RESPONSE TO SALT STRESS AT MORPHO-PHYSIOLOGICAL AND YIELD ATTRIBUTES IN MUNGBEAN

JANNATUL FERDOUS

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

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BY

JANNATUL FERDOUS

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Approvedby:

(Prof. Dr. A.K.M Ruhul Amin)	**(Dr. JasimUddain)**
Supervisor	**Co-supervisor**

Prof. Dr. Mohammad Ali
Director
Examination Committee

Institute of Seed Technolgy

Sher-e Bangla AgriculturalUniversity

Sher-e-Bangla Nagar

Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, "RESPONSE TO SALT STRESS AT MORPHO-PHYSIOLOGICAL AND YIELD ATTRIBUTES IN MUNGBEAN" submitted to the Institute of Seed Technology, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of therequirements for the degree of ***MASTER OFSCIENCE in SEED TECHNOLOGY****, embodies the result of a piece of bona fideresearch work carried out by,* ***JannatulFerdous****Registration No. 15-06995 under my supervision andguidance. No part of the thesis has been submitted for anyother degree or diploma.*

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

……………………………

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

………………

Dated:

Place: Dhaka, Bangladesh

DEDICATED TO MY BELOVED

PARENTS,ELDERSISTER AND YOUNGER BROTHERS

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ABSTRACT

A pot experiment was performed at the Sher-e-Bangla Agricultural Universityin net house, during the period of 10th September to 12th November of 2016 to observe and understand the growth and yield attributes of different mungbean varieties (BARI Mung 5 and BARI Mung6) under different salt stress (50mM, 75 mM and 150mM) condition. Mungbean is an ecologically important food grain legume crop. Susceptibility towards salinity stress has limited the productivity of mungbean.Significant variations and adaptability among stressed and non-stressed plants were observed in both varieties in case of germination attributes. The plants in early vegetative stage were found more tolerant to salinity as compared to plants in late vegetative and reproductive stage. Results showed that all growth characters such as plant height, no. of leaf per plant, fresh weight and dry weight of leaves, and relative water content of two varieties decreased with increased salinity levels. Though BARIMung6 showed little decreased attributes compared to BARI Mung-5.BARI Mung5 variety recorded very convergent values under three salinity levels. BARI Mung6 variety showed better yield attributes(pods/plant, seeds/plant, seed yield/plant, and seeds/pod)than BARI Mung5under different salt stress conditions. Therefore, it can be concluded that salt stress significantly affect on plant growth and yield attributes in different Mungbean varieties, though BARI Mung6 showed better tolerance against salt stress.

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LIST OF ACCRONYMS AND ABBREVIATION

ABBREVIATION	ELABORATION
SAU	Sher-e-Bangla Agricultural University
et al.	and others
Cm	centimeter
NaCl	Sodium chloride
IPCC	Intergovernmental Panel on Climate Change
FAO	Food and Agricultural Organization
USDA	United States Department of Agriculture
BARI	Bangladesh Agricultural Research Institute
DAE	Department of Agricultural Extension
BBS	Bangladesh Bureau of Statistics
PS I	Photosystem I
RCBD	Randomized CompleteBlockDesign
mM	Milimolar
KCl	Potassium chloride
Temp.	Temperature
RH	Relative Humidity

ABBREVIATION	ELABORATION
°C	Degree Celcius
Cm	Centimeter
G.	Gram
ANOVA	Analysis of Variance
LSD	Least Significant Difference
Knowed.	Knowledge
J.	Journal
Af.	African
Biotech	Biotechnology
Pak.	Pakistan
Biol.	Biological
Sci.	Science
Aus.	Australian
Vol.	Volume
Advan.	Advance
Int.	International
Res.	Research
Tech.	Technology
Ann.	Annual
Rev.	Review

ABBREVIATION	ELABORATION
Hort.	Horticulture
Biochem.	Biochemistry
Eds.	Edition
Univ.	University
Behav.	Behaviour
Nat.	Natural
Agron	Agronomy
Exp.	Experimental
Bot.	Botany
Dev.	Development
Med.	Medicine
Chem.	Chemistry
Biosys.	Biosynthesis
Dept.	Department
BAU	Bangladesh Agricultural University
Elem.	Element
Rep.	Report
Ann	Annual
Microbiol.	Microbiology

CHAPTER I

INTRODUCTION

Pulse crop is important protein source for the majority of the people of Bangladesh. It contains protein about twice as much as cereals. It also contains amino acid lysine, which is generally deficit in food grains (Elias et al.,1986). In the existing cropping systems, pulses fit well due to its short duration, low input, minimum care required and drought tolerant nature. Among the food legumes grown, lathyrus, lentil, chickpea, blackgram, and mungbean are the major and they contribute more than 95% to the total pulses production in the country (Rahman, 1998).

Mungbean (*Vignaradiata)* is an important short duration (65-90 days) legume crop under leguminosae family which has high nutritive values and nitrogen fixing ability. It belongs to the genus Vigna that is composed of more than 150 species originating mainly from Africa and Asia where the Asian tropical regions have the greatest magnitude of genetic diversity (USDA-ARS GRIN, 2012).It is a self-pollinated diploid crop with 2n = 2x = 22 chromosomes. Mungbean (*Vignaradiata*) is widely grown in Bangladesh Now a days; it is being cultivated after harvesting of Rabi crops (wheat, mustard, lentil, etc.). As mungbean is a short duration crop, it can fit in as a cash crop between major cropping seasons. It holds the 3rd in protein content and 4th in both acreage and production in Bangladesh (MoA, 2014). The agro-ecological condition of Bangladesh is favorable for growing this crop. Mungbean grain is a good source of protein and carbohydrates (Khan, 1981). On the nutritional point of view, mungbean is one of the best among pulses (Khan, 1981). It is widely used as "Dal" in the country like other pulses. According to FAO (2013) recommendation, a minimum intake of pulse by a human should be 80 gm/day, whereas it is 7.92 g in Bangladesh (BBS, 2012). This is because of fact that national production of the pulses is not adequate to meet our national demand. In Bangladesh, total production of pulses is only 0.65 million ton against 2.7 million tons requirement. This means the shortage is almost 80% of the total requirement (Rahman and Ali, 2007).

At present, the area under pulse crop is 0.406 million hectare with a production of 0.322 million tons (BBS, 2013), where mungbean is cultivated in the area of 0.108 million ha with production of 0.03 million tons (BBS, 2014).

