SCREENING OF SALT TOLERANT GENOTYPES OF SOYBEAN

PRITHIKONA ROY

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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SCREENING OF SALT TOLERANT GENOTYPES OF SOYBEAN

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PRITHIKONA ROY

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APPROVED BY:

Prof. Dr. Md. Abdullahil Baque **Department of Agronomy** **Supervisor**	**Prof. Dr. Md. Fazlul Karim** **Department of Agronomy** **Co-supervisor**

Prof. Dr. Md. Shahidul Islam
Department of Agronomy
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled “ ***SCREENING OF SALT TOLERANT GENOTYPES OF SOYBEAN”*** *submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***Master of Science*** *in* ***Agronomy,*** *embodies the result of a piece of bona fide research work carried out by* ***PRITHIKONA ROY,*** *Registration No.* ***11-04342*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:

Dhaka, Bangladesh

Professor Dr. Md. Abdullahil Baque
Supervisor
Department of Agronomy
Sher-e-Bangla Agricultural University,
Dhaka-1207

Dedicated

To

My Beloved Parents

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The Author

SCREENING OF SALT TOLERANT GENOTYPES OF SOYBEAN

ABSTRACT

An experiment was carried out in the central laboratory of Sher-e-Bangla Agricultural University, Dhaka during January to March 2017 for screening salt tolerant genotypes of soybean. The experiment consisted of 15 soybean genotypes *viz,* V_1 (Shohagh), V_2 (BARI soybean 5), V_3 (BARI soybean 6), V_4 (BD-2324), V_5 (BD-2326), V_6 (BD-2337), V_7 (BD-2346), V_8 (BD-2349), V_9 (BD-2351), V_{10} (BD-2352), V_{11} (BD-2353), V_{12} (BD-9402), V_{13} (BD-9418), V_{14} (BD-9420) and V_{15} (BD-9426). Seeds of 15 genotypes were collected from Bangladesh Agricultural Research Institute (BARI). The performance of the genotypes was tested under 5 levels of salinity *viz*. Control (No salt), 5, 10, 15 and 20 dSm^{-1}. The experiment was laid out in Completely Randomized Design (CRD) with five replications. There are significant differences observed among the different levels of salinity in case of almost all the parameters. For all the soybean genotypes used in the study, the highest seedling emergence rate was observed under control condition where no salinity stress was imposed. Salinity stress both at 15 dSm^{-1} and 20 dSm^{-1} NaCl significantly reduced the seedling emergence rate for all soybean genotypes. The highest germination rate (85.88%) was found from V_3 (BARI soybean 6) followed by V_2 (BARI soybean 5) and V_9 (BD-2351) which were 83.64 and 69.98% respectively at control and the lowest germination rate was found from V_5 (BD-2326) (18.97%) followed by V_{11} (BD-2353) (24.09%), V_{10} (BD-2352) (30.10%) and V_{14} (BD-9420) (29.65%) at 20 dSm^{-1}. Accordingly, more or less similar trend was found on shoot length, root length, fresh weight $plant^{-1}$, dry weight $plant^{-1}$, relative water content, turgid weight, water retention capacity, water saturation deficit and vigour index. Among 15 soybean genotypes V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) are salt tolerant which are attributed to higher germination rate, shoot length, root length, dry weight, relative water content, water retention capacity and vigour index and rest of the soybean genotypes were found to be sensitive to salt stress.

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ABBREVIATIONS AND ACRONYMS

% = Percentage
BARI = Bangladesh Agricultural Research Institute
BBS = Bangladesh Bureau of Statistics
BCSRI = Bangladesh Council of Scientific Research Institute
Ca = Calcium
cm = Centimeter
CV % = Percent Coefficient of Variation
DAS = Days After Sowing
DMRT = Duncan’s Multiple Range Test
e.g. = exempli gratia (L), for example
et al., = And others
etc. = Etcetera
FAO = Food and Agricultural Organization
g = Gram (s)
GM = Geometric mean
i.e. = id est (L), that is
K = Potassium
Kg = Kilogram (s)
L = Litre
LSD = Least Significant Difference
M.S. = Master of Science
m^2 = Meter squares
mg = Miligram
ml = MiliLitre
No. = Number
^{o}C = Degree Celceous
P = Phosphorus
SAU = Sher-e-Bangla Agricultural University
USA = United States of America
var. = Variety
Mg = Microgram

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L. Merrill), is a widely grown crop for its edible bean which has numerous usesd with innumerable possibilities of not only improving agriculture, but also supporting industries. Soybean is a major source of edible oil (20%) and high quality protein (40%). It is a rich source of amino acids, vitamins and minerals. Recently, soybean has become an important crop in Bangladesh for its increasing demand as an ingredient of poultry and fish meal as well as for the consciousness of its healthy nutrition as human food. It is one of the most economic and nutritious crops in the world (Yaklich *et al*., 2002). The seeds of soybean contain 42-45% protein as well as 22% edible oil (*Mondal et al*., 2002).

Soybean is a very important recognized oil seed and protein crop in the world. It is a good source of protein, unsaturated fatty acids, minerals like Ca and P including vitamins A, B and D that meet different nutritional needs (Rahman, 1982). The seed contains about 40-45% protein, 18-20% edible oil and 20-26% carbohydrate (Gowda and Kaul, 1982).The multipurpose use of soybean is gradually increasing day by day in our country. Soybean oil is used as a raw material in manufacturing anti biotic, paints, varnishes, adhesives, lubricants etc. Soybean meal is used as protein supplement in human diet, cattle and poultry feeds.

Soybean is a major oil seed crop of world grown in an area of 91million hectare with production of 204 metric ton and productivity of 2,233 kg/ha. The crop is mainly cultivated in USA, China, Brazil, Argentina and India. India contributes more than 90 per cent of world’s acreage. In India it is grown over an area of 8.17 million hectare with production of 9.46 metric ton and productivity of 1,069 kg per ha (Anon., 2007). Major soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh and Gujarat. In

Karnataka, soybean occupies an area of 1.62 lakh hectare with the production of 1.53 lakh tonnes and productivity of 950 kg per ha (Anon., 2007).

In Bangladesh, about five thousand hectares of land is under soybean cultivation and annual production is approximately 4 thousand metric tons with an average yield of 1.5-2.3 t/ha (BARI, 2006). The low productivity of soybean both at national and state level is attributed to abiotic and biotic stresses like drought, salinity, weeds, insect pests and diseases. Among these, salinity a great threat to soybean production by increasing cost of cultivation and impairing quality of produce in many ways.

Excess amount of salt in the soil adversely affects the plant growth and development. The increasing use of water of poor quality, the continuous addition of waste salts to our environment, as well as the increasing contamination of under water resources lead to gradual soil salinization. Global estimates are that more than 800 million hectares of land throughout the world are salt affected (Munns *et al*., 2008). This amount accounts for more than 6% of the world's total land area.

Salt affects the process of germination as high salt concentrations decrease the osmotic potential of soil solution creating a water stress in plants. Secondly, they cause severe ion toxicity since, Na^+ is not readily sequestered into vacuoles as in halophytes (Munns*et al*., 2008). Salt tolerance at germination is easy to measure and performances of many crops are studied at germination stage under saline conditions (Mensah *et al*., 2006 and Khayatnezhad *et al*., 2010). Different varieties of crop plants and legumes have been analyzed for salt tolerance at germination and the results revealed important information about varietal differences (Mensah and Ihenyen, 2009 and Hakim *et al*., 2010). This helps in identifying the tolerant varieties, which can be further studied and economically exploited.

Among the legumes, soybean cultivation is rapidly spreading. Soybean is a versatile food plant that used in its various forms is capable of supplying most nutrients. Soybean germplasms display a spectrum of salt tolerance capability from high to low. In china, salt tolerance of germplasm is extensively studied (Shao *et al*., 1993). However, untill now Indian soybean varieties have not been studied for their salt tolerance.

Soybean has been classified as moderately salt sensitive, together with maize, potato, tomato and other crops (Katerji *et al*., 2003). Saline conditions hamper germination, growth (Wang and Shannon, 1999), and nodule formation (Singleton and Bohlool, 1984) in soybean, resulting in significant reductions in seed yield (Parker *et al*., 1983; Yang and Blanchar, 1993).

Soil salinity impairs physiological functions by multiple mechanisms, including water stress, specific ion toxicity, ion imbalance stress, and induced nutrient deficiency (Munns and Tester, 2008; Zhang *et al*., 2010). The relative importance of these detrimental stresses may vary according to crop species, growth stages, and the duration of the stress imposed (Jones, 1981; Munns and Tester, 2008). In soybean, genotypic differences in tolerance were particularly associated with the ability to prevent aboveground parts of plants from accumulating sodium (Na) and chlorine (Cl) (Essa, 2002).

Hence, in the present investigation fifteen soybean genotypes are analyzed for the response towards increasing salt stress. Study on the response of soybean to salinity stress may be helpful in breeding salt tolerant varieties. With the above facts keeping in view the present investigation was undertaken with following objectives:

i) To screen out salt tolerant genotypes of soybean,
ii) To find out the critical salt tolerance level of soybean genotypes, and
iii) To determine germination rate, seedling growth and water relation behavior of soybean under salt stress.

CHAPTER II

REVIEW OF LITERATURE

Salinity stress is one the most deleterious abiotic stresses reducing crop production across the world. It is one of the most important stresses limiting crop production in arid and semiarid regions (Saboora, 2006) and it is a great problem in the coastal region of Bangladesh, where a vast area remains fallow for long time. Very limited research works have been conducted to adapt soybean in the saline area of Bangladesh. An attempt has been made to find out the performance of soybean at different levels of salinity. To facilitate the research works different literatures have been reviewed in this chapter under the following headings.

2.1 Salinity effect on different cultivars

Kumar (2017) found that conducted an experiment under different salinity stress (NaCl and Na_2SO_4) concentrations to study the effect of salinity on germination and seedling growth of soybean varieties (BSS-2 and JS-335). Salinity is one of the most widespread environmental stresses heavily on the crop affects fertility. The results showed that salinity stress caused by NaCl and Na_2So_4 reduced both germination and seedling growth of both varieties of soybean. JS-335 appeared more tolerant under different NaCl concentrations and more sensitive under different Na_2So_4 concentrations than BSS-2.

El-Sabagh *et al*. (2015) conducted a pot experiment to study the response of three Egytp soybean cultivars (Giza-111, Giza-82 and Giza-35) to salinity stress (Control, 10 dSm^{-1} NaCl). The results showed that the cultivars had a negative response to salinity stress and most of the measured plant yield traits, oil and protein content. Results indicated that Giza-111 cultivar surpassed other cultivars in all characters under study. The highest value of seed yield, seed oil and protein percent observed in Giza-111 with the compare to other cultivars under salinity conditions. It was concluded that soybean is a sensitive plant to salinity stress, but the extent of this sensitivity varies among cultivars. As a result, Giza-111 cultivar showed more capability to survive under salinity condition compared with another cultivars regarding of almost all plant traits examined. Considering, Giza-111 was found more appropriate under salinity condition.

Yasuta and Kokubun (2014) tested that the super-nodulating En-b0-1 genotype is more salinity tolerant than a normal nodulating genotype with a pot experiment. Results showed that under saline conditions imposed during pre-flowering, En-b0-1 formed heavier nodules, resulting in greater N uptake, higher photosynthetic activity, and greater biomass production compared with Enrei. Saline treatment increased the concentrations of sodium (Na) and chlorine (Cl) in all plant parts regardless of genotype; but in En-b0-1, the concentrations of these elements in shoots were significantly lower, while those in roots and nodules were higher than in Enrei. When the salinity treatment was imposed during the reproductive growth stages, En-b0-1 maintained higher N uptake, leading to better alleviation of salinity-induced yield reduction than in Enrei. The super-nodulating genotype En-b0-1 was more tolerant to salinity than its parental normal-nodulating cultivar, due to its superior nodulation and prevention of excessive accumulation of Na and Cl in shoots, which were retained in roots and nodules.

Kondetti *et al*. (2012) carried out an experiment to observe the effect of salinity stress on eleven (Co-1, CoSoy-2, DS-40, GujratSoy-1, JS-80-21, MACS-13, MAUS-2, NRC-2, PalamSoy, Pusa-16 and Shilageet) Indian soybean varieties were analyzed under increasing salinity levels (0, 120, 180, 240 and 300 dSm-1) of NaCl. Salinity had adverse effects on germination and all the physiological parameters (root length, shoot length, root/shoot ratio, dry matter production in root and shoot, moisture content in root and shoot) for early seedling growth. The results revealed that varietal difference was present for all the parameters. The varietal difference was pronounced at high (240 and 300 dSm-1) salt concentrations of NaCl.Co-1, GujratSoy-1 and NRC-2 varieties were salt sensitive and CoSoy-2, DS-40, PalamSoy, Pusa-16 varieties were salt tolerant, and rest varieties were moderate in their response towards salt.

