African J. Biotechnol.* **8**(2): 155-159.

Kayani, S. A., Naqvi, H. H. and Ting, I. P. (1990). Salinity effects on germination and mobilization of reserves in jojoba seed. *Crop Sci.* **30**:704-708.

Kaymakanova, M. (2009). Effect of salinity on germination and seed physiology in bean *(Phaseolus vulgaris* L.). *Biotechnol. Biotechnol. Eq 23/2009/Se.*

Keshavarzi, M. H. B. (2012). Studying the effects of different levels of salinity which caused by NaCl on early growth and germination of *Lactuca Sativa* L seedling. *J. Stress Physiol. Biochem.* **8**(1):203-208.

Keshavarzi, M. H. B., Rafsanjani, M. S. O., Moussavinik, S. M. and Lak, A. P. (2011). Effect of salt (NaCl) stress on germination and early seedling growth of Spinach (*Spinacia oleracea* L.). *Ann. Biol. Res.* **2**(4): 490-497.

Khan, M. A., Ungar, I. A. and Showalter, A. M. (2000). Effects of sodium chloride treatments on growth and ion accumulation of the halophyte. *Seed Sci. Technol.* **31**: 2763 -2774.

Lee, J. T., Prasad, V., Yang, P. T., Wu, J. F., David Ho, T. H., Charng, Y. Y. and Chan, M. T. (2003). Expression of Arabidopsis CBF1 regulated by an ABA/stress inducible promoter in transgenic tomato confers stress tolerance without affecting yield. *Plant Cell Environ.* **26**:1181-1190.

Maiti, R. K., Baquie, A., Singh, V. P., Arreola, E. S., Ebeling, P. W., Lezama, B. F. and Pamela, O. T. L. (2004). Comparative study of the response of 17 vegetable crop species to different levels of salinity at germination stage cultivated in high lands of Puebla Mexico. *Rese.Crops.* **4**(2): 223-229.

Meneguzzo, S. and Navarilzzo, I. (1999). Antioxidative responses of shoots and roots of wheat to increasing NaCL concentrations. *J. Plant Physiol.* **155**: 274-280.

Mittova, V., Tal, M., Volokita, M. and Guy, M. (2003). Up-regulation of the leaf mitochondrial and peroxisome antioxidative systems in response to salt induced oxidative stress in the wild salt-tolerant tomato species. *Lycopersicon pennellii. Plant Cell Environ.***26**: 845-856.

Mohammadi, G. R. (2009). The influence of NaCl priming on seed germination and seedling growth of canola (*Brassica napus* L.) under salinity conditions. *American-Eurasian J. Agril. Environ. Sci.* **5**(5): 696-700.

Moosavi, S. G. and Jouyban, Z. (2013). Effect of salt stress on germination and early seedling growth of *Nigella sativa* L. *Int. J. Traditional Herbal Med.* **1**(2): 45-48.

Moradi, P. and Zavareh, M. (2013). Effects of salinity on germination and early seedling growth of chickpea (*Cicerarietinum* L.) cultivars. *IJFAS J.* -2013-2-3/70-74 ISSN 2322-4134.

Munns, R., James, R. A. and Lauchli, A. (2006). Approaches to increasing the salt tolerance of wheat and other cereals. *J. Expt. Bot.***57**:1025-1043.

Muhammad, G., Marco, A. M. (2005). Causes of varietal differences in salt tolerance. *Int. Congr. Plant Physiol.* pp.960-968.

Mutawa, M. M. A. (2003). Effect of Salinity on germination and seedling growth of chickpea (*Cicer arietinum* L.) genotypes. *Int. J. Agric. Biol.* **5**(3): 226-229.

Nasser, J. and Sholi, Y. (2012). Effect of salt stress on seed germination plant growth photosynthesis and ion accumulation of four tomato cultivars. *American J. Plant Physiol.* **7**: 269-275.

Noreen, S. and Ashraf, M. (2008). Alleviation of adverse effects of salt stress on sunflower (*Helianthus annuus* L.) by exogenous application of salicylic acid: growth and photo-synthesis. *Pakistan J. Bot.* **40**(4): 1657-1663.

Omami, E. N. (2005). Effect of salinity stress on amaranth seed germination and seedling growth. University of Pretoria edition.

Omran, S. and Tawfik, N. (2013). Effect of salinity stress on coriander (*Coriandrum sativum*) seeds germination and plant growth. *Egyptian Acad. J. Biol. Sci.* **4**(1):1-7.

Parada, A. K. and Das, A. B. (2006). Salt tolerance and salinity effects on plants a review. *Ecotoxicol. Environ. Safety*. **60**: 324-349.