Unpredicting environmental conditions and increasing complexity of the environment, global climate change now become one of the most disastrous and calamitous threat to the world agriculture. Due to climate change world environment as well as agriculture fall in different biotic (Living organisms such as insects, pathogenic fungi, bacteria, and viruses) and abiotic stresses (water deficit or drought, salinity, high or low temperature, light, nutrient, heavy metals) and inhibits plant growth, development and productivity (Hasanuzzaman*et al.,* 2012). Among the different abiotic stresses, salt stress is the major factor for limiting crop growth and productivity in many regions of the world which can cause yield losses up to 100% (Saha*et al.,* 2010). The increased salinity of arable land is expected to have devastating global effects, resulting in up to 50% land loss 7 by the middle of the twenty-first century (Hasanuzzaman*et al.,* 2013).Salt stress imposes substantial adverse effects on the performance and physiology of the crop plants, which eventually leads to plant death as a consequence of growth arrest and metabolic damage (Hasanuzzaman*et al.,* 2012). However, the intensity of adverse and injurious effects of salinity stress depends upon the nature, plant species, duration, stage, concentration, and mode of salt application to the crop. Generally, salinity problems increase with increasing salt concentration in irrigation water. The reduction in production mungbean cultivars reach up to 50% under salt stress. The growth reduction in *Vigna*spp under salt stress resulted from ions toxicity and altered water relations that cause large accumulation of sodium and magnesium and reduced calcium and potassium concentration in root and shoots (Harbir*et al.*, 1989). Presence of excess soluble salt in soil is one of the major factors that reduces the growth and development of cultivated crop plant in coastal areas of Bangladesh. Pitman and Läuchli, (2002), reported that at least 20% irrigated lands are affected by salt stress in world. In Bangladesh more than 30% of the cultivable land is in the coastal area. Out of 2.86 million hectares (ha) of coastal and off-shore lands about 1.056 million ha of arable lands are affected by varying degrees of salinity (SRDI, 2010). In the last three decades about 170,000 ha of agriculture land has been degraded by increased salinity (Ministry of Agriculture and FAO, 2013).The reasons for salinity in Bangladesh are: a) intrusion of sea water due to river drying in the winter, b) cyclone in the coastal area and c) influx of salts from the deep and around to the surface through capillary movement during the dry season. The problem of salinity is severe in the winter though during summer the salt concentration decreases dramatically due to monsoon rains. Cropping intensity in saline area of Bangladesh is relatively low, mostly 170% (FAO, 2007). To feed the millions of people of Bangladesh food production must be increased in these areas. An evaluation of the crop plants in saline environment will certainly provide suitable material as a resource of agronomic traits or genes that can be introduced in the salt sensitive legume crops by breeding (Nair *et al.*, 2012). Recently, Sehrawat*et al.*, (2013) reviewed that mungbean also encounters the cumulative adverse effects of other environmental factors as insects, pests, and high temperature, pod-shattering along with salt stress causing high yield loss.

To develop salt stress tolerant varieties of mungbean, different genotypes, after proper through physiological and biochemical attributes, those confers salt tolerance, must be assessed to identify therefore direct adaptation to saline agricultureor future breeding applications. Salt tolerant mungbean variety may be an alternative for increasing production in these saline soils.

Considering the above factors the present experiment was conducted to evaluate yield attributes and yield of mungbean varieties with the following objectives:

I. To investigate the effect of salt stress on mungbean plants

II.To find out the interaction effect of different varieties and salt stress ongrowth and yield performances of mungbean.

CHAPTER II

REVIEW OF LITERATURE

2.1 Mungbean

Mungbean is thought to have originated in South and Southeast Asian regions. It is widely grown in India, Pakistan, Bangladesh, Myanmar, Thailand, the Philippines, China and Indonesia. It is also grown in parts of East and Central Africa, the West Indies, USA and Australia. Mungbean is traditionally grown in two cropping patterns. About 60-65% of the total mungbean is grown under the boro (winter) rice mungbean-aus (rainfed) rice cropping system in five southern districts: Patuakhali, Barisal, Madaripur, Noakhali, and Cox's Bazar from mid-January to April. Mungbean grain contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981 and Kaul, 1982). On the nutritional point of view, mungbean is one of the best among pulses (Khan, 1981).

Augmentation of modern develop varieties (i.e: insect and disease resistance, heat tolerant and early harvesting varieties) and hybrid varieties with farm mechanization, mungbean production per hectare area now increases. Stress both biotic and abiotic greatly affects crop growth and yield.

Protein malnutrition remains a major nutrition problem in Asia and affects children most severely (WHO, 2000 and USDA-ARS, 2010). About 150 million children worldwide are underweight and 182 million are stunted. At least 70% of these children are in Asia. Meat is a good protein source, but is either excluded from vegetarian diets or unaffordable for poor households where protein and micronutrient deficiencies are most prevalent. However, mungbean is cheap source of protein, and an important nutritious dietary component of vegetarians in Asian countries especially in South-east Asia (Keatinge*et al.*, 2011). If global food production is to be maintained it seems reasonable to predict that enhancement of the salt tolerance of crops will be an increasingly important aspect within a widening number of plant breeding programs. Future progress in mungbeanbreeding requires urgent action to identify accessions with favourable agronomic traits and to provide tools to exploit the allelic diversity of mungbean for crop improvement.

Literature reported that the greater accumulation of salt decreased the osmotic potential of soil solution eliciting water stress in plants and further interactions of the salts with mineral nutrition caused nutrient imbalance and deficiencies, oxidative stress or even pathology ultimately lead to plant death as a consequence of growth arrest and metabolic damage (McCue and Hanson, 1990; Maathuis and Amtmann, 1999; Zhang *et al.*, 2001; Tavakkoli*et al.,* 2010; Hasanuzzaman*et al.,* 2012). Due to the complex nature of salt stress and lack of appropriate techniques for introgression little progress has been made in developing salt tolerant mungbean varieties.

2.2 Salt stress and its effects on mungbean plants:

Legumes are economically important crops and serve as sources of nutritious food, feed and raw-materials for humans, animals and industries respectively. Additionally, legumes have a symbiotic association with nitrogen-fixing rhizobia present in the root nodules, thus plants do not require external nitrogen sources. However, legumes are highly salt-sensitive crops, and a high concentration of Na^+ and Cl^- ions around the root zone in water-scarce areas limits geographical range of legumes in arid and semiarid climates where evapotranspiration exceeds precipitation. Usually, salt stress affects plants in two modes: osmotic stress and ion toxicity. However, for legume species particularly, there is a third mode: reduced nodulation by rhizobia, as salinity affects them either directly or indirectly. However, response of legumes and other plant species differ liable to prevailing conditions and extent of stress intensity. Therefore, it is necessary to enhance productivity of food grain legumes and to exploit valuable natural resources more efficiently to meet the demand for nutritious food from a growing population.

Salt stress is the concentration of dissolved mineral salts (electrolytes of cations and anions) present in the soil and water. The major cations in saline soil solutions consist of

Na^+, Ca^{2+}, Mg^{2+} and K^+ and the major anions are Cl^-, SO_4^{2-}, HCO_3^-, $CO_3^{2-}$and NO_3^{-}. Plants in saline soils not only suffer from high sodium level, but also affected by some degree of hypoxia by the action of Na^+ ions because when they occupy the cation exchange complex of clay particles, makes the soil more compact, thereby hampering soil aeration. According to the USDA Salinity Laboratory, saline soils have the EC is ≥4 dS m^{-1}.

Kingburg and Epstein, (1984) reported that various strategies have been adopted by plant scientists in overcoming salinity where one important component is the evaluation of genetic variability of the cultivated species or its wild relatives to identify a tolerant genotype that may sustain a reasonable yield on salt affected soils.

Magda and El-Kramany. (2005) compared growth, yield, yield components and chemical composition in seeds of four mungbean varieties under three salinity levels and observed significant variations for all these traits.

Recently, Sunil *et al*. (2012) also observed that salt stress adversely affected the biometric, morpho-physiological, biochemical and biophysical characters of mungbean.

Salinity tolerance is influenced by many plant, soil, and environmental factors and their interrelationships. Characters such as yield, survival, vigor, leaf damage, plant height, and accumulation of specific ions in shoots, roots, or leaves have been the most commonly used criteria for identifying salinity tolerance (Mass and Hoffman, 1977 and Noble and Shannon, 1988). Salt tolerance is a developmentally regulated, stage-specific phenomenon, so that tolerance at one stage of development may not be correlated with others tolerance at other developmental stages (Shannon, 1984). Evaluation of salt tolerance in legumes has been attempted by a variety of cultural techniques with plant material ranging from germinating seeds to seedlings to mature plants (Chauba, 1997; Hafeez*et al.*, 2002).