Milne (2012) studied on the effects of 30 and 60 dSm^{-1} NaCl on Lettuce *(Lactuca sativa* L.), grown in soilless culture, with additions of 0, 1, 2 and 4 dSm-1 Si was evaluated. Height, leaf number, weight, chlorophyll content and elemental analysis of plants were examined.

Saberi *et al.* (2011) conducted a pot experiment where two forage sorghum varieties (Speed feed and KFS4) were grown under salinity levels of 0, 5, 10 and 15 dSm^{-1}. Leaf area of plants were also reduced in response to salinity and decreasing soil water availability, while the suppressive effect was magnified under the combined effect of the two factors. Salinity and water stress significantly affected the total leaf area of ratoon crop. The maximum total leaf area was obtained in the control treatment but with increasing salinity and infrequent irrigation, this parameter was found to decrease. Maximum leaf area of 1167 dSm^{-1} plant^{-1} was attained in plants with normal irrigation, without water stress. Under effects of salinity 5, 10 and 15 dSm-1 the leaf area was reduced by 7, 12 and 17%, respectively.

Bouaounia *et al*. (2000) studied the salt tolerance of durum wheat (*Triticum turgidum*). They observed decreased growth of whole plants, delayed emergence of new leaves and limited K^+ and Ca^{++} accumulation in these organs under NaCl treated soil salinity. Moreever, Na^+ accumulation decreased from older to younger leaves. Cellular dry matter production was not much affected in spite of a drop in cellular water content. Depressive effects of K^+ and Ca^{++} accumulation were evident while Na^+ cellular accumulation increased with NaCl concentration. These results suggest that wheat has mechanisms to restrict Na^+ transport and accumulation in younger leaves.

Islam and Salam (1996) conducted a pot experiment. The variety Pokkali, BINA 19, BINA 13 and IRATOM 24 were grown in nutrient solutions with different salinity levels (control, 0.9% NaCl). The biomass of BINA 19 was not affected with increased salinity. The biomass of Pokkali and IRATOM 24 decreased with increase in salinity.

Mohammad *et al*. (1995) conducted an experiment with five wheat lines (PK-15869, PK-15885, PL-16171, PK-16172 and PK-16187) under saline condition. These lines were tested for salt tolerance in the presence of specific ions (Na^+, Ca^{++}, Cl^-, SO_4^{--}). The seeds were germinated on agar medium containing varying salt concentrations (EC0,5,10,20,25 and 30 dSm^{-1}). The genotypes PK-16171 showed the highest percentage germination, shoot length, plant fresh weight and dry matter yield under different salinity levels. Fresh and dry weights of plants were reduced in the presence of salinity in majority of the trails. Two genotypes, PK-15885 and PK-16171 showed salt tolerance.

Gupta and Shrivastava (1989) also observed in a sand culture trial that the effects of ionic osmotic stress alone and in comnination with NaCl, tow wheat cultivars differed significantly. They observed Karicha-65(tolerant) was superior to Kalayansona (susceptible) in maintaining higher leaf area and root growth under both types of stress. They had the opinion the salinity stress was less injurious than osmotic ionic stress.

Kemal-ur-Rahim (1988) carried out an experiment with 4 winter wheat cultivars grown in a culture solution where he failed to observe any adverse effects of salinity, up to 75 mM NaCl but greater than 120 mM NaCl was sufficient to jeopardize survival of the crop in salt sensitive cultures. Salinity had little effect on photosynthesis but a large effect on grain yield and dry matter production was noticed. It increased root:shoot ratio, stomatal density and specific leaf weight.

2.2 Effect of salinity on morphological characters of plant

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

Nawaz *et al.* (2010) reported that applications of salt in the growth medium caused reduction in shoot length of sorghum cultivars. Under saline conditions 50 dSm-1proline was more effective to reduce the effect of NaCl than 100 mM proline in both cultivars. Proline level 50 mM showed 26.58% and 11.78% increased shoot length as compared to NaCl stresses plants. However, high concentration of proline (100 dSm-1) was not so much effective as compared to low concentration i.e. 50mM.

Jafari *et al.* (2009) studied that the interactive effects of salinity, calcium and potassium on physio- morphological traits of sorghum *(Sorghum biclolor* L.) in a green-house experiment. Treatments included 4 levels of NaCl (0, 80, 160, and 240mM NaCl), 2 levels of CaCh (0 and 20mM), and 2 levels of KCl (0 and 20mM). Salinity substantially reduced the plant growth as reflected by a decrease in the plant height, shoot and root weight.

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

Siringam *et al.*, 2009 and Cha-um *et al.*, 2007 reported that the reduction in the growth of soybean plants subjected to salt stress may be due to an increased uptake of toxic sodium. The NaCl is readily dissolved in water solvent yielded toxic Na+ that is easily absorbed into root tissues and transport throughout plant organs, leading to toxic ion damage, osmotic stress and nutritional imbalance resulting retardation in vegetative growth.

Liu *et al.* (2008) reported significant reduction in the dry biomass of halophyte *Suaeda salsa* when exposed to different concentration of NaCl under different water regimes.

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

Munns and Tester (2008) observed that osmotic effect, which develops due to increasing salt concentration in the root medium, is a primary contributor in growth reduction in the initial stages of plant growth. This stage can be characterized by reduction in generation of new leaves, leaf expansion, development of lateral buds leading to fewer braches or lateral shoots formation in plants.

Memon *et al.* (2007) conducted a pot experiment on silty clay loam soil at Sindh Agriculture University, in Tando Jam, Pakistan. Sarokartuho variety of Sorghum *(Sorghum bicolor* L.) was continuously irrigated with fresh (control) and marginally to slightly saline EC 2, 3, 4 and 5 (dSm-1) waters. Increasing water salinity progressively decreased plant height and fodder yield (fresh and dry weight) per plant.

Mortazainezhad *et al.* (2006) had observed that tiller number decreased with increasing salinity levels imposed at all growth stages in rice. Soil salinity affects the growth of rice plant. But the degree of deleterious effect may vary on the growth stages of plant. During germination rice is tolerant, but it becomes very sensitive during the early seedling stage. Similar result was also reported by many workers in rice (Islam, 2004; Rashid, 2005; Karim, 2007).

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

Parida and Das (2005) observed salt stress affects some major processes such as root/shoot dry weight and Na^+/K^+ ratio in root and shoot.

Sixto *et al.* (2005) stated that depending on increasing salinity levels, decrease in vegetative growth parameters has been observed in plants. Decrease in root, stem and shoot developments, fresh & dry stem and root weights; leaf area and number and yield have been observed in plants subject to salinity stress.

Ali and Awan (2004) conducted a research on Salt tolerance in eighteen advanced rice genotypes was studied under an artificially salinized (EC= 8.5 dSm^{-1}) soil conditions after 90 days of transplanting. The results showed that the yield per plant, and number of productive tillers, panicle length and number of primary braches per panicle of all the genotypes were reduced by salinity.

Islam (2004) conducted a pot experiment to study the effect of salinity (3, 6, 9, 12 and 15 dSm^{-1}) on growth and development of rice under induced salinity condition and observed that number of leaves decreased with the increased salinity level. Similar result was also observed by Rashid (2005) in rice.

Netondo *et al.* (2004) conducted an experiment where sorghum plants were grown in sand culture under controlled greenhouse conditions. The NaCl concentrations in complete nutrient solution were 0 (control), 50, 100, 150, 200, and 250 dSm^{-1}. Salinity significantly reduced leaf area by about 86% for both varieties of sorghum and these decreases were similar for the two sorghum varieties.

Javaid *et al.* (2002) investigated the salinity effect (0, 20, 50 and 75 mM NaCl) on plant height in four rice variety and reported that salinity affects the morphological characters of the studied plants and plant height decreased with increased salinity levels.

Javaid *et al.* (2002) investigated the salinity effect (0, 20, 50 and 75 mM NaCl) on plant height, stem diameter, TDM, leaf number and leaf area in four *Brassica* species and reported that salinity affected the morphological characters of the studied plants and leaf number as well as leaf area decreased with increased ssalinity levels.

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

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

Chakraborti and Basu (2001) conducted a pot experiment to study the effect of salinity (0, 6 and 9 dSm^{-1}) on growth and development of sesame under induced salinity condition and observed that number of leaves decreased with the increased salinity level.

El-Midaoui *et al.* (1999) conducted a greenhouse experiment with three sunflower cultivars (cv. Oro 9, Flamm e pinto and Ludo) under four salinity levels of 0, 50, 75 and 100 mM NaCl. They reported that plant growth was adversely affected by increasing salinity. Similar results were also reported by Steduto *et al.* (2000) in sunflower.

Shannon and Grieve (1999) reported that salinity changes the roots structure by reducing their length and mass, therefore roots may become thinner or thicker.

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

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

Abdullah *et al.* (2001) conducted an experiment for finding out the effect salinity stress on seed set of IR-28 rice under different salinity levels and found that panicle length was significantly decreased due to salinity stress.

Chakraborti and Basu (2001) studied salt tolerance ability in 9 sesame varieties under saline condition and reported that capsule per plant, seeds per capsule and seed yield decreased under saline condition in all studied varieties of sesame.

Yasuta and Kokubun (2014) reported that the lower yield reduction of a super-nodulating en-b0-1 compared with its normal-nodulating parent Enrei under salinity stress was primarily due to the larger seeds number of en-b0-1 .

Saberi *et al.* (2011) found that increased salinity significantly reduced forage dry yield from 44.09 gm plant^{-1} in the control to 32.76 g plant^{-1} at salinity with 15 dSm^{-1}. For every one unit increase in salinity, the forage yield decreased by 5.2 units and for every one unit increase in water stress (irrigation frequency), the forage yield decreased by 3.6 units.

Hamayun (2010) reported that, the adverse effects of NaCl induced salt stress on growth attributes and endogenous levels of gibberellins (GA), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA) soybean cv. Hwangkeumkong was showed. 1000 seed weight and yield significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

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

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

Karim (2007) conducted an experiment to investigate the effect of different salinity levels (0, 6, 9 and 12 dSm^{-1}) and reported that all parameters including panicle length decreased with increased salinity levels. Panicle length was adversely affected by soil salinity levels as reported by most of the researchers (Islam *et al*., 1998; Hossain, 2002; Islam, 2004; Natarajan *et al*., 2005 and Rana, 2007).

Karim (2007) reported that grain yield decreased with increased salinity levels. The yield was decreased due to production of decreased number of effective tillers $hill^{-1}$, decreased number of grains $panicle^{-1}$and 1000-seed weight. Similar result was also reported by many researchers (Islam *et al*., 1998. Hossain, 2002; Sen, 2002; Islam 2004; Rashid, 2005 and Hossain, 2006).

Rana (2007) carried out a pot experiment with 5 levels of salinity (0, 3, 6, 9 and 12 dS/m) of three rice varieties viz., BRRl dhan-42, STM-1 and STM-2 and reported that plant height, number of tillers $hill^{-1}$, TDM $hill^{-1}$, leaf area $hill^{-1}$, root dry weight $hill^{-1}$ and yield contributing characters and yield decreased significantly with increase in salinity levels. Among the advanced rice lines BRRIdhan-42 showed more tolerance for all studied parameters compared to STM-1 and STM-2.

Hajer *et al*. (2006) and Cuartero and Munoz (1999) conducted two different experiment separately on tomato under saline condition and reported the effect of NaCl salinity stress on the growth of tomato plants was reflected in lower fresh and as well as dry weights.

Ali *et al*. (2005) conducted a pot experiment with three salinity levels (0, 6 and 9 dSm^{-1}) and observed that 1000-seed weight decreased with increased salinity level in sesame. Again, Thakral *et al*. (1996) studied six *B. carinatus* species under 0-125 meq L^{-1} chloride solution and observed that siliqua $plant^{-1}$, 1000-seed weight and seed yield decreased under salinity.

El-Hendawy *et al*. (2005) reported that tiller number of wheat was affected more by salinity than leaf number and leaf area at the vegetative stage. Salinity decreased dry weight per plant significantly at all growth stages. Spikelet number on the main stem decreased much more with salinity than spike length, grain number and 1000-grain weight at maturity. They also concluded that an increase in tiller number per plant and spikelet number per spike will improve the salt tolerance of wheat genotypes in breeding programs.

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

Gain *et al*. (2004) studied the effect of salinity (0, 7.81, 15.62, 23.43 and 31.25 dSm^{-1}) on yield attributes and yield in rice and reported that number of spikelet $panicle^{-1}$, 1000-grain weight and dry mass decreased with increasing salinity levels but the decrement was less in salt tolerant varieties than salt susceptible varieties

This statement was supported many workers (Ahmed *et al.*, 1980; Islam *et al.*, 1998; Islam, 2004 and Hossain, 2006).