Perez-Alfocea, F., Balibrea, M. E., Santa, A., Cruz, E. M. T. (1996). Agronomical and physiological characterization of salinity tolerance in a commercial tomato hybrid. *Plant Soil.* **18**: 251-257.

Ratnakar, A. and Rai, A. (2013). Effect of sodium chloride salinity on seed germination and early seedling growth of *Trigonella foenum-graecum* L. *J. Environ. Res.* **1**(4): 304-309.

Redman, R. E. and Belyk, M. (1994). Growth of transgenic and standard canola (*Brassica napus* L.) varieties in response to soil salinity. *Canadian J. Plant Sci.* **74**(4): 797-799.

Robina, S. and Sheela, A. (2006). Stimulation of antioxidant system and lipid peroxidation by abiotic stresses in leaves of *Momordica charantia*. *J. Environ. Res.* **1**(4): 324-332.

Rus, A. M., Riorios, S., Olmos, E., Santa-Cruz, A., Bolarin, M. C. (2002). Long term culture modifies the salt responses of callus lines of salt-tolerant and salt-sensitive tomato species. *Plant Physiol.* **157**: 413-420.

Sarwar, M. G. M. (2005). Impacts of sea level rise on the coastal zone of Bangladesh. Master's Thesis, Lund University Sweden.

Schmidhalter, U. and Oertli, J. J. (2001). Germination and seedling growth of carrots under salinity and moisture stress. *Plant Soil.* **132**: 243-251.

Shannon, M. C. (1994). Breeding selection and the genetics of salt tolerance In: RC Staples, GH Toenniessen (eds.). *Salinity tolerance in plants: Strategies for crop improvement,* John Wiley and Sons, New York. pp. 231-254.

Sharma, N., Abrams, S. R., Waterer, D. R. (2005). Uptake movement activity and persistence of an abscisic acid analog (8' acetylene ABA methyl ester) in marigold and tomato. *J. Plant Growth Regul.* **24**: 28-35.

Simon, E. W. (1984). Early events in germination In: Murray DR edition. *Seed physiology*. *Australia*: Academic Press.

Smirnoff, N. (1993). The role of active oxygen in the response of plants to water deficit and dessicacation. *New Phytologist.* **125**: 27-58.

Singh, P. K., Chauhan, R. R., Chaudhary, R. and Singh, A. (2012). Salt Tolerance of *Sorghum bicolor* cultivars during germination and seedling growth. *Res. J. Recent Sci.* **1**(3): 1-10.

Sivritepe, N., Bosland, W. and Ghabari, A. (2003). The effects of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. *Scintia Horticulture.* **97**: 229-237.

Syvertsen, J. P., Lee, L. S. and Grosser, J. W. (2000). Limitations on growth and net gas exchange of diploid and tetraploid citrus rootstock cultivars grown at elevated CO_2. *J. American Soc. Hort. Sci.* **125**: 228-34.

Tabatabaei, S. A. and Anagholi, A. (2012). Effects of salinity on some characteristics of forage sorghum genotypes at germination stage. *Int. J. Agri. Crop Sci.* **4** (14): 979-983.

Tsakalidi AL, Zakynthinos GN, Varzakas T 2011: Effect of NaCl and GA_3 on seed germination and seedling growth of eleven medicinal and aromatic crops. *Journal* *of Medicinal Plants Research* **5 (17):** 4065-4073.

Turhan, A., Turhan, H. and Seniz, V. (2011). Effects of different salt concentrations (NaCl) on germination of some spinach cultivars. *J. Agril. Faculty Uludag Univ.* **1**: 65-77.

Tyerman, S. D. and Skerrett, I. M. (1999). Root ion channels and salinity. *Scientia Horticulturae.* **78**: 175-235.

Ungar, I. A. (1995). Seed germination and seed-bank ecology of halophytes Marcel Dekker, New York. pp. 599-627.

Ungar, I. A. (1996). Effect of salinity on seed germination growth and ion accumulation of *Atriplex patula* (Chenopodiaceae). *American J. Bot.* **83**: 604-607.

Wambua, J. M., Makobe, M. N., Njue, E. M. and Nyende, A. B. (2010). Hydroponic screening of Sorghum (*Sorghum bicolor* L Moench) cultivars for salinity tolerance. *JAGST* **12**(2): 1.

Yeo, A. R. (1998). Molecular biology of salt tolerance in the context of whole plant physiology. *J. Expt. Bot.* **49**: 915-929.