2.2.1 Effect of salinity on seed germination and seedling growth

The most critical stage in seedling establishment is seed germination that determines fruitful crop production. Acceptable growth of plants in arid and semi-arid lands which are under exposure of salinity stress is related to the ability of seeds for best germination under unfavourable conditions, so necessity of evaluation of salinity tolerant genotypes is important at primary growth stage. Increasing salinity levels during mungbean seed germination significantly reduced germination characters and seedling characters with varying responses for mungbean cultivars (Naher*and Alam.* 2010; Kandil*et al*., 2012). Salinity may affect mungbean seed germination by producing an outside osmotic potential that avoids water uptake or due to toxic effects of Na+ and Cl- ions during seed germination (Murillo-Amador *et al*., 2002; Khajeh-Hosseini*et al*., 2003).

Mahdavi*et al*. (2007) reported that germination reduction may be due to increased dormancy in crop seeds under salinity stress and observed injury to mungbean cultivars with irrigation water containing electrical conductivity (EC) of 4 m mhos/cm.

Maliwal and Paliwal (1982) observed that germination of all the 42 cultivars of mungbean and black gram was delayed and decreased with an increase in salinity level. Seedling height also decreased significantly at higher salinity and the salt tolerance limit varied with the cultivar.

Win *et al.,* (2014) also suggested that genetically diverse germplasm resistant to salt stresses within *Vigna*genotypes could be of practical value to study the mechanism governing salt tolerance and for the delivery of genetic resourcesfor salinity in breeding program.

The differences between mungbean cultivars in final germination index might be due to the genetically factors and heredity variation similar to the findings of Singh *et al.*(2012) and Salah Uddin *et al.*(2009).

2.2.2 Effect of salt stress on relative water content (RWC)

The plants tend to prolong stress tolerance by using several mechanisms that tend to postpone or tolerate desiccation as reduction of water loss, maintaining of turgor pressure and osmotic potential (Jeannette *et al*., 2003). High concentration of salts in the root zone (rhizosphere) reduces soil water potential and the availability of water in shoot and root which further influence cellular physiology and metabolic pathways (Lyod*et al*., 1989 and Misra and Dwivedi, 2004). As a result of this reduction of the relative water content, dehydration at cellular level and osmotic stress are observed in mungbean and other crop plants (Munns, 2002). High salt depositions in the soil generate a low water potential zone in the soil making it increasingly difficult for the plant to acquire both water as well as nutrients (Mahajan and Tuteja, 2005). Therefore, salt stress essentially results in a water deficit condition in the plant and takes the form of a physiological drought.

2.2.3 Effect of salinity stress on photosynthetic pigments

Photosynthesis

Photosynthesis is one of the most promising physiological processes contributing to plant growth and productivity of crops for food. Under salinity stress the reduction in photosynthetic rate is not only attributed to stomata closure leading to a reduction of intercellular CO_2 concentration, but also to non-stomatal factors finally resulted in reduced quantum yield. It is affected by leaf expansion rate, leaf area, and leaf duration, as well as by photosynthesis and respiration per unit leaf area under salt stress. Inhibition of photosynthesis is also associated with decline in pigment contents resulted from the reduction in leaf area (Dhingra*et al.*, 1993), or due to decrease in leaf organic acid with salinily (Cachorro*et al*., 1993) or due to decrease in PS II electron transport activity (Mishra and Dwivedi2004) or due to increase in amylase activity and /or decrease ininvertaseactivity (Promila and Kumar, 2000), or due to les stomatal openings in leaf (Rady*et al* ., 2011).Salt stress directly or indirectly affects the photosynthetic functions by changing the structural organization and physio-chemical properties of thylakoid membranes. Generally, plant water status under stressful environments is maintained by regulating stomatal conductance and transpiration rate (Dey*et al.,* 2005).

Yeo *et al.,* (1998)reported that high Na+ levels also lead to reduction in photosynthesis and production ofreactive oxygen species. Nafees*et al.,* (2010) reported disturbance in photosynthetic processes due to accumulation of toxic ions, decrease in water and osmotic potential under salinity stress. In other words, photosynthetic capacity in crop plants is the primary component of dry matter productivity. Thus, final biological yield or economical yield can be increased either by increasing rate of photosynthesis finally contribute to the biological yield or economical yield of crop plants (Natr and Lawlor, 2005).

2.2.4 Effect of salinity stress on morphology and growth

The most common salinity effect is a general stunning of plant growth. Literature reported gradual reduction in seed germination, plant height, shoot and root length, dry matter, biomass, root, stem and leaf weights with progressive increase in salinity stress in mungbean plants (Mohamed and El-Kramany. 2005) and also in other crops Yadav*et al.,* (2011). As salt concentration increases above a threshold level both the growth rate and ultimate sizeof most plant species progressively decrease. Wahid *et al.,* (2004) reported salt induced injury symptom on mungbean such as enhanced chlorosis and necrosis. Meiri*et al,* (1970) reported that not all the plant parts are affected equally due to salinity, top arial growth is often suppressed more that the root growth. It is possible that under salt stress the plant expends more photosynthetic energy in root production in search of water and or reducing water loss and thus maintains relatively high plant water relations. Growth inhibition by salt stress may be due to the diversion of energy from growth tomaintenance that may include the regulation of ion concentration in various organs andwithin the cell, the synthesis of organic solutes for osmoregulation or protection ofmacromolecules, and for maintenance of membrane integrity (Maas, 1978 and Greenway and Gibbs, 2003). Due to NaCl, the growth of root, shoot and leaves either increased or decrease (Ashraf and Rasul, 1988). Singh and Chatrath, (2001) reported stunted stem and succulent leaves under salinity stress due to inhibition of cell division and enlargement in the plant's growing point and elongation of the palisade cells caused by toxic Cl^- ions. El-Hendawy*et al.,* (2005) reported that salinity significantly decreased dry matter production.

Saha*et al.,* (2010) also reported drastic effect of salinity stress on the roots as compared to shoots, accompanying reductions in length, number of root hairs and branches, while the roots became stout, brittle and brown in color.

2.2.5 Effect of salinity stress on yield characteristics

Soil salinity caused reduction in flowering, and severe yield loss in many crop plants including legumes viz., soyabean, mungbean, wheat, barley, bean, rice and cotton (Singh *and Singh.*2011and Magda and El-Kramany, 2005).

Mudgal (2004) reported decreased plant growth, delayed flowering, decreased number of flowers, impaired pod-settingresulting in more decrease in number of pods than the seeds in chickpea and pea due to salinity stress.

Mass (1986) suggested that salinity may affect pollination and thus decrease seed set and grain yield.

Reduction of yield and its component rated under salt stress condition may also be attributed to low production, expansion, senescence and physiologically less active green foliage (Rawson *et al.,* 1988; Schactman and Liu, 1999; Kumar *et al.,* 2003 and Wahid *et al.,* 1997) thus reduced photosynthetic rate might be a supplementary effect. The morpho-physiological characteristics also play a crucial role directly or indirectly in the reduction of efficiency per day of plant as well as effective filling period of seed and may lead to decrease the yield of crop.

According to Gill, (1979) lengthening the time required for seed filling under salt stress push the plants at seed filling and maturity to high temperature and water stress due to the summer. The effect of both salt and water stress might lead to shriveled seeds and consequent lower yield.

Singh *et al.* (2001) also reported that grain yield reduced because of decrease in dry matter content, leaf size and increase in root: shoot ratio under salt stress.

Ahmed, (2009) also reported that reduced yield in mungbean under salt stress may be due to reduced efficiency per day of plant to fill the developing seeds, which may lead to reduced number of seeds/pod or plant and dry matter yield of individual seed.

Sharma and Gill (1994) reported that Delayed maturity due to salt stress pushes the plant also to desiccation stress causing shriveled seeds. Earlier workers reported significant variability for grain yield in mungbean (Tickoo*et al.,* 1988 andRehman*et al.,* 2009).