Netondo *et al*. (2004) conducted an experiment to determine how salinity affects growth, water relations, and accumulation of cations of nutritional importance in various organs of grain sorghum. Two Kenyan sorghum varieties, Serena and Seredo, were grown in a greenhouse in quartz sand supplied with a complete nutrient solution to which 0 (control), 50, 100, 150, 200, and 250 mM NaCl was added. The 250 mM NaCl treatment significantly reduced the relative shoot growth rates, measured 25 days after the start of salt application, by 75 and 73%, respectively, for Serena and Seredo, and stem dry weight by 75 and 53%.

Leena and Kiran (2003) reported that in Vadodara, Gujarat, India to test the effect of salt stress on *Sorghum bicolor*. Though there was a reduction in the chlorophyll content of the plants subjected to salt stress, the fresh and dry weights of the plants were reduced only at the earlier stages.

Debnath (2003) and Rahman (2003) worked with mustard to know the effect of different levels of salinity (0, 5, 7, 10 and 15 dSm^{-1}) on yield attributes and dry matter partitioning and reported that harvest index decreased with increased salinity levels.

Katerji *et al*. (2003) reported that soybean yield of sensitive cultivars is decreased dramatically under salt stress. Soybean yield was 80% at 4.0 dS m^{-1} and 44% at 6.7 dS m^{-1} versus 100% at 0.8 dS m^{-1}. Maas (1986) and Bolarin *et al.* (1993) reported that, all stages of plant development including seed germination, vegetative growth and reproduction show sensitivity to salt stress and economic yield is reduced under salt stress.

Hossain (2002) conducted a pot experiment with three salinity levels (0, 6 and 9 dSm^{-1}) and observed that harvest index decreased with increase of salinity level in rice. Similarly, Islam (2004) reported that harvest index decreased with the increase of salinity level in rice. Again, Hossain*et al*. (2006) worked with rice to know the effect of different levels of salinity (0, 6, 9, and 15 dSm^{-1}) on yield attributes and dry matter partitioning and reported that harvest index decreased with increased salinity levels. Similar result was also reported by Rana (2007) in rice.

From the above discussed review of the literature it can be concluded that the growth and yield of soybean is adversely affected due to salinity stress and there is a significant in varietal variation in soybean exists in the respond of soybean to salinity stress

CHAPTER III

MATERIALS AND METHODS

A screening trial of 15 soybean cultivars for salinity tolerance was performed. In this chapter, the materials used and methodology followed during the experimental period are described in details.

3.1 Experimental site

An experiment was conducted in the Central Laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh from January to March, 2016.

3.2 Planting materials

Fifteen (15) soybean genotypes were used and collected from Bangladesh Agricultural Research Institute, Gazipur. Three released soybean variety and twelve advanced lines were used for the experiment. Collected seed samples were dried for 3 hours under sunlight. The three (3) test varieties were V_1 = Shohag, V_2 = BARI soybean 5 and V_3 = BARI soybean 6 and twelve (12) advanced lines were V_4 = BD-2324, V_5 = BD-2326, V_6 = BD-2337, V_7 = BD-2346, V_8 = BD-2349, V_9 = BD-2351, V_{10} = BD-2352, V_{11} = BD-2353, V_{12} = BD-9402, V_{13} = BD-9418, V_{14} = BD-9420, V_{15} = BD-9426. Seedlings are raised in a separate Petri dish for each genotype.

3.3 Seed placement for germination

The test genotypes of soybean for the experiment were dried for 3 hrs under sunlight. Filter paper were cut according to the petridish size and place into the bottom of the dish. 30 seeds of each soybean genotypes were placed into the petridish. 0, 1.4625, 2.925, 4.3875 and 5.85 g NaCl were dissolved in 500 ml distill water separately to get 0, 5, 10, 15 and 20 dSm^{-1} NaCl solution, respectively. The salt solutions were used in wetting the filter paper which is used in Petri dishes for germinating the soybean seeds. These seeds were dried at room temperature. Then these seeds were set on the different leveled Petri dishes.

3.4 Equipment used

For conducting the experiment petri dish and filter paper were used. Those were used for raising of seedlings. According to the Petri dish size filter paper were cut and set into the bottom of the dish. 30 seeds of each soybean genotypes were dried under the sunlight. Then those were placed into the petri dish.

3.5 Treatment

Fifteen (15) soybean genotypes with 5 salinity levels as NaCl were used for the experiment under the present study. The following soybean genotypes and salinity levels were used:

3.5.1 Soybean genotypes: 15 soybean genotypes

1. V_1 = Shohag
2. V_2 = BARI soybean 5
3. V_3 = BARI soybean 6
4. V_4 = BD-2324
5. V_5 = BD-2326
6. V_6 = BD-2337
7. V_7 = BD-2346
8. V_8 = BD-2349
9. V_9 = BD-2351
10. V_{10} = BD-2352
11. V_{11} = BD-2353
12. V_{12} = BD-9402
13. V_{13} = BD-9418
14. V_{14} = BD-9420
15. V_{15} = BD-9426

3.5.2 Salinity levels: 5 salinity levels

1. S_0 = 0 dSm^{-1}
2. S_1 = 5 dSm^{-1}

3. $S_2 = 10\ dSm^{-1}$
4. $S_3 = 15\ dSm^{-1}$
5. $S_4 = 20\ dSm^{-1}$

3.6 Conduction of the experiment

3.6.1 Seed collection

Soybean seeds were collected from Bangladesh Agricultural Research Institute, Gazipur.

3.6.2 Observation and precaution

During the experiment every phase was ovserbed properly. Different equipments were used properly. Moisture levels in Petri dishes were maintained carefully so that no seeds were getting dried. Fungus infected seeds were removed from Petridis to keep the other seeds safe from fungal infection. The salt solutions were sprayed as per treatment on Petri dish until getting the saturated condition and it was continued 6 hrs interval.

3.7 Seed Treatment

Seeds were soaked into water. Then seeds were allowed to dry in room temperature. To regain optimum moisture level 2 to 3 days required for drying. Alcohol was used for surface sterilization so that the seeds were not infected by fungus.

3.8 Data collection

Data on seedling emergence of all the soybean genotypes were collected from 1 to 10 days after sowing. Normal seedlings were counted and percent of seedling emergence was recorded upto 10 days after setting seeds for germination test. Seedling mortality was also counted upto 10 days after seed sowing. The uprooted seedlings were washed with tap water and excess water was soaked with tissue paper. Five (5) healthy seedlings were selected and data were collected from these after 10 days of sowing. The plant parts were oven dried in an oven at 70^0 C for 4 days to measure the dry weight. Data on growth parameters of each level of NaCl salinity treatment were compared with the respective control treatment.

The following data were taken:

1. Rate of germination (%)
2. Shoot length (mm)
3. Root length (mm)
4. Fresh weight plant^{-1}
5. Dry weight plant^{-1} (mg)
6. Turgid weight (mg)
7. Relative water content (%)
8. Water saturation deficit
9. Vigour index

3.9 Procedure of recording data

3.9.1 Rate of germination (%)

The number of sprouted and germinated seeds were counted daily. Germination was recorded at 24 hrs interval and continued up to 10th day. As germinated seed more than 2 mm long plumule and radicle was counted.

The germination rate was calculated using following formula:

$$\text{Rate of germination (\%)} = \frac{Total\ Number\ of germinated\ seeds}{Total\ seed\ placed\ for\ germination} \times 100$$

3.9.2 Shoot length (mm)

From each Petri dish five healthy seedlings were selected. The shoot length of these five healthy seedlings was measured finally at 11 DAS. Measurement was done using the unit millimeter (mm) by a meter scale.

3.9.3 Root length

From each Petri dish, five healthy seedlings were selected. Then the Root length of these five seedlings was recorded finally at 11 DAS. Measurement was done using a meter scale and unit was expressed in millimeter (mm).

3.9.4 Fresh weight plant^{-1} (mg)

Five plants at 10 days after sowing (DAS) were collected and cleaned then weighed separately by shoot and root. The total weight of shoot and root was calculated to get fresh weight of whole plant and then averaged.

3.9.5 Dry weight plant^{-1} (mg)

The dry weight of shoot and root of the five seedlings from each Petri dish was measured at finally at 11 DAS. The sample was dried in an oven at 70°C till attained a constant weight. Then dry weight was recorded. The weight was converted to milligram (mg).

3.9.6 Turgid weight (mg)

Leaf of each seedling was placed into the petridish for 24 hrs and then leaves were soaked with distilled water for recording the turgid weight. After 24 hrs the turgid weight of leaves was recorded.

3.9.7 Relative water content (%)

Relative water content was measured using following formula:

Relative water content (WRC) (%) = $\frac{Fresh\ weight - Dry\ weight}{Tugid\ \ weight - Dry\ weight} \times 100$

3.9.8 Water saturation deficit

By using following formula water saturation deficit was measured:

Water saturation deficit (WSD) = 100- Relative water content

3.9.9 Vigour index

By using following formula vigour index was calculated:

Vigour index $=\frac{Total\ \ germination\ \ \times Seedling\ \ lengt\,h\ (mm\,)}{100}$

3. 10 Design

The single factor experiment was laid out in Completely Randomised Design (CRD) with 5 replications.

3.11 Statistical Analysis

For different parameter data were recorded.Then the recorded data were compiled and tabulated in proper form for statistical analysis. Data analysis was done for statistical test by using Completely Randomised Design (CRD). The data were analyzed using “Analysis of Variance (ANOVA)” technique with the help of computer package programme “MSTAT-C” and mean difference among the treatments were adjudged with LSD (Least Significant Difference) which was described by Gomez and Gomez (1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the results obtained from the experiment. The experiment was conducted to screen 15 soybean genotypes under 5 levels of salinity stress in terms of seedling emergence, plant stand establishment and some plant seedling growth parameters such as shoot length, root length, root and shoot fresh and dry weight. The data have been presented in tabular and graphical form. This chapter discusses and presents the results with nessesary headings and sub- headings.

4.1 Effect of salinity on seed germination

Salinity stress has adverse effects on soybean development periods, especially on seed germination and post-germinative growth. Germination percentage found from this experiment was significantly different and varied among soybean genotypes under different levels of saline concentration (Appendix II and Table 1). Under control condition V_3 (BARI soybean 6) was found the best genotype (96.77%) in respect of seed germination which was closely followed by V_2 (BARI soybean 5) (94.32%) and V_9 (BD-2351) (91.87%).V_3 (BARI soybean 6) gave the highest germination rate (92.32, 89.99, 89.45 and 85.88%, at 5, 10, 15 and 20 dSm^{-1}, respectively) at 0, 5, 10,15 and 20dS m^{-1} NaCl levels which were closely followed by V_2 (BARI soybean 5) (90.98, 86.73, 86.77 and 83.64% at 5, 10, 15 and 20 dSm^{-1} respectively) V_9 (BD-2351) (87.43, 83.03, 75.20 and 69.98% at 5, 10, 15 and 20 dSm^{-1} respectively). So, V_3 (BARI soybean 6),V_2 (BARI soybean 5) and V_9 (BD-2351) showed consistence result against all the NaCl concentrations. The rate of germination decreases with the increasing of saline concentration.

On the contrary, the lowest germination rate was counted in V_5 (BD-2326) (52.89%) and V_{10} (BD-2352) (57.48%) at 0 dSm^{-1} which were statistically similar. Under control condition, V_5 (BD-2326), V_{10} (BD-2352) and V_{11} (BD-2353) gave the lowest germination percentages 52.89%, 57.48% and 60.76% respectively. At different salt levels, V_5 (BD-2326) gave the lowest germination rate (39.95, 35.56, 24.15 and 18.97% at 5, 10, 15 and 20% respectively) which was closely followed by V_{10} (BD-2352) (42.99%, 39.84%, 31.06% and 30.10% at 5, 10, 15 and 20 dS m^{-1}) and V_{11} (BD-2353) (48.54%, 39.65%, 28.76% and 24.09% at 5, 10, 15 and 20 dS m^{-1}). The rate of germination percentage rapidly decreases with the increasing of NaCl concentration.

So, in the context of germination percentage to salinity tolerance/sensitivity, it may be concluded that among 15 soybean genotypes V_3 (BARI soybean 6), V_2 (BARI soybean 5) V_9 (BD-2351) might be referred as salt tolerance cultivar and V_5 (BD-2326), V_{10} (BD-2352) and V_{12} (BD-9402) as most salinity sensitive cultivar. Similar result was also found by different scientists in different crops for examples: Khatkar and Kuhad in wheat, Shirazi (2001), Lallu and Dixit (2005) in mustard and Bera *et al*. (2006) in chickpea. In the physiological point of view, the absorption of more K^+/Na^+ is beneficial. Increasing trend of salinity level decrease the ratio and probable reason injured the embryo (Cramer *et al*, 1994).