Yildirim, E., Karlidag, H. and Dursun, A. (2011). Salt tolerance of *Physalis* during germination and seedling growth. *Pakistan J. Bot.* **43**(6): 2673-2676.

Yilmiz, K. E. and Akinci, S. (2004). Effect of salt stress on growth and Na, K contents of pepper (*Capsicum annum* L.) in germination and seedling stages. *Pakistan J. Biol. Sci.* **4**(4): 606-610.

Zhani, K., Elouer, M. A., Aloui, H. and Hannachi, C. (2012). Selection of a salt tolerant Tunisian cultivar of chili pepper (Capsicum frutescens) *Eurasia J. Biosci.* **6**: 47-59.

Zhifang, G. and Losecher, W. H. (2003). Expression of a celery mannose 6-phosphate reeducates in

Arabidopsis thaliana enhances salt tolerance and induces biosynthesis of both mannitol and a glucosyl-mannitol dimmer. *Plant Cell Environ.* **26**: 275-283.

Zhu, J. and Meinzer, F. C. (1999). Efficiency of C_4 photosynthesis in *Atriplex lentifortnis* under salinity stress. *Australian J. Plant Physiol.* **26**: 79-86.

Zhu, J. K. (2003). Regulation of ion homeostasis under salt stress. *Current Opinion Plant Biol*. **6**: 441-445.

APPENDICES

Appendix I. Analysis of variance of the data on germination of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of germination at different days after sowing							
		4	5	6	7	8	9	10	11
Variety (A)	5	160.14*	1551.55*	2253.97*	2679.28*	2432.33*	2440.63*	2149.92*	2169.54*
NaCl concentration (B)	4	2268.60*	8677.16*	13467.65*	15474.31*	18616.50*	18693.51*	18846.27*	18919.82*
Variety (A) X NaCl concentration (B)	20	93.89*	461.95*	352.81*	299.03*	255.54*	250.45*	228.20*	228.41*
Error	60	0.23	0.82	2.289	4.27	5.22	6.134	7.04	7.00

*Significant at 5% level of significance

^{NS} Non significant

Appendix II. Analysis of variance of the data on radicle length of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of radicle length at different days after sowing			
		5	7	9	11
Variety (A)	5	5.56*	2.87*	5.25*	5.64*
NaCl concentration (B)	4	76.04*	102.09*	122.16*	122.42*
Variety (A) X NaCl concentration (B)	20	0.96*	0.38*	0.56*	0.50*
Error	60	0.01	0.02	0.03	0.03

*Significant at 5% level of significance

^{NS} Non significant

Appendix III. Analysis of variance of the data on plumule length of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of plumule length at different days after sowing			
		5	7	9	11
Variety (A)	5	2.98*	2.13*	2.67*	3.17*
NaCl concentration (B)	4	32.43*	55.34*	70.92*	76.12*
Variety (A) X NaCl concentration (B)	20	0.53*	0.30*	0.41*	0.43*
Error	60	0.01	0.01	0.02	0.03

*Significant at 5% level of significance

^{NS} Non significant

Appendix IV. Analysis of variance of the data on radicle fresh weight of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of radicle fresh weight at different days after sowing			
		5	7	9	11
Variety (A)	5	5.50*	13.49*	24.75*	45.77*
NaCl concentration (B)	4	69.74*	160.14*	244.62*	283.07*
Variety (A) X NaCl concentration (B)	20	1.19*	2.15*	3.12*	5.38*
Error	60	0.01	0.04	0.12	0.17

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on radicle dry weight of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of radicle dry weight at different days after sowing			
		5	7	9	11
Variety (A)	5	0.18*	0.23*	0.23*	0.24*
NaCl concentration (B)	4	5.57*	5.40*	7.54*	8.51*
Variety (A) X NaCl concentration (B)	20	0.04*	0.05*	0.04*	0.03*
Error	60	0.001	0.002	0.002	0.003

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on plumule fresh weight of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of plumule fresh weight at different days after sowing			
		5	7	9	11
Variety (A)	5	33.62*	51.42*	50.90*	65.23*
NaCl concentration (B)	4	465.05*	699.20*	1022.20*	1129.37*
Variety (A) X NaCl concentration (B)	20	6.36*	4.31*	6.56*	7.68*
Error	60	0.08	0.20	0.35	0.58

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on plumule dry weight of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square of plumule dry weight at different days after sowing			
		5	7	9	11
Variety (A)	5	0.04*	0.05*	0.13*	0.10*
NaCl concentration (B)	4	0.99*	1.46*	2.51*	2.70*
Variety (A) X NaCl concentration (B)	20	0.01*	0.01*	0.02*	0.02*
Error	60	0.001	0.001	0.001	0.001