Aher and Dahat (1999) confirmed that epistatic component was involved in the expression of grain yield per plant in mungbean. The exploitation of previously existing genetic variability in the breeding material as well as the creation of new variation in conjunction with its genetic knowledge is of fundamental significance for initiation of a breeding program aimed at improved yield (Khattak*et al.,* 2004 and Ali *et al.,*2008).

2.2.6 Effect of salinity stress on relative distribution of mineral ions (Na^+, K^+, and Ca^{2+})

The effect of salinity on mineral ions was due to decrease in xylem exudation rate and leaf water potential, relative water content and water retention capacity concurrently with increased water saturation deficit and water uptake capacity (Kabir*et al.,* 2013). Sodium ions in saline soils are toxic to plants because of their adverse effects on K^+ nutrition, cytosolic enzyme activities, photosynthesis, and metabolism (Niu et al., 1995). Salt stress caused increase in Na^+ and Cl^- in leaves, shoots, and roots of mungbean plants whereas decrease in other essential elements as K^+, Ca^{2+} ions as compared with the non stressed plants (Nandini*et al.*, 2002; Rashid *et al.*, 2004 andYasar*et al.*, 2008) and the K^+/Na^+ ratio could be used to as a selection criterion for salt tolerance (Bassiouny and Bekheta, 2001). The increased NaCl stress caused increase in Na^{+}, Ca^{2+}, and Cl^{-} and decrease in K^{+} and Mg^{2+} levels along with the ratio of K^{+}/Na^{+}, and Ca^{2+}/Na^{+} in a number of plants. The toxic level of specific ions alter ionic homeostasis leading to nutrient imbalance because under conditions of high external sodium ions, the transport proteins face difficulties to distinguish between the Na^{+}, and K^{+} ions having similar radii (Blumwald*and Groves,* 2000).

As a consequence of this the potassium content, K^{+}/Na^{+} selectivity and cell membrane stability decreases while, electrolyte leakage increases significantly by salinity in different cultivars of mungbean. Salinity stress elicits a transient increase of calcium ion that has at least two roles in salt tolerance, a pivotal signaling function in the salt stress response leading to adaptation and a direct inhibitory effect on a Na^{+} entry system (Knight *et al.*, 1997; Matsumoto *et al.*, 2001). Arun*et al.*,(1997) reported that under salt stress conditions, calcium content increased which downregulated the uptake of K^{+} and Mg^{2+}.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location

The experiment was conducted at the experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka ($90^{0}77'$ E longitude and $23^{0}77'$ N latitude) during the period from 10^{th} September 2016 to 12^{th} November 2016. The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.6. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.3 Climate

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from April to September, but scanty rainfall associated with moderately low temperature prevailed during the period from October to March. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Materials

3.4.1 Plant materials

Two mungbean varieties BARI Mung- 5 and BARI Mung- 6 were used in the experiment. The features of two varieties are presented below:

BARI Mung- 5: BARI Mung variety is grown in kharif season. It is a line crossed varietyofmungbean released by BARI in 1997. Grain colour its green. The cultivar matures at 50- 60 days of planting. It attains a plant height 40-45 cm. The cultivar gives an average yield of 1.8 t/ha.

BARI Mung- 6: Plant height 40-45 cm, photo insensitive and can be grown in Kharif-I, Kharif-II and late Rabi, after flowering stage plant growth become stunted, leaf and seed color deep green and leaf broad, seed large shaped with smooth seed coat, pods matured at a same stage. Grain large, 1000 seed weight 51-52 g, after wheat harvest sowing up to April first week, It is sowing also Kharif-2 and Rabi season , crop duration 60-70 days. The cultivar gives an average yield of 2.0 t/ha.

3.4.2 Earthen pot

Empty earthen pots with 18 inch depth were used for the experiment. Twelve kilogram sun-dried soils were put in each pot. After that, pots were prepared for seed sowing.

3.5 Salinity treatment

Three level salt stress treatments were imposed by adding different amount of Sodium chloride (NaCl) to pot. The required amount of salt was applied at 3 equal splits weekly intervals with a view to gradually develop salt stress in soil.The salinity levels were

C (control), S50 (50 mM), S75 (75 mM) and S150 (150 mM). When water added as irrigation without salt then it termed as control (C) while 204.75g salts in S50, 306.74g salts in S75 and 614.25g salts in S150. The first split of salts solution was applied at 15 days old seedlings while the other splits of salt solution was applied 30 days and 45 days after sowing. For adding salt, at first salt was dissolved in required amount of water to maintain 80% field capacity of the pot soil and applied homogenously in each pot.

3.6 Treatments

The experiment consisted of two factors as mentioned below:

a) Factor A: varieties

i. BARI Mung 5 (V_1)

ii. BARIMung 6 (V_2)

b) Factor B: Salinity level

i**.** T_0: 0 mM (control)

ii. T_1: 50 mM

ii. T_2: 75 mM

iii. T_3: 150 mM

There were 8 (2 × 4) treatments combination such as V_1T_0, V_1T_1, V_1T_2, V_1T_3, V_2T_0, V_2T_1, V_2T_2, and V_2T_3in the experiment.

3.7 Design and layout of the experiment

The experiment was laid out in a CompletelyRandomized Design (CRD) with three replications. There were 24 pots all together replication with the given factors.

3.8 Seed collection

Seeds of BARI Mung 5 and BARI Mung 6 were collected from Pulse Seed Division of Bangladesh Agriculture Research Institute, Joydebpur, Gazipur. The collected mungbean varieties were free from any visible defects, disease symptoms and insect infestations.

3.9 Pot preparation

The collected soil was sun dried, crushed and sieved. The soil and fertilizers were mixed well before placing the soils in the pots. Soils of the pots were poured in polythene bag. Each pot was filled up with 12 kg soil. Pots were placed at the net house of Sher-e Bangla Agricultural University. The pots were pre-labeled for each variety and treatment. Finally, water was added to bring soil water level to field capacity.

3.10 Fertilizer application

Fertilizers used in the experimental pots were cowdung, urea, triple super phosphate, murate of potash and gypsum at the rate given value in a tabulated form one-third of urea and the whole amount of other fertilizers were incorporated with soil at final pot preparation before sowing.

Fertilizer doses are as follows:

Fertilizers	Amount (kg/ha)	Actual amount/pot (g)
Urea	55	0.175gm
Triple super	74	1.21gm

phosphate		
Muriate of potash	50	0.35gm
Cowdung	10 ton/ha	70gm

3.11 Seed sowing technique

Twenty five healthy seeds of each variety were sown in each pot. After germination 5-6 plants were allowed to grow in each pot.

3.12 Intercultural operations

3.12.1 Gap filling and thinning

After sowing seeds continuous observation was kept. It was observed that germination percentage and seedling establishment was poor in 150 mM salt stress. Thinning was done to maintain spacing of the plants.

3.12.2 Weeding and irrigation

Sometimes there were some weeds observed in pots which were uprooted manually. Irrigation was given along with salt stress treatment to maintain field capacity moisture level.

3.12.3 Plant protection measures

There was no insect pests appeared. Moreover, the pots were protected by netting to prevent birds.

3.13 Data Collection:

Seed quality parameters

- Germination percentage
- Vigour index

Physiological parameters:

- Relative water content (RWC)

Crop growth parameters

- Plant height at 15, 30, 45 days and harvest
- No. leaves/ Plant at 15, 30, 45 days and harvest

Yield and yield contributing parameters

- No. of pods/ plant
- No. of seeds/ pod
- Pod length
- 1000 seed weight (gm)/plant
- Seed yield
- Stover yield
- Biological yield
- Harvest index

3.14 Germination percentage

Total germination percentage was calculated by the following formula:

TGP (%) = (No. of germinated seeds/ total no of seeds set for germination) × 100.