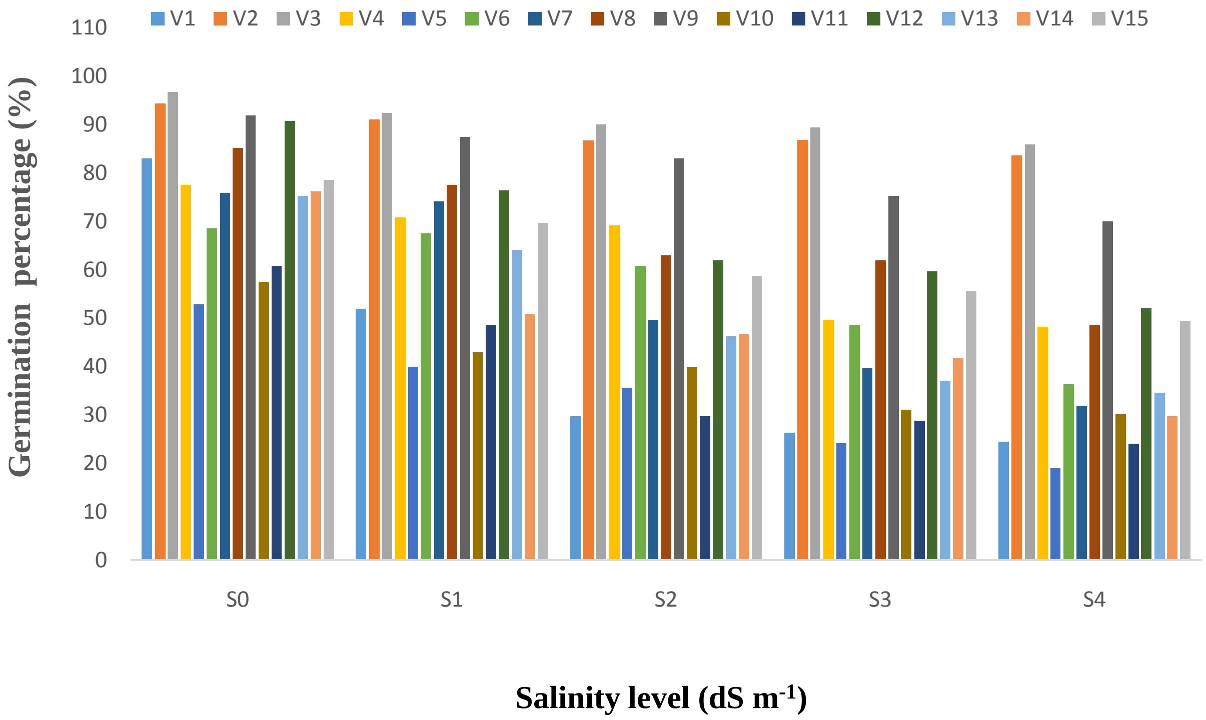

Figure 01. Effect of salinity levels on the fresh weight plant^{-1} (mg) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.2 Shoot length (mm)

Shoot length of soybean genotypes was significantly affected by different salinity levels (Appendix III and Table 2). Results revealed that at control condition, the genotype V_3 (BARI soybean 6) gave the highest shoot length (164.5 mm) which is closely followed by V_2 (BARI soybean 5) (155.3 mm) and this genotype also showed the best performance on shoot length at different salinity levels (141.4, 102.7, 96.60 and 90.40 mm at 5, 10, 15 and 20 dSm^{-1} respectively) these were closely followed by V_2 (BARI soybean 5) (87.73, 80.93, 68.13 and 59.42mm at 5, 10, 15 and 20 dS m^{-1} respectively).

On the contrary, V_5 (BD-2326) showed the lowest shoot length (76.60 mm) at control condition. V_5 (BD-2326) also showed the lowest shoot lengths (26.00, 13.25, 7.12 and 4.50 mm at 5, 10, 15 and 20 dSm^{-1} respectively) at different salinity levels which were closely followed by V_{10} (BD-2352) (34.40, 14.67, 10.75 and 9.00mm at 5, 10, 15 and 20 dS m^{-1} respectively).

At 20 dSm^{-1} NaCl solution, maximum shoot length was recorded for V_3 (BARI soybean 6) (90.40 mm) followed by V_2 (BARI soybean 5) (59.42 mm) but V_4 (BD-2324), V_5 (BD-2326), V_{10} (BD-2352), V_{11} (BD-2353) and V_{12} (BD-9402) showed the corresponding results 11.67 mm, 4.50 mm, 9.00 mm, 12.67 mm and 13.00 mm respectively. Consequently it may be reported that V_3 (BARI soybean 6) and V_2 (BARI soybean 5) soybean cultivars may be considered as salt tolerant.

Shoot was severely affected by salt stress and as a consequence a drastic reduction was observed for salt stress sensitive genotypes. Similar findings were also reported by Moud and Maghsoudi (2008), Datta *et al*. (2009) and Dager *et al*. (2004).

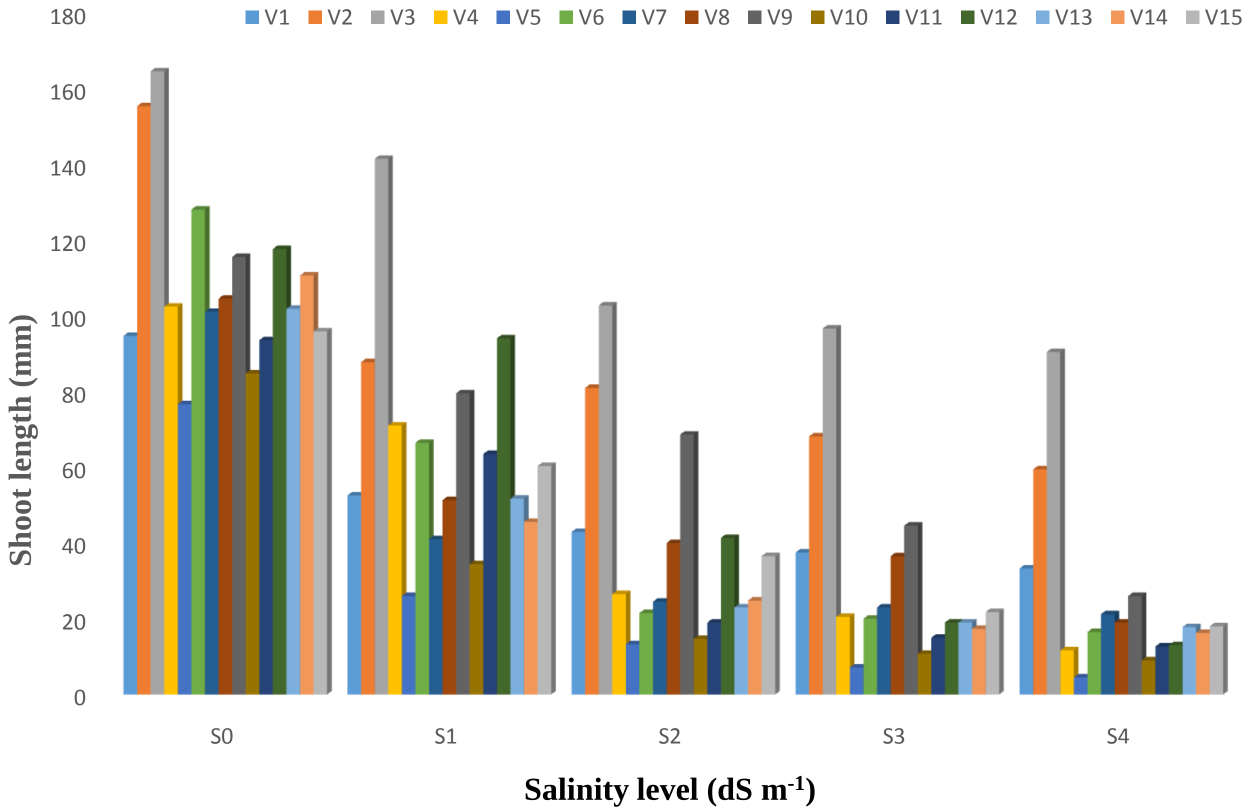

Figure 02. Effect of salinity levels on shoot length (mm) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.3 Root length (mm)

The root length varied significantly among soybean genotypes under different salinity levels (Appendix IV and Table 3). The soybean genotypes, V_3 (BARI soybean 6) gave the highest result (137.8 mm) at control condition and also gave the highest result (99.40, 95.13, 76 and 59.14 mm at 5, 10, 15 and 20 dSm^{-1} respectively) at different salt concentrations . V_2 (BARI soybean 5) gave the slower reduction result (50.87, 49.20, 34.58 and 21mm at 5,10, 15 and 20 dSm^{-1} respectively) with the increasing of salt concentration. At 0 dSm^{-1} salt solution root length ranges from 137.80 mm in V_3 (BARI soybean 6) to 16.67 mm in V_5 (BD-2326). V_3 (BARI soybean 6) and V_2 (BARI soybean 5) gave distinctly the highest result 59.14 and 21mm at 20 dSm^{-1}.

On the contrary at the same saline concentration seedlings of V_5 (BD-2326), V_6 (BD-2337), V_8 (BD-2349), V_9 (BD-2351) and V_{10} (BD-2352) gave 1.5, 4.5, 5, 3.67 and 5.67 mm root lengths respectively. So, it can be concluded that in respect of root length V_3 (BARI soybean 6) and V_2 (BARI soybean 5) soybean genotypes could be salt tolerance and V_5 (BD-2326), V_6 (BD-2337), V_8 (BD-2349), V_9 (BD-2351) and V_{10} (BD-2352) sensitive to salt. V_5 (BD-2326), V_6 (BD-2337), V_9 (BD-2351) and V_{10} (BD-2352) might be very much sensitive to salt at higher salt concentration in the respect of root length.

Root length severely affected by salt stress and consequently a drastic reduction was noticed for salt stress sensitive genotypes. Similar findings also reported by Moud and Maghsoudi (2008), Datta *et al*. (2009), Tarmatt and Munns (2005) and Dager *et al*. (2004).

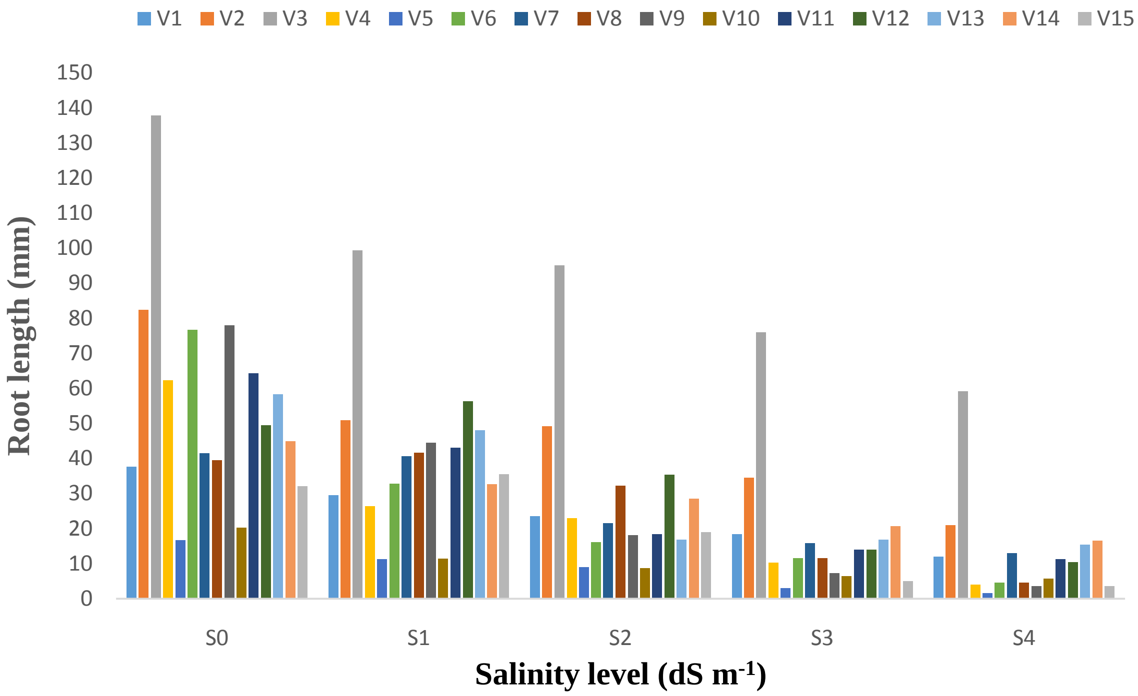

Figure 03. Effect of salinity levels on the root length (mm) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag

V_2 = BARI soybean 5

V_3 = BARI soybean 6

V_4 = BD-2324

V_5 = BD-2326

V_6 = BD-2337

V_7 = BD-2346

V_8 = BD-2349

V_9 = BD-2351

V_{10} = BD-2352

V_{11} = BD-2353

V_{12} = BD-9402

V_{13} = BD-9418

V_{14} = BD-9420

V_{15} = BD-9426

4.4 Fresh weight plant^{-1} (mm)

Salinity level had highly significant influence on fresh weight plant^{-1} of different wheat genotypes (Appendix V and Table 4). It was found that at control condition V_3 (BARI Soybean 6) gave the best result (115.5 mg) followed by V_2 (BARI soybean 5) (108.3 mg) and V_6 (BD-2337) (98.27 mg) where V_3 (BARI Soybean 6) gave the highest fresh weight plant^{-1} at all salt concentrations (96.62, 60.68, 54.52 and 38.43 mg at 5, 10, 15 and 20 dSm^{-1} respectively) followed by V_2 (BARI soybean 5) (76.36, 50.55, 47.36 and 32.76 mg at 5, 10, 15 and 20 dSm^{-1} respectively) and V_9 (BD- 2351) (69.6, 43.75, 37.52 and 31.06 mg at 5, 10, 15 and 20 dSm^{-1} respectively). On the other hand, V_5 (BD-2326) gave the lowest fresh weight plant^{-1} (48.77 mg) at control condition followed by V_{11} (BD-2353) (66.74 mg), V_1 (Shohag) (72.50 mg) and V_{15} (BD-9426) (71.58 mg). V_5 (BD-2326) also showed the lowest result (17.46, 8.395, 6.4 and 3.12 mg at 5, 10, 15 and 20 dSm^{-1} respectively) closely followed by V_{10} (BD-2352) (23.71, 11.66, 8.55 and 6.18 mg at 5, 10, 15 and 20 dS m^{-1} respectively) and V_{11} (BD-2353) (52.73,13.78, 9.58 and 7.14 mg respectively) at different salt concentrations.