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on plumule dry weight of tomato as influenced by combined effect of variety and NaCl concentration

Source of variation	df	Mean square values of	
		Germination coefficient	Vigority index
Variety (A)	5	4.03*	370712.18*
NaCl concentration (B)	4	727.63*	2860884.64*
Variety (A) X NaCl concentration (B)	20	0.72*	45743.73*
Error	60	0.35	759.79

*Significant at 5% level of significance

[NS] Non significant

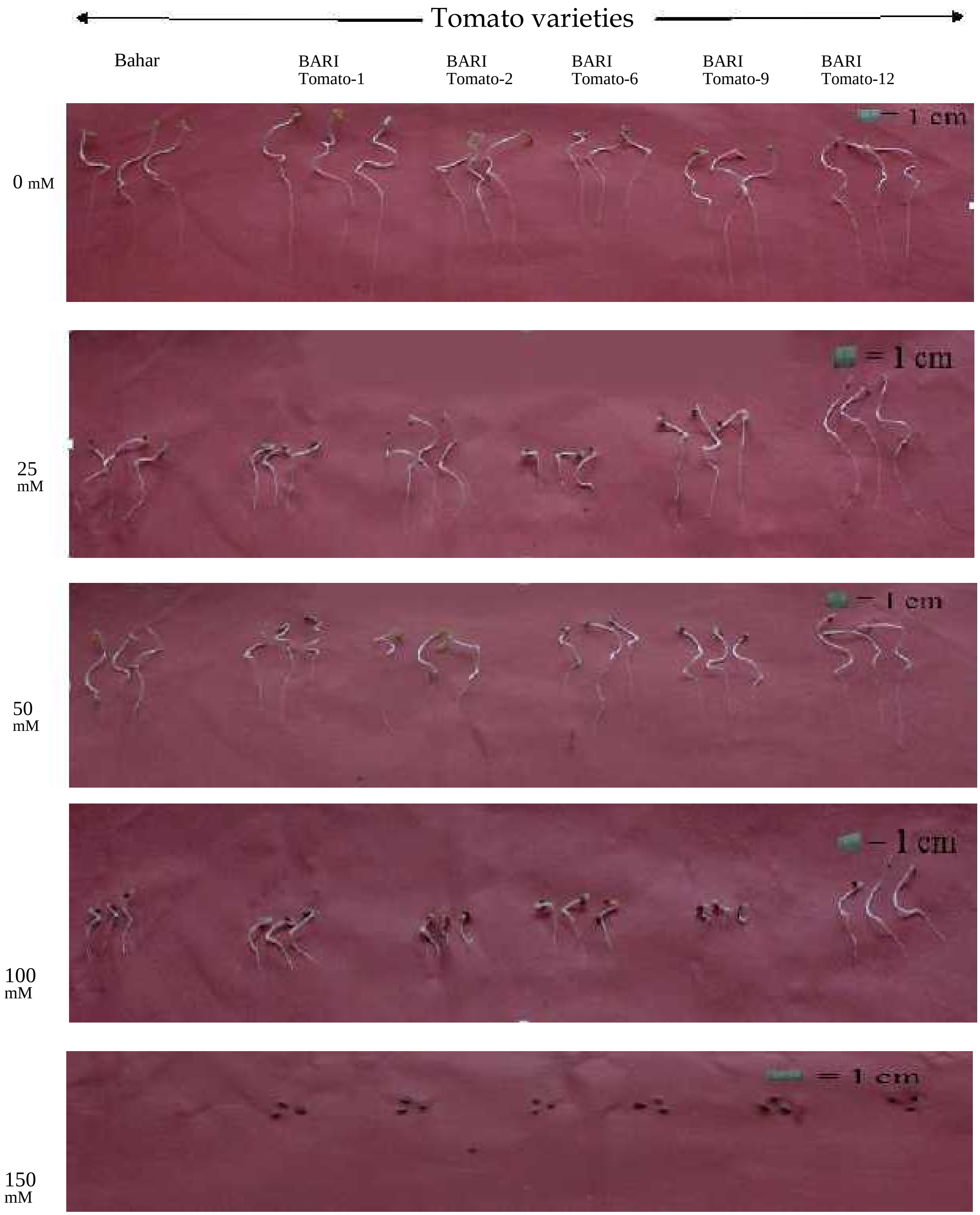


Plate 1. Photograph showing combined effect of NaCl salt and variety on seed germination and seedling growth of tomato