3.15Vigour Index (VI)

Vigour Index (VI) was calculated fromtotal germination and seedlings length by using the formula

Vigour index= $\frac{\text{TGP (\%) x seedlings length (cm)}}{100}$

Here,

TGP = total germination percentage

3.16Plant height (cm)

The height of plant was recorded in centimeter (cm) at 15, 30, 45 DAS and atharvest. Data were recordedfrom 3 plants from each pot and average plant height plant^{-1}was recorded as pertreatment. The height was measured from the ground level to the tip of the plantby a meter scale.

3.17Determination of Relative water content (RWC)

Leaf relative water content (RWC) was measured according to Barrs and Weatherley, (1962). Leaf laminas were weighed (FW), then placed immediately between two layers of filter paper and immersed in distilled water in a Petri dish for 24 h in a dark place. Turgid weight (TW) was measured after gently removing excess water with a paper towel. Dry weight was measured after 48 h oven drying at 70°C. Finally, RWC was determined using the following formula:

RWC (%) = $\frac{FW-DW}{TW-DW} \times 100$

3.18Number of leaves plant^{-1}

The number of leaves plant^{-1}was counted at 15, 30, 45 DAS and at harvest. Data were recorded from 3 plants from each pot and average number of leaves plant^{-1}was recorded as per treatment.

3.19Number of pods plant^{-1}

Numbers of total pods of 3 plants from each pot were counted and the mean numbers were expressed as plant^{-1}basis.

3.20Number of seeds pod^{-1}

The number of seeds pods-1 was recorded from randomly selected pods at the time of harvest. Data were recorded as the average of 10 pods selected at random from each pot.

3.21Pod length

Pod length was taken from randomly selected 10 pods and the mean length was expressed as per pod basis.

3.22Weight of 1000 seeds

One 100 cleaned, dried seeds were counted randomly from each harvest sampleand weighed by using a digital electric balance and weight was expressed in gramby multiplying 10.

3.23Seed yield

The seeds collected from plant of each pot were sun dried properly. The weight of seeds was taken and converted the seed yield in g plant^{-1}.

3.24Stover yield

The stover collected from plant of each pot was sun dried properly. The weight of stover was taken and converted the stover yield in g plant^{-1}.

3.25Harvest index (%)

Harvest index was calculated from the seed and stover yield of mungbean for each plant and expressed in percentage.

Harvest index (%) = $\frac{\text{Seed yield}}{\text{Seed yield+Stover yield}} \times 100$

Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant differences on yield and yield contributing characters of mungbean under the treatments designed. The mean values of all the characters were calculated and the analysis of variance (ANOVA) was performed by the 'F'(variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

Seed quality parameters

4.1 Germination percentage

Plants life cycle start with germination which is considered as the most critical stage. Plant growth, development and yield is greatly affected when germination stage falls under adverse environmental conditions like drought, high temperature, low temperature, salinity etc. Among them, salt stress markedly inhibited germination of seeds by creating low osmotic potential preventing water uptake (Kaya *et al.*, 2006 and Wei *et al.*, 2013).

4.1.1 Effect of variety

Percentage of germination showed no significant variation between the two varieties of mungbean(Figure 1A). BARI Mung 6 (94%) had the maximum germination percentage, where BARIMung 5 (92%) had minimum germination percentage.

4.1.2Effect of salinity treatments

The data (Figure 1B) showed that salinity also reduced the percentage of germination in both mungbean varieties.The highest germination percentagewas found in control (T_0) treatment. Germination percentage decreased with increased salinity level. The lowest germination percentage was found in T_3(49%).

4.1.3: Interaction effect of variety and salinity treatments

In the present study, treatment V_1T_0 (BARI Mung 5) and V_2T_0(BARI Mung 6) showed the highest germination percentage (Figure 1C). But imposing of salt stress, germination percentage decreased significantly. Germination percentage decreased with increasing salt concentration. That's why V_1T_3 and V_2T_3 showed the lowest germination percentage compared to other treatments (Figure 1C). These finding are supported by earlier work on germination attributes on cowpea and mungbean by Wests and Francios(2004) and Naher and Alam(2010) respectively. The effect of salinity on germinating seeds in many species is not only on lowering the percentage of germination, but also on lengthening the time needed to complete germination (Ayers 1952).

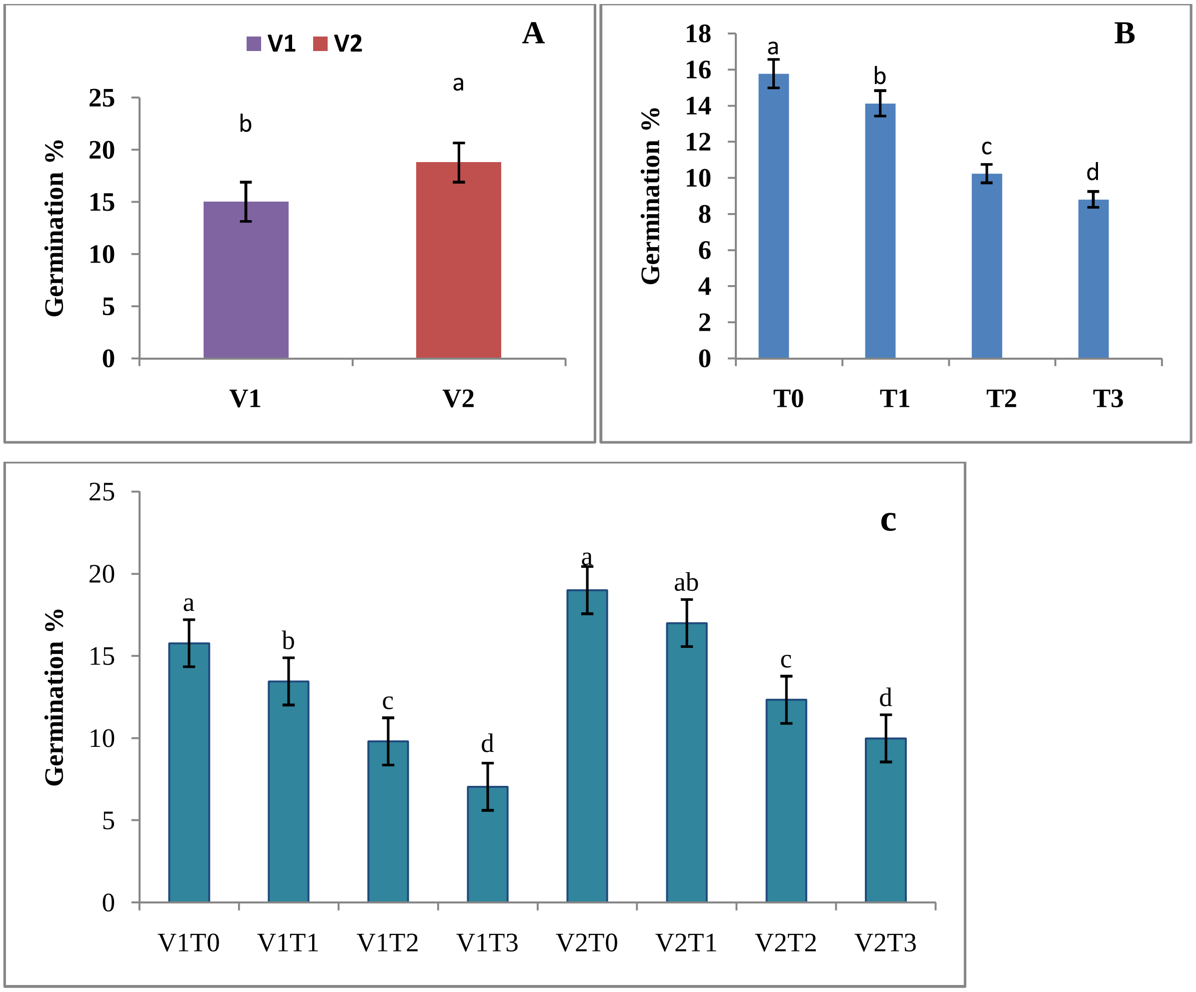

Figure 1: (A) Effect of variety, (B) Effect of salinity treatments, and (C) Interaction effect of variety and salinity treatments on germination percentage of mungbean. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