It can be concluded that V_3 (BARI Soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) showed the promising performance in terms of fresh weight plant^{-1}. Fresh weight plant^{-1} was decreasing with the increasing of salinity level. Seedling growth is one of the most important character for screening of salt tolerance at the early growth stage and affect plant weight (Karim *et al*. 1992).

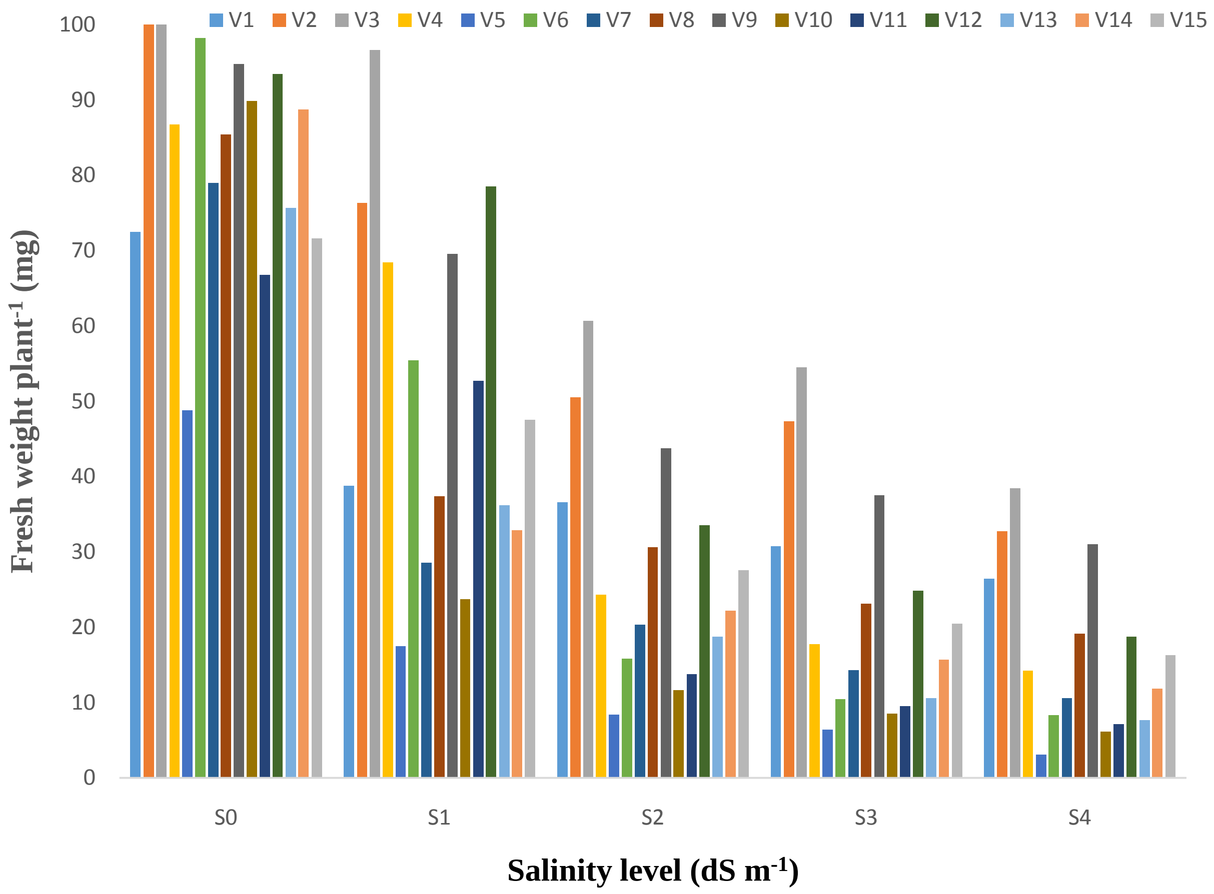

Figure 04. Effect of salinity levels on the fresh weight plant^{-1} (mg) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.5 Dry weight plant^{-1} (mg)

Salinity level had highly significant influence on dry weight plant^{-1} of different soybean genotypes (Appendix VI and Table 5). Shoot dry weight reduction showed consistency for V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_6 (BD-2337) genotypes with the increasing of salinity levels. At control condition maximum shoot dry weight was reported from V_3 (BARI soybean 6) genotype (23.70 mg) followed by V_2 (BARI soybean 5) (23.19 mg) and V_6 (BD-2337) (22.75 mg) whereas V_5 (BD-2326), V_{10} (BD-2352) and V_{11} (BD-2353) showed more sensitivity to saline condition and produced lowest dry weight (13.70, 15.41 and 16.45 mg respectively). At 20 dsm^{-1}, V_2 (BARI soybean 5), V_3 (BARI soybean 6) and V_9 (BD-2351) showed higher consistency against salinity compared to other tested genotypes.

Therefore, V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) soybean genotypes showed promising performance against saline conditions in terms of dry weight plant^{-1}.

The reduction in leaf dry weight due to salinity was reported by Karim *et al.* (1993) in triticale, Khan *et al.* (1997) in rice, Aziz *et al.* (2005) in mungbean and Mannan, *et al.* (2013) in soybean. Under salt stress condition, cell expansion is reduced due to low turgor, as well as excess accumulation sodium ion damaged cell membrane and organelles, resulting in plant growth reduction (Karim *et al.* 2012).

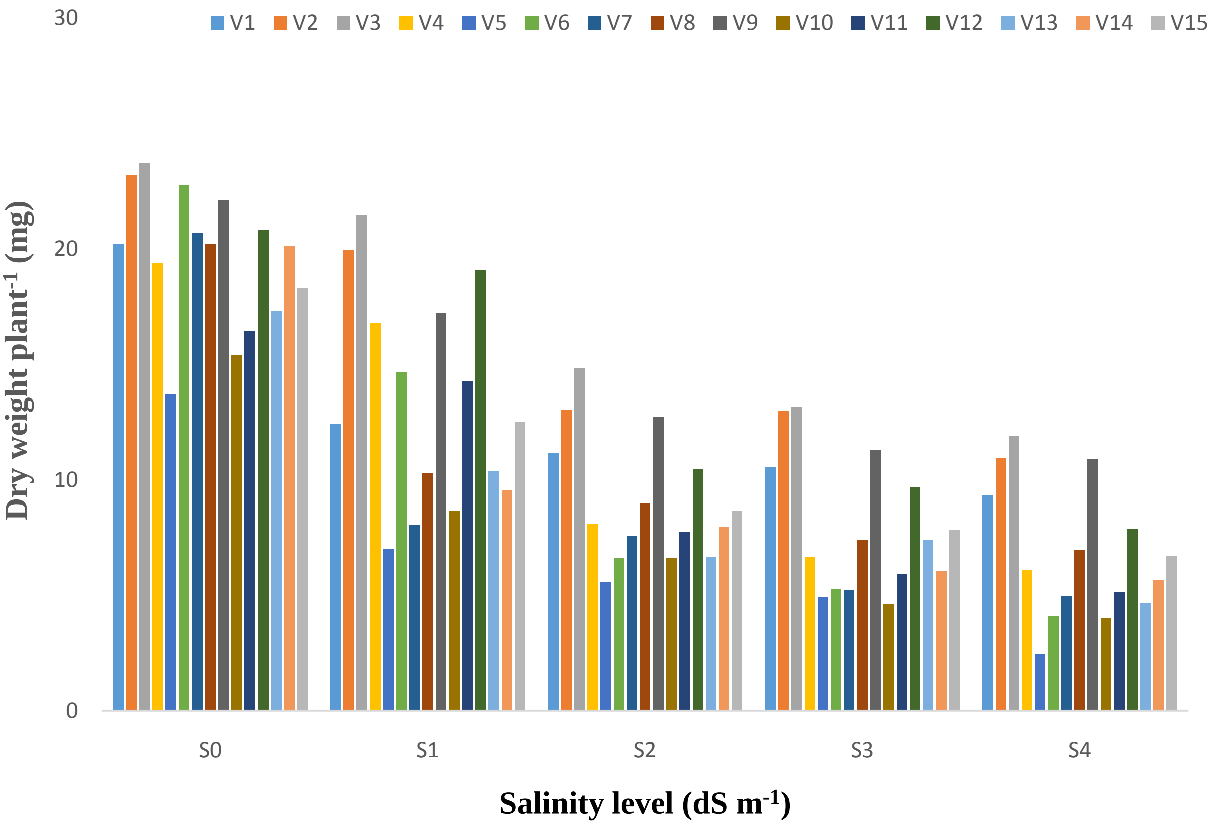

Figure 05. Effect of salinity levels on the dry weight plant^{-1} (mg) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349

V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.6 Turgid weight (mg)

Significant influence was found in terms of turgid weight affected by different salinity levels to the selected soybean genotypes (Appendix VII and Table 6). It was found that V_3 (BARI soybean 6) gave the best performance on turgid weight at control condition (136 mg) followed by V_2 (BARI soybean 5) (129.8 mg). V_3 (BARI soybean 6) gave the best performance on turgid weight (117.3, 82, 74.5 and 62.7 mg at 5, 10, 15 and 20 dS m^{-1} respectively) at different salinity levels followed by V_2 (BARI soybean 5) (97, 70.4, 65.6 and 53.8 mg at 5, 10, 15 and 20 dS m^{-1} respectively).

Whereas V_5 (BD-2326) showed more sensitivity to saline condition and produced lower turgid weight (65.60 mg) closely related to V_{10} (BD-2352) (79.40 mg) and V_{11} (BD-2353) (80.00 mg) at control condition. Even at all salinity concentrations V_5 (BD-2326) showed the lowest performance on turgid weight (30.1, 23.4, 16.9 and 8.2 mg at 5, 10, 15 and 20 dS m^{-1} respectively) closely followed by V_{10} (BD-2352) (41.80, 34.10, 25.48 and 15.70 mg at 5, 10, 15 and 20 dS m^{-1} respectively) and V_{11} (BD-2353) (66.60, 33.00, 27.90 and 18.50 mg at 5, 10, 15 and 20 dS m^{-1} respectively).

Therefore, V_3 (BARI soybean 6) and V_2 (BARI soybean 5) soybean genotypes showed promising performance against saline conditions in terms of turgid weight. V_5 (BD-2326), V_{10} (BD-2352) and V_{11} (BD-2353) showed the salt sensitivity at different salt concentrations.

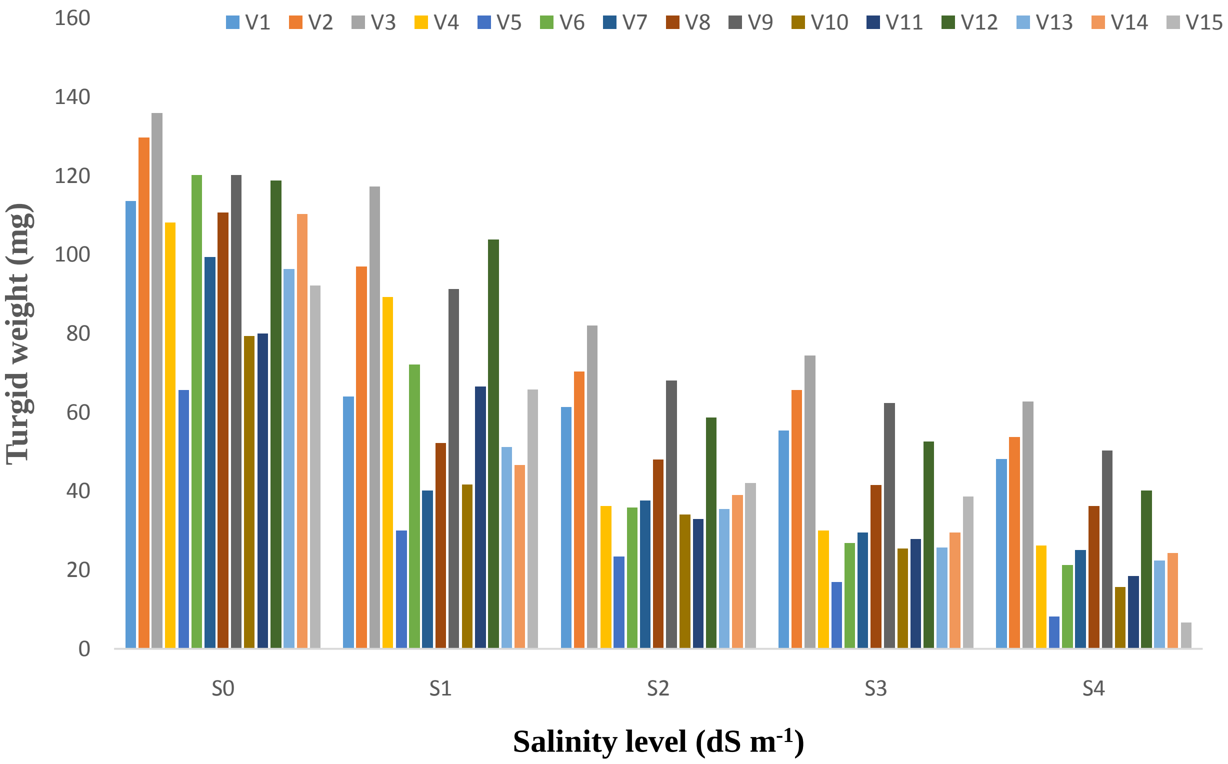

Figure 06. Effect of salinity levels on turgid weight (mg) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.7 Relative water content (%)

Relative water content (RWC) could be a reliable and simple way to assess the water status of leaves. The relative water content of a leaf is a measurement of its hydration status relative to its maximum water holding capacity at full turgidity and denotes the physiological consequences of cellular water deficit. Water potential that posses the energy status of plant water which is effective for the transportation of water in the soil-plant-atmosphere chain. A wide range of statistical difference was observed for relative water content of soybean genotypes at different salt concentrations (Appendix VIII and Table 7). At control condition, V_3 (BARI soybean 6) gave the best performance (81.76%) which was closely followed by V_2 (BARI soybean 5) (79.87%), V11 (BD-2353) (79.13%) and V6 (BD-2337%) (77.42%). At 20 dsm^{-1}, V_3 (BARI soybean 6) and V_2 (BARI soybean 5) showed higher performance in respect of other genotypes regarding relative water content. V_3 (BARI soybean 6) gave the highest performance (78.42, 68.25, 67.44 and 52.24% at 5, 10, 15 and 20 dSm^{-1} respectively).

V_5 (BD-2326), V_{11} (BD-2353) and V_{12} (BD-9402) were minimum efficient for relative water content. V_5 (BD-2326) gave the lowest performance (67.57%) in terms of relative water content under control condition and (45.23, 15.77, 12.21 and 11.34% at 5, 10, 15 and 20 dSm^{-1} respectively) at different salinity levels.

At highest salt level (20 dSm^{-1}) relative water content ranges V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) exhibited highest results (52.24, 50.90 and 51.04% respectively). So, it can be concluded that V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) soybean genotypes can be considered as salt tolerant in terms of relative water content. Sairam *et al*. (2002) reported that under salt stress relative water content was higher in salt tolerant cultivar than the sensitive one.

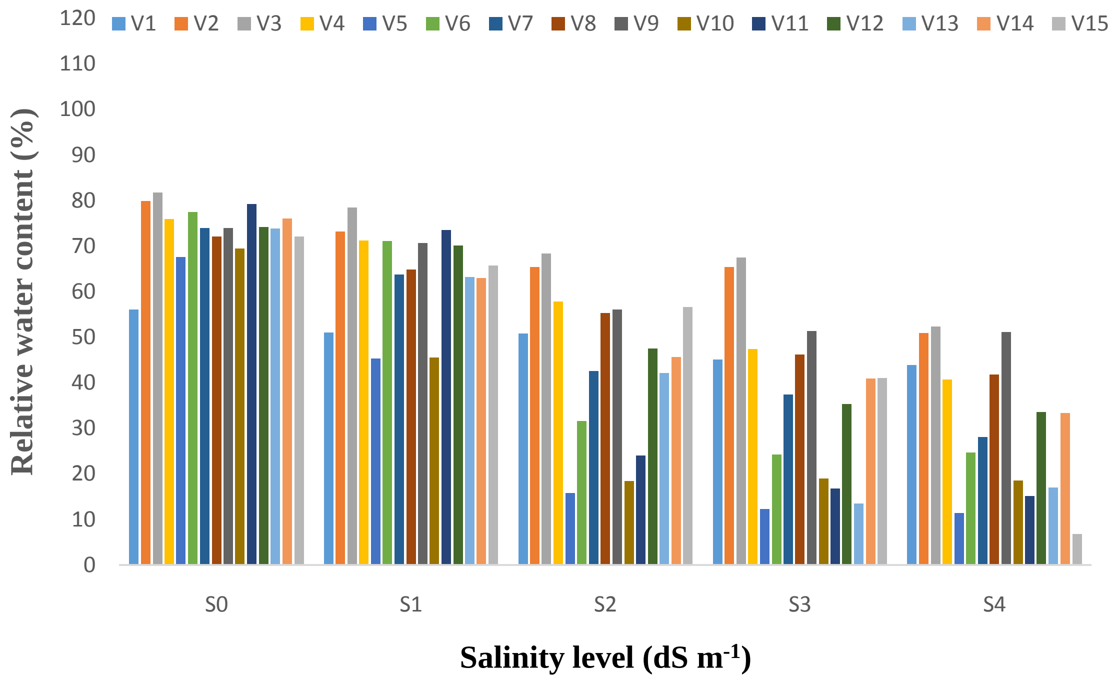

Figure 07. Effect of salinity levels on relative water content (%) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.8 Water saturation deficit (%)

The amount by which the water vapor in the air must be increased to achieve saturation without changing the environmental temperature and pressure. It is opposite to relative water content. Salinity level had highly significant influence on water saturation deficit among different soybean genotypes (Appendix IX and Table 8). The result revealed that water saturation deficit ranges from 44.01 in V_1 (Shohag) to 18.24 in V_3 (BARI soybean 6) at non-saline condition but at different salinity levels V_3 (BARI soybean 6) gave lowest results (21.58, 31.75, 32.56 and 47.76% at 5, 10, 15 and 20 dSm^{-1}, respectively) where V_5 (BD-2326) gave highest water saturation deficit (54.77, 84.23, 87.79 and 88.66% at 5, 10, 15 and 20 dSm^{-1}, respectively). At 20 dSm^{-1}, significantly lowest water saturation deficit was observed for V_3 (BARI soybean 6) (47.76%), V_2 (BARI soybean 5) (49.10%) and V_9 (BD-2351) (48.96%) where V_5 (BD-2326) and V_{11} (BD-2353) were prominently sensitive to higher salt concentration. Therefore, V_3 (BARI soybean 6) and V_2 (BARI soybean 5) genotypes exerted better tolerance against salty condition in case of water saturation deficit.

Under salt stress condition tolerance plant can grow vigorously minimize the salt uptake and maximize potential salt load per unit area by their compartmentalization technique and provide better water use efficiency thus plant growth not hampered (Flower *et al.*, 1988).

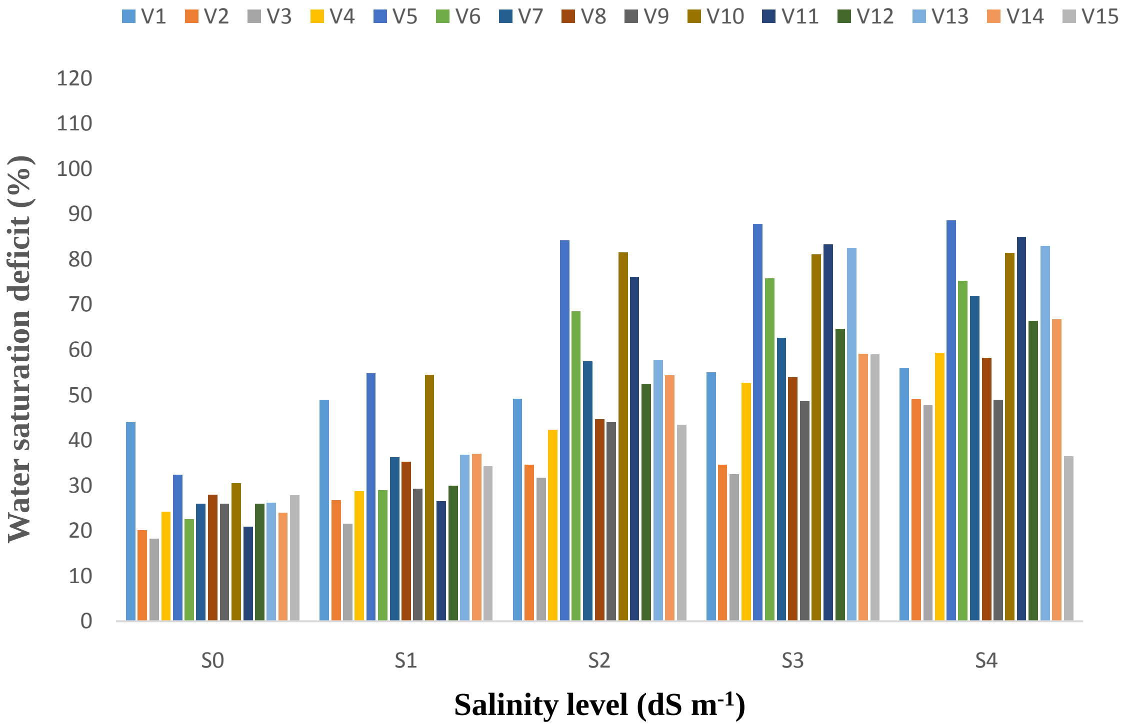

Figure 08. Effect of salinity levels on water saturation deficit (%) of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

4.9 Vigour index

Salinity level significantly affected vigour index among different soybean genotypes (Appendix X and Table 9). The reduction rate of vigour index was slow in case of V_3 (BARI soybean 6) followed by V_2 (BARI soybean 5) *i.e.* they hold a consistently decreasing trend but most soybean genotypes exerted rapid reduction of vigour index with the increasing of salinity level. V_3 (BARI soybean 6) scored the maximum vigour index (159.20, 130.60, 92.69, 86.41and 77.64 at 0, 5, 10, 15 and 20 dSm^{-1}, respectively) followed by V_2 (BARI soybean 5) (146.5, 79.82, 70.19, 59.12 and 49.70 at 0, 5, 10, 15 and 20 dSm^{-1} respectively). On the other hand the minimum vigour index were recorded from V_5 (BD-2326) (40.51, 10.39, 4.71, 1.72 and 0.85 at 0, 5, 10, 15 and 20 dSm^{-1}, respectively).

In terms of vigour index, V_3 (BARI soybean 6) and V_2 (BARI soybean 5) can be considered as best soybean genotypes.