Where, V_1: BARI Mung-5 | T_0: 0 (control)

V_2: BARI Mung-6 | T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

4.2 Vigour index

4.2.1 Effect of variety

Significant variation was observed in vigour index due to the effect of variety shown in Figure 2A. BARI Mung 6 have higher vigour index (83.14%)compared to BARI Mung 5

4.2.2 Effect of salinity treatment

Upon exposure to salt stress, seed vigour indexdecreased significantly compared to control (Figure2). The highest vigour indexwas found at control plants (T_0). Seed vigour index decreased significantly with increased salinity levels and the lowestvigour indexwas found inT_3treatment.

4.2.3 Interaction effect of variety and salinity treatments

There have significant differences between treatments. Control treatments V_1T_0 and V_2T_0 showed better vigour index then other treatments. Exposure of salt stress drastically decreased seed vigor index in germinating mungbean seeds. Treatment V_1T_3 and V_2T_3 showed lower vigour index in comparison to other treatments (Figure 2C).Similar results were also reported by Naher and Alam (2010) and Hajieret al., (2006).

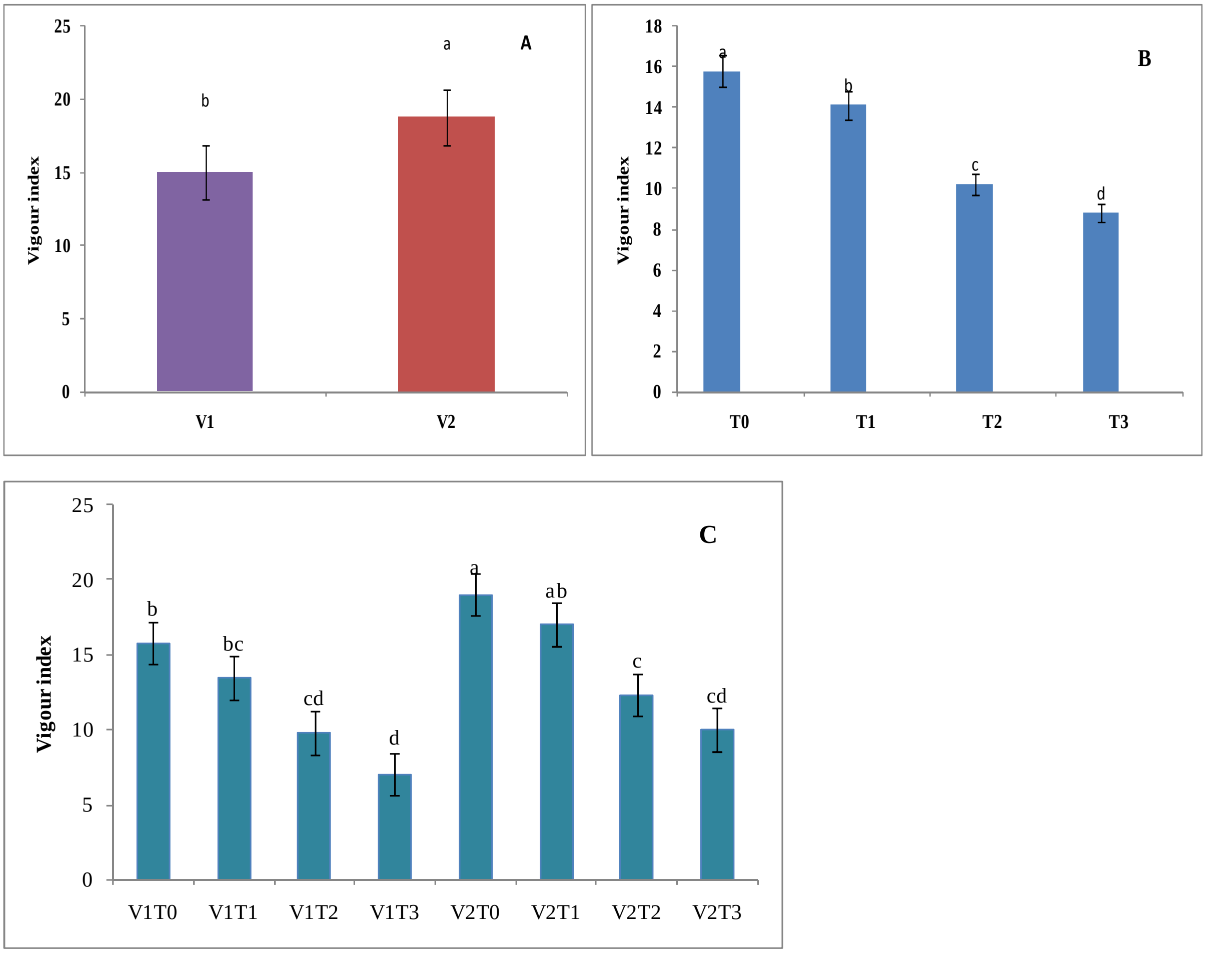

Figure 2: (A) Effect of variety, (B) Effect of salinity treatments, and (C) Interaction effect of variety and salinity treatments on vigour index of mungbean. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

Where, V_1: BARI Mung-5

V_2: BARI Mung-6

T_0: 0 (control)

T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

4.4 Plant height (cm)

4.4.1 Effect of variety

Plant height of mungbean at 15, 30, 45 DAS and at harvest showed statistically no significant variation due to different varieties. At 15,30, 45 DAS and at harvest, the taller plant was recorded from BARI mung 6 but statistically no significant variation found between varieties in respect of plant height (Figure 3).