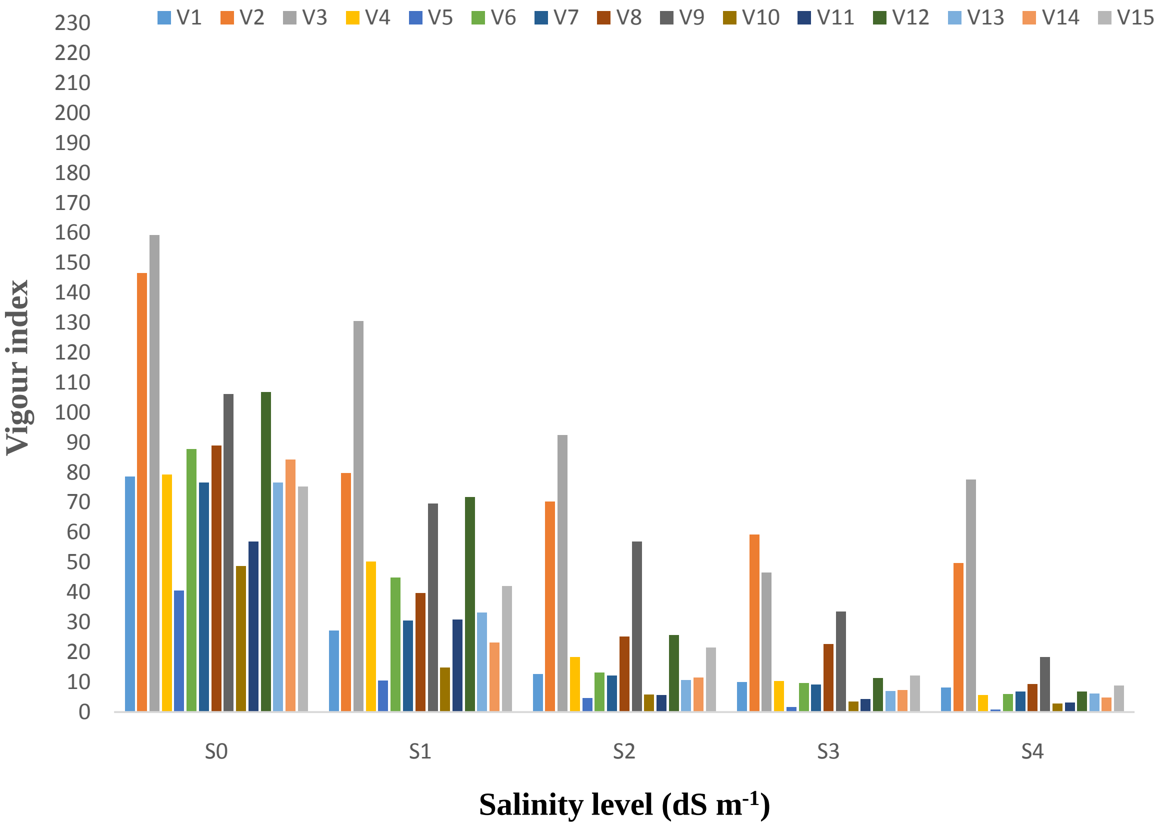

Figure 09. Effect of salinity levels on vigour index of different soybean genotypes (LSD $_{(0.01)}$ = 4.999, 4.754, 4.702, 4.405, 4.111 and S_0= 0 dS m^{-1} , S_1 = 5 dS m^{-1}, S_2 = 10 dS m^{-1}, S_3 = 15 dS m^{-1}, S_4 = 20 dS m^{-1})

Here,

V_1 = Shohag
V_2 = BARI soybean 5
V_3 = BARI soybean 6
V_4 = BD-2324
V_5 = BD-2326
V_6 = BD-2337
V_7 = BD-2346
V_8 = BD-2349
V_9 = BD-2351
V_{10} = BD-2352
V_{11} = BD-2353
V_{12} = BD-9402
V_{13} = BD-9418
V_{14} = BD-9420
V_{15} = BD-9426

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was carried out for screening salt tolerant soybean genotypes, in the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during February to March, 2016. The experiment comprises of 15 soybean genotypes *viz* V_1 (Shohagh), V_2 (BARI soybean 5), V_3 (BARI soybean 6), V_4 (BD-2324), V_5 (BD-2326), V_6 (BD-2337), V_7 (BD-2346), V_8 (BD-2349), V_9 (BD-2351), V_{10} (BD-2352), V_{11} (BD-2353), V_{12} (BD-9402), V_{13} (BD-9418), V_{14} (BD-9420) and V_{15} (BD-9426). Seeds of 15 genotypes were collected from Bangladesh Agricultural Research Institute (BARI). The performance of the genotypes was tested under 5 levels of salinity *viz*. Control (No salt), 5, 10, 15 and 20 dSm^{-1}. The experiment was laid out in completely randomized design (CRD) with 5 replications.

In case of almost all the parameters, the significant differences were observed among the influence of different salinity level. The salt tolerant capability was evaluated in terms of seedling emergence rate at 10 days after sowing. The estimation of plant survival rate was done at 10 days after sowing and plant parameters such as root length, shoot length, dry weight of root and shoot per plant counted at 10 days after seed sowing.

According to the performance, of these 15 soybean genotypes under 5 salinity level, V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) were identified as the most salt tolerant soybean genotypes. All the soybean varieties showed their best performance under the treatment when no salinity was imposed. On the other hand, all the soybean varieties showed the worst performance under the salinity stress of 20 dSm^{-1} salinity level. All the genotypes were significantly inhibited by each of the salinity level comparing with the control condition (no salinity). However, due to salinity stress the inhibition of all the plant parameters varied among the soybean genotypes used in the study. Salinity stress affected seedling emergence of all the soybean genotypes. All the soybean genotypes used in the study gave the highest seedling emergence rate observed under control condition where no salinity stress was imposed. Salinity stress both at 15 dSm^{-1} and 20 dSm^{-1} significantly reduced of the seedling emergence rate in all soybean genotypes.

The lowest germination rate was found from V_5 (BD-2326) (18.97% at 20 dSm^{-1}) followed by V_{11} (BD-2353), V_{10} (BD-2352) and V_{14} (BD-9420) while the highest one in V_3 (BARI soybean 6) (85.88%) followed by V_2 (BARI soybean 5) (83.64%) and V_9 (BD-2351) (69.98%). Accordingly, more or less similar trend was found for higher performance on shoot length (mm), root length (mm), fresh weight $plant^{-1}$ (mg), shoot dry weight (mg), relative water content (%), turgid weight (mg), water saturation deficit (%) and vigour index and V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) gave the best performance where the lower performance was found for shoot length (mm), root length (mm), fresh weight $plant^{-1}$ (mg), shoot dry weight (mg), relative water content (%), turgid weight (mg), water saturation deficit (%) and vigour index from V_5 (BD-2326) were observed at all salinity levels.

Considering the above results obtaining from the present study it may be concluded that -

- Among 15 soybean genotypes V_3 (BARI soybean 6), V_2 (BARI soybean 5) and V_9 (BD-2351) soybean genotypes are salt tolerant which are attributed to higher germination rate, shoot length, root length, dry weight, relative water content, water retention capacity and vigour index.
- Rests of the soybean genotypes were found to be sensitive to salt stress gave the worst performance.

REFERENCES

Abdullah, Z., Khan, M.A. and Flowers, T.Z. (2001). Causes of sterility in seed set of rice under salinity stress. *J. Agron. Crop Sci*.**167**(1): 25-32.

Alaa El-Din, S.E. (2013). Effect of Salinity Stress on Coriander (*Coriandrumsativum*) Seeds Germination and Plant Growth. *Egypt. Acad. J. Biol. Sci.* **4**(1): 1- 7.

Ali, M.A., Islam, M.T. and Islam, M.T. (2005). Effect of salinity on some morpho-physiological characters and yield in three sesame cultivars. *J. Bangladesh Agril. Univ*., **3**: 209-214.

Ali, Y. and Awan, A.R. (2004). Influence of salinity at seedling stage on seed yield and yield contributing characters of different rice lines. *Intl. J. Biol.Biotech*.**1**: 175-179.

Angrish, R., Kumar, B. and Datta, K.S. (2001). Effect of gibberalic acid and sulfate salinity on growth and yield of wheat. *Indian J. Plant Physiol*.**6**: 172-177.

Anonymous, (2007), Soybean, www.ikisan.com, pp. 1-7.

Babu, S. and Thirumurugan, T. (2001). Effect of NaCl priming for increased salt tolerance in sesame. *J. Ecobiol*.**13**: 309-311.

BARI (Bangladesh Agriculture Research Institute (2006). KrishiProjuktiHatboi (in Bangla). 4th ed. Bangladesh Agril. Res. Inst., Gazipur, Bangladesh. pp. 209-211.

Bera, A. K., Pati, M. K. and Bera, A. (2006). Bassionolide ameliorates adverse effect on salt stress on germination and seedling growth of rice. *Indian J. Plant Physiol.* **11**(2): 182-189.

BINA. (2008). Screening of wheat varieties based on salinity tolerance. Annual Report of 20072008. Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. p. 56.

Bolarin, M. C., Perez-Alfocea, F., Cano, E. A., Estan, M. T. and Carol, M. (1993). Growth, fruit yield and ion concentration in tomato genotypes after pre- and post-emergence salt treatments. *J. A. Soc. Hort. Sc.***118**: 655-660.

Bouaouina, S., Zid, E., Hajji, M. and Royo, C. (2000). Tolerance to salinity, ion transport and chlorophyll fluorescence in durum wheat (*Triticum turgidum* L.). Proceedings of seminar, Zaragoza, Spain, 12-14 April, 2000. **40**: 239-243.

Chakraborti, P. and Basu, A. K. (2001). Combining ability in sesame under alluvial and salt stress with special reference to yield. *Crop Res. (Hisar),* **22**: 78-84.

Cha-um S., Vejchasarn P. and Kirdmanee C. 2007. An effective defensive response in Thai aromatic rice varieties (*Oryza sativa* L. spp. *indica*) to salinity. *J. Crop Sci. Biotechnol.* **10:** 257-264.

Cramer, G. R., Alberico, G. J. and Schmidt, C. (1994). Salt tolerance is not associated with the sodium accumulation of two maize hybrids. *Australian J. Plant Physiol.* **21**: 675-692.

Debnath, S. C. (2003). Effect of salinity on growth and yield in three mustard varieties. M.S. Thesis, Dept. Crop Bot. Bangladesh Agril. Univ., Mymensingh.

Dagar, J. C., Bhagwan, H. and Kumar, Y. (2004). Effect of growth performance and biochemical content of S*alvadorapersica* when irrigated with water of different salinity. *Indian J. Plant Physiol.* **9**(3): 234-238.

Datta, J. K., Nag, S., Banerjee, A. and Mondal, N. K. (2009). Impact of salt stress on five varieties of wheat (*Triticum aestivum* L.) cultivars under laboratory condition. *J. App. Sci. Environ.***13**(3): 93-97.

El-Hendawy, S., Hu, Y. and Schmidhalter, U. (2005). Growth, ion content, gas exchange, and water relation of wheat genotypes differing in salt tolerances. *Australian. J. Agric. Res*.**56**: 123-134.

El-Midaoui, M., Talouzte, A., Benbella, M., Berville, A. and Tersae, M. (1999). Response of five sunflower varieties to different concentration of sodium chloride.Proc. 4th European Conf. on Sunflower Biot., France, 20-23 Oct. p. 125-138.

El-Sabagh, A., Sorour, S. and Ueda, A. (2015). Evaluation of salinity stress effects on seed yield and quality of three soybean cultivars. Azarian Journal of Agriculture (AJA). 2(5). 2015: 138-141.

Essa, T.A. (2002). Effect of salinity stress on growth and nutrient composition of three soybean (*Glycine max* L. Merrill) cultivars. *J. Agron. Crop Sci.* **188**: 86-93.

Flower, T. J., Salma, F. M. and Yeo, A. R. (1998). Water use efficiency in rice in relation to plant. *Plant cell Environ.* **11:** 453-459.

Gain, P., Mannan, M. A, Pal, P. S., Hossain, M. M. and Parvin, S. (2004). Effect of salinity on some yield attributes of rice. *Pakstan. J. Biol. Sci*. **77**: 60-762.

Gorai, M., Ennajeh, M., Khemira, H., and Neffati, M. (2010). Combined effect of NaCl-salinity and hypoxia on growth, photosynthesis, water relations and solute accumulation in Phragmitesaustralis plants. Flora - Morphology, Distribution, Functional Ecology of Plants, (in press).

Gowda, C.L.L. and Kaul, A.K. (1982). Pulses in Bangladesh. BARI and FAO Publication, Gazipur, Bangladesh. pp. 338-407.

Gupta, S.C. and Shrivastava, J.P. (1989). Effect of salt stress on morpho physiological parameter in wheat (7: astivur L.). *Indian J. Plant Physiol*. **32**(2): 169-171.

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

Hakim, MA. Juraimi, AS. and Begum, M. (2010). *African J. Biotech*, 2010, 9, 13, 1911-1918.

Hamayun, M. (2010). Effect of salt stress on growth attributes and Endogenous growth hormones of soybean Cultivar hwangkeumkong. . *J. Bot*. **42**(5): 3103-3112.

Hossain, M.A. (2002). Effect of salinity stress in some varieties of rice. M.S. Thesis, Dept. Crop Bot., *Bangladesh Agril. Univ*., Mymensingh.

Islam, M.R. and Salam; M.A. (1996). Growth and yield performance of some selected rice lines under different salinity regimes. *Bangladesh J. Train. Dev*. **9**(2): 53-56.

Islam, M.Z. (2004). Morpho-physiological and biochemical attributes of mutant rice under different saline levels. M.S. Thesis, Dept. Crop Bot., Bangladesh Agril. Univ., Mymensingh.

Jafari, M.H.S., Kafi, M. and Astarie, A. (2009). Interactive effects of NaCl induced salinity, Calcium and potassium on physiomorphological traits of sorghum *(Sorghum bicolor*L.). *Pak. J. Bot.* **41**(6): 3053-3063.

Jampeetong, A. and Brix, H. (2009). Effects of NaCl salinity on growth, morphology, photosynthesis and proline accumulation of *Salvinianatans. Aquatic Bot.* **91**(3): 181186.

Javaid, M.M., Salam, M.A. and Khan, M.F.A. (2002). Effect of sodium chloride and sodium sulphate on IRRI rice. *J. Agric. Res.***13**: 705-710.

Jones, R.G.W. 1981. Salt tolerance. In C.B. Johnson ed., Physiological Processes Limiting plant Productivity, Butterworths, London. 271-292.

Karim, M.A., E. Utsunomiya, N. and S. Shigenaga. 1992. Effect of sodium chloride on germination and growth of hexaploid triticale at early seedling stage. *Japan J. Crop Sci***.** **61**(2): 279-284.

Karim, M. R. (2007). Effect of salinity on growth, yield and yield attributes of rice cultivars. M.S. Thesis, Dept. Crop Bot., Bangladesh Agril. Univ. Mymensingh.

Karim. M.A., Kondo, T. Ueda, K., H. Higuchi, and E. Nawata. 2012. Effect of NaCltratment on Growth and Some Physiological Charararacteristics of a salt-tolerant soybean genotype AGS 313 bred in Bangladesh. Trop. Agril. Develop. **56**: 139-142.

Kemal-ur-Rahim, K. (1988). The effect of salinity on photosynthesis & other physiologicall process in spring wheat varieties. Dissertation international, B (Science & Engineering). **49**(5): 14708.

Khan, M. S. A., Hamid, A., Salahuddin, A. B. M., Quasem, A. and Karim, M. A. (1997). Effect of sodium chloride on growth, photosynthesis and mineral ions accumulation of different types of rice. *J. Agron. Crop Sci*., **179**: 149-161.

Katerji, N., van Hoorn, J.W., Hamdy, A. and Mastrorilli, M. 2003. Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. Agril. Water Manage. **62**: 37-66.

Khatkar, D. and Kuhad, M. (2000). Short-term salinity induced changes in two wheat cultivars at different growth stages. *Biologia Plantarum*.**43**: 629-632.

Khayatnezhad, M. Gholamin, R. jamaati-e- Somarin, S. Zabihi-e-Mahmoodabad, R. (2010). *American-Eurasian J. Agric. & Environ. Sci*. **9**(2): 128-132.

Kondetti, P., Jawali, N., Apte, S. K. and Shitole, M.G. (2012). Salt tolerance in Indian soybean (*Glycine max* (L.) Merill) varieties at germination and early seedling growth. *Ann. Biol Res.* **3**(3):1489-1498.

Kumar, A. (2017). Germination Behaviour of Soybean Varieties under Different Salinity Stress. International Journal of Applied Agricultural Research. ISSN 0973-2683 **12**(1). pp. 69-76.

Lallu and Dixit, R. K. (2005). Salt tolerance of Mustard genotype at seedling stage. *Indian J. Plant Physiol.* **14**(2): 33-35.

Leena, A. and Kiran, G.S. (2003). Effect of NaCl stress on growth of Sorghum bicolor L. Monech. *J. Eco. Physiol*. **6**(3/4):137-140.

Liu, X., Huang, W., Niu, Z., Mori, S. and Tadano, T. (2008). Interactive effect of moisture levels and salinity levels of soil on the growth and ion relation of halophyte. *CodSm-1unication in Soil Sci. and Plant Analy.,* **39**: 741-752.

Maas, E. V. (1986). Salt tolerance of plants. *Appl. Agric. Res.* **1**: 12-25.

Memon, M.S., Rajpar, I., Sial, N.B. and Keerio, M.I. (2007). Effects of continuous application of saline water on growth and fodder yield of *Sorghum bicolor* L. cv. *Sarokartuho. Intl. J. Biol. Biotech.* **4**(2/3): 177-180.

Mensah, JK. Akomeah, PA. Ikhajiagbe, B. Ekpekurede, EO. (2006). *African J. Biotech.* **5**(20):1973-1979.

Mensah, JK. And Ihenyen, J. (2009). Nigerian annals of natural sciences. **8**(2):17 – 24.

Milne, C. J. (2012). The alleviation of salinity induced stress with applications of silicon in soilless grown *Lactuca sativa L. Intl. J. Physic. Sci.,* **7**(5): 735-742.

Mohammad, M., Shibli, R., Ajlouni, M. and Nimri, L. (1998). Tomato root and shoot responses to salt stress under different levels of phosphorus nutrition. *J. Plant Nutr.* **21**(8): 1667-1680.

Mohammad, A.S., Riai, S. and Niazi, B. (1995). Performance of some wheat germplasm under the ion effect wider saline conditions. *Sarhad J. Agril*. **11**(3): 341-348.

Mondal, M.R.I., Wahab M.A, Alam M.S., Ahmed M.M.U. and Begum F. (2002). Leaflet of BARI soybean 5. ORC, BARI,Joydebpur, Gazipur.

Mortazainezhad, F., Khavarinejad, R. and Emami, M. (2006). Study of some parameters of yield and praline in rice plants under NaCI salinity stress. *J. New Agric. Sci.* **2**: 93-98.

Moud, A.M. and Maghsoudi, K. (2008). Salt stress effects onrespiration and growth of germinated seeds of different wheat (*Triticum aestivum* L.) cultivars. *World J. Agril. Sci.* **4**(3): 351-358.

Munns, R. (2005). Genes and salt tolerance: bringing them together. *New Phytol*. **167**: 645-663.

Munns, R. and Tester, M. (2008). Mechanism of salinity tolerance. *Annu. Rev. Plant Biol.* **59**: 651-681.

Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance. *Ann. Rev. Plant Biol*. **59**: 651-681.

Nawaz, K., Talat, A., Hussain, I. K. and Majeed, A. (2010). Induction of Salt Tolerance in Two Cultivars of Sorghum *(Sorghum bicolor*L.) by Exogenous Application of Proline at Seedling Stage. *WorldApp. Sci. J.* **10**(1): 93-99.

Netondo, G. W., Onyango, J. C. and Beck, E. (2004). Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress. *Crop Sci*. **44**(3): 806–811.

Parida, A. K. and Das, A. B. (2005). Salt tolerance and salinity effects on plants, a review. *Ecot. Environ. Safe.* **60**: 324-349.

Parker, M.B., Gascho, G.J. and Gains, T.P. 1983. Chloride toxicity of soybeans grown on Atlantic Coast flatwoods soils. *Agron. J.* **75**: 439-443.

Prakash, N. D., and Chen, D. (2010). Impact of spatially variable soil salinity on crop physiological properties, soil water content and yield of wheat in a semi-arid environment. *Australian. J. Agril. Eng*. **1**(3):93-100.

Rafat, S. and Rafiq, A. (2009). Vegetative Growth and Yield of Tomato as Affected by the Application of Organic Mulch and Gypsum under Saline Rhizosphere. *Pakistan. J. Bot*. **41**(6): 3093-3105.

Rahman, L. (1982). Cultivation of soybean and its uses. City Press, Dhaka: 5-7.

Rahman, M. M. (2003). Effect of salinity stress on physiological features and yield in three mustard varieties. M.S Thesis, Dept. Crop Bot., Bangladesh Agril. Univ. Mymensingh.

Rana, M. S. (2007). Effect of salinity on growth and photosynthetic potential in some advanced rice lines. M.S. Thesis, Dept. Crop Bot. Bangladesh Agril. Univ. Mymensingh.

Rashid, M. M. (2005). Effect of salinity at different growth stages of transplanted aman rice mutants. M.S. Thesis, Dept. Crop Bot. Bangladesh Agril. Univ., Mymensingh.

Saberi, A. R., Aishah, H. S., Halim, R. A. and Zaharah, A. R. (2011). Morphological responses of forage sorghums to salinity and irrigation frequency. *African J. Biotech.* **10**(47): 96479656.

Saboora, A. and Kiarostami, K. (2006). Salinity tolerance of wheat genotype at germination and early seedling growth. *Pak. J. Biol. Sci*. **9**(11): 2009-2021.

Shannon, M. C. and Grieve, C. M. (1999). Tolerance of vegetable crops to salinity. *Scientia Hortic*. **78**: 5-38.

Shao, GH. Wan, CW. Chang, RZ Chen, YW. (1993). Crops. **1**:39–40.

Shirazi, M.U., Asif, S. M., Khanzada, B., Khan, M.A., Ali, M., Mumtaj, S., Yousufazai, M. N. and Saif, M. S. (2001). Growth ion accumulation in some wheat genotypes under NaCl stress. *Pakistan J. Biol. Sci.* **4**: 388-91.

Singleton, P.W. and Bohlool, B.B. 1984. Effect of salinity on nodule formation by soybean. *Plant Physiol.* **74**: 72-76.

Sixto, H., Grau, J. M., Alba, N., and Alia, R. (2005). Response to sodiumchloride in different species and clones of genus *Populus*L. *Forestry*. **78**: 93-104.

Uddin, M. N., Islam, M. T. and Karim, M. A. (2005). Salinity tolerance of three mustard/rapeseed cultivars. *J. Bangladesh Agric. Univ*. **3**: 203-208.

Wang, D. and Shannon, M.C. 1999. Emergence and seedling growth of soybean cultivars and maturity grops under salinity. *Plant Soil.* **214**: 117-124.

Yang, J. and Blanchar, R.W. 1993. Differentiating chloride susceptibility in soybean cultivars. *Agron. J*. **85:** 880-885.

Yaklich, R. W., Vinyard B., Camp M. and Douglass S. (2002). Analysis of seed protein and oil from soybean northern and southern region uniform tests. *Crop Sci*. **42**: 1504-15

Yasuta, Y. and Kokubun, M. (2014). Salinity Tolerance of Super-Nodulating Soybean Genotype En-b0-1. *Plant Prod. Sci.* **17**(1): 32 40 (2014).

Zhang, J.L., Flowers, T.J. and Wang, S.M. 2010. Mechanisms of sodium uptake by roots of higher plants. *Plant Soil.* **326**: 45-60.

APPENDICES

Appendix I. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from January to March 2016

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
		Max	Min	Avg.			
2016	February	26	18	22	48	0.0	235.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II. Analysis of variance of the data on germination percentage (%) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Rate of germination (%) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	115.21**	143.64**	128.34**	117.48**	103.88**
Error	56	4.554	6.836	5.746	4.519	4.882

Appendix III. Analysis of variance of the data on shoot length (mm) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Shoot length (mm) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	116.09*	209.23**	152.16**	242.28**	147.79**
Error	56	13.907	10.446	8.442	8.411	6.714

Appendix IV. Analysis of variance of the data on root length (mm) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Root length (mm) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	196.303**	106.827**	152.874**	140.205**	112.676*
Error	56	12.435	8.652	6.987	3.844	2.503

Appendix V. Analysis of variance of the data on fresh weight (mg) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Fresh weight (mg) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	183.361**	161.504**	156.092**	103.735*	102.923**
Error	56	11.233	8.052	4.811	1.585	1.552

Appendix VI. Analysis of variance of the data on dry weight (mg) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Dry weight (mg) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	48.0204**	42.633**	26.215*	18.753*	15.022*
Error	56	0.186	0.158	0.127	0.112	0.104

Appendix VII. Analysis of variance of the data on turgid weight (mg) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Turgid weight (mg) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	120.634*	223.867**	132.244*	103.249*	62.423**
Error	56	4.144	2.091	2.081	1.063	1.034

Appendix VIII. Analysis of variance of the data on relative water content (%) of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Relative water content (%) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	181.439*	190.128**	174.961**	153.897**	91.958**
Error	56	8.184	7.449	5.478	5.877	4.704

Appendix VIII. Analysis of variance of the data on water saturation deficit of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Water saturation deficit (%) at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	104.775**	71.309**	73.014**	68.989*	49.821**
Error	56	6.477	5.229	46.058	4.726	2.203

Appendix X. Analysis of variance of the data on vigour index of Soybean genotypes as influenced by different levels of salt concentrations

Genotypes	Degrees of freedom	Vigour index at different NaCl concentration				
		0 dS m^{-1} (S_0)	5 dS m^{-1} (S_1)	10 dS m^{-1} (S_2)	15 dS m^{-1} (S_3)	20 dS m^{-1} (S_4)
Treatment	14	52.332*	47.036**	39.795*	22.386*	12.621**
Error	56	0.362	0.307	0.276	0.186	0.148

Appendix XI: Pictures of salinity effect in soybean

Plate 1. Experimental view

Plate 2. Sprouting of soybean seeds

Plate 3. Sprouted soybean seedlings at 10th day