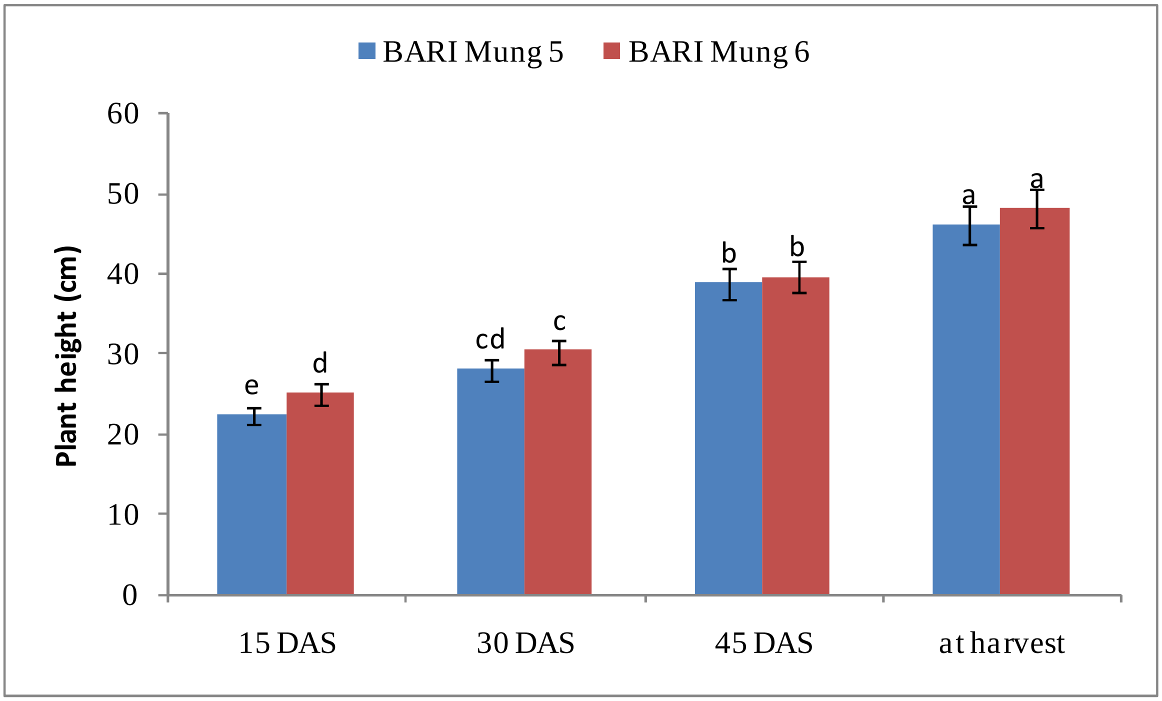

Figure 3: Effect of different varieties (BARI Mung 5 and BARI Mung6) on plant heights (cm). Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

4.4.1 Effect of salinity treatments

Plant heightof mungbean at 15, 30, 45 DAS and at harvest showed significant variation for different levels of salinity. Maximum no. of leaves plant^{-1}was found from T_0at harvest stage which was statistically significant from all othertreatment combinations. With the increasing salinity, no. of leaves plant^{-1} decreased significantly (Figure 4).

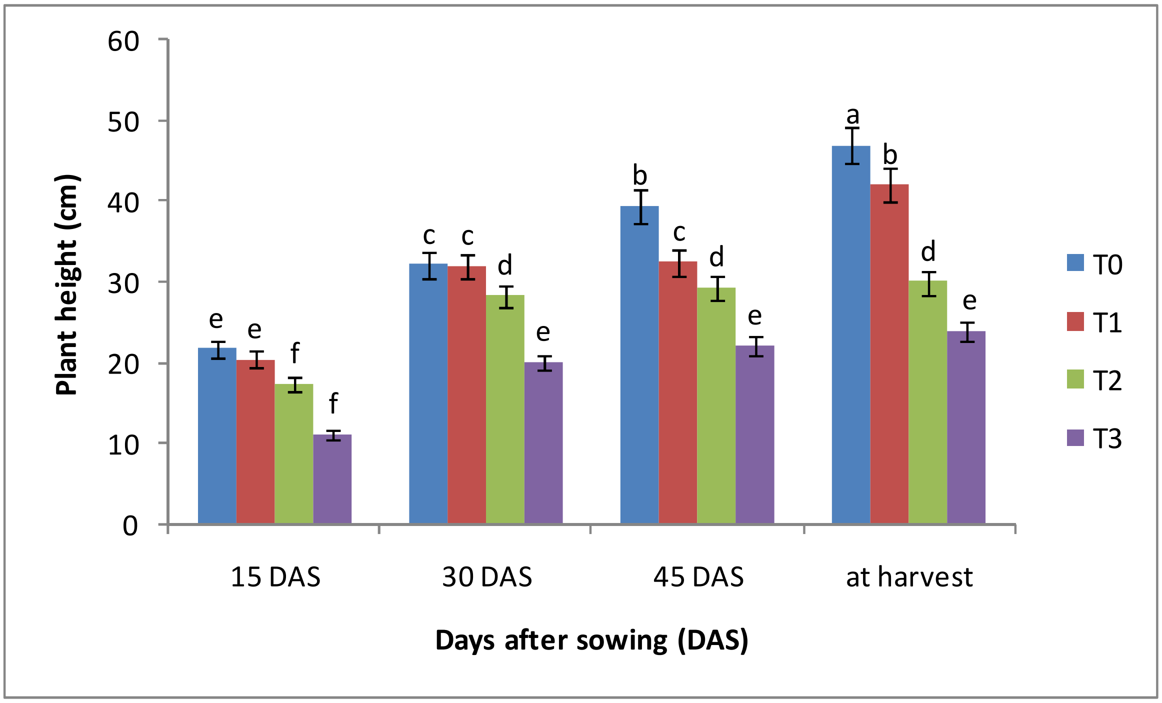

Figure 4: Effect of salinity on plant heightsof BARI Mung 5and BARI Mung6. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

*T_0: 0 (control), T_1: 50 mM salt, T_2: 75 mM salt, T_3: 150 mM salt

4.4.3: Interaction effect of variety and salinity treatments

Plant growth is characterized by some morphological traits like plant height, Plant FW and DW, shoot length, root length etc. In the following experiment treatments V_1T_0, V_1T_1, V_1T_2, V_2T_0,V_2T_1 and V_2T_2 exhibited no significant differences. But upon exposure to high salt stress plant height decreased significantly compared to V_1T_3 and V_2T_3 treatments (Table 1). However, the present study indicated the BARI Mung 6 is little bit more tolerant to salt stress than BARI Mung 5.

Cell is basic components of all living organism and water is the basic requirement for cell growth and development. Salt stress hinders cell expansion and reduces stomatal opening and carbohydrate supply ultimately affects growth and development of plants (Kang *et al.*, 2012 and Hasanuzzaman*et al.*, 2013).Generally speaking, we may infer that, the elongation of the stem when treated with low concentrations of salts may induce osmotic adjustment activity in the plants which may improve growth. On the other hand, the noticed decrease in the length of the stem, also due to treatment with sodium chloride solution, could be due to the negative effect of this salt on the rate of photosynthesis, the changes in enzyme activity (that subsequently affects protein synthesis), and also the decrease in the level of carbohydrates and growth hormones, both of which can lead to inhibition of the growth (Mazher*et al.*, 2007).

Table 1. Interaction effect of different varieties and salinity levels on plant height ofmungbean

Treatments	Plant height (cm) at			
	15 DAS	**30 DAS**	**45 DAS**	**Harvest**
V_1T_0	20.03 a	28.30 a	37.11 a	45.88 a
V_1T_1	18.70 b	23.33 ab	30.22 ab	42.40 ab
V_1T_2	12.78 b-d	18.87 b	24.04 b-d	32.30 b-d
V_1T_3	9.43 d	15.20 c	22.66 cd	28.78 d
V_2T_0	23.11 bc	32.22 ab	44.28 b	47.92 b
V_2T_1	19.44 b-d	29.80 bc	39.39 bc	43.80 bc
V_2T_2	15.55 b-d	22.00 b	27.08 b	37.02 bc
V_2T_3	11.30 e	18.42 cd	24.60 cd	33.33 cd
LSD(0.05)	**2.042**	**1.973**	**2.955**	**2.844**
CV (%)	**6.06**	**5.79**	**4.60**	**4.89**

Where, V_1: BARI Mung-5
V_2: BARI Mung-6

T_0: 0 (control)
T_1: 50 mM salt
T_2: 75 mM salt
T_3: 150 mM salt

4.5 Relative water content

4.5.1Effect of variety

There have statistically no significant differences between two mungbean varieties. The higherrelative water content was recorded from BARI Mung 6at 15, 30 and 45 DAS which was statistically similar to BARI Mung 5(Figure 5).

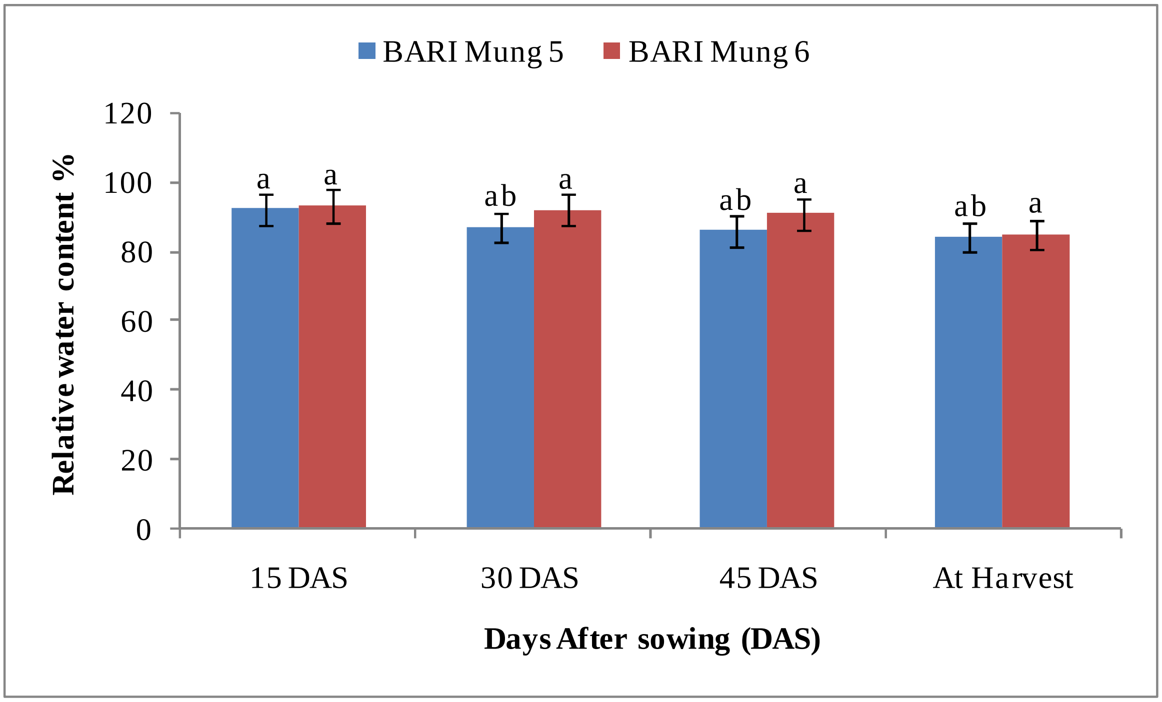

Figure 5: Effect of different varieties (BARI Mung 5 and BARI Mung6) on relative water content (%) ofMean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

4.5.2 Effect of salinity treatments

Relative water contentof mungbean at 15, 30, 45 DAS and at harvest showed significant variation for different levels of salinity. Relative water contentvalue was highest from T_0at 15 DAS old seedlings which was statistically similar to 30, 45 DAS old seedlings. With the increasing salinity, relative water content decreased significantly (Figure 6).

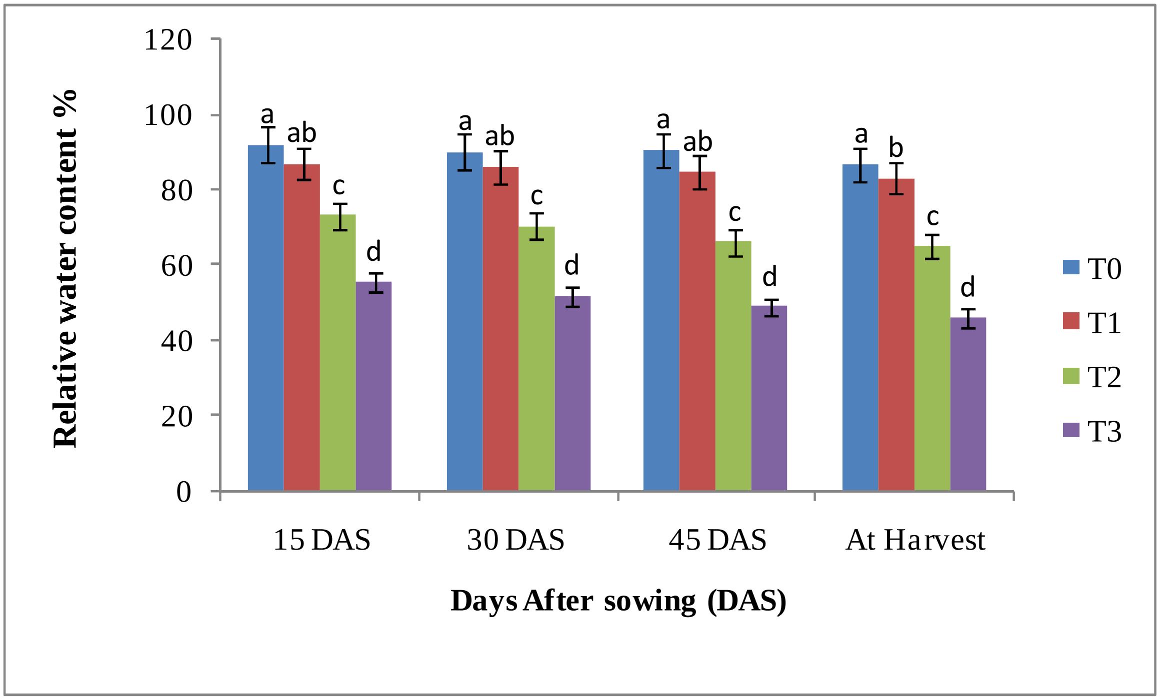

Figure 6: Effect of salinity on relative water content of BARI Mung 5and BARI Mung6. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

*T_0: 0 (control), T_1: 50 mM salt, T_2: 75 mM salt, T_3: 150 mM salt

4.5.3: Interaction effect of variety and salinity treatments

Water is the most important component for the survival of all living organism. Under salt stress condition, water lost from the cell of plants that result in decreased relative water content. Salt stress significantly decreased relative water content of mungbean compared with the control treatments. In the following experiment treatments, control treatmentsV_1T_0 andV_2T_0 exhibited no significant differences under 15, 30, 45 DAS and at harvest. But upon exposure to high salt stress, relative water content in V_1T_3 and V_2T_3treatments decreased significantly compared to control and all other combinations (Table 2).

Table 2. Interaction effect of different varieties and salinity levels on number of relative water contentof mungbean

Treatments	**Relative water content (%) at**			
	15 DAS	**30 DAS**	**45 DAS**	**Harvest**
V_1T_0	91.03 a	88.30 a	87.11 a	85.88 a
V_1T_1	84.70 b	83.33 a	80.22 ab	82.40 a
V_1T_2	70.84 c	68.83 b	64.40 b	62.99 b
V_1T_3	49.78 e	45.78 d	42.12 d	38.78 d
V_2T_0	93.11 a	92.22 a	94.28 a	87.92 a
V_2T_1	89.44 b	89.11 a	89.21 a	83.80 a
V_2T_2	75.55 c	72.19 b	67.81 b	67.02 b
V_2T_3	61.30 de	58.01 c	55.60 c	53.33 c
LSD(0.05)	**6.871**	**4.799**	**4.243**	**4.155**
CV (%)	**2.120**	**3.138**	**2.716**	**1.431**

Where, V_1: BARI Mung-5

V_2: BARI Mung-6

T_0: 0 (control)

T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

4.6 Leaves/ plant

4.6.1 Effect of variety

There was significant variation observed for leaves/ plant due to varietal variation (Figure 7). BARI Mung 6 (84.35%) recorded the higher leaves/ plant compared to BARI Mung 5 (77.3%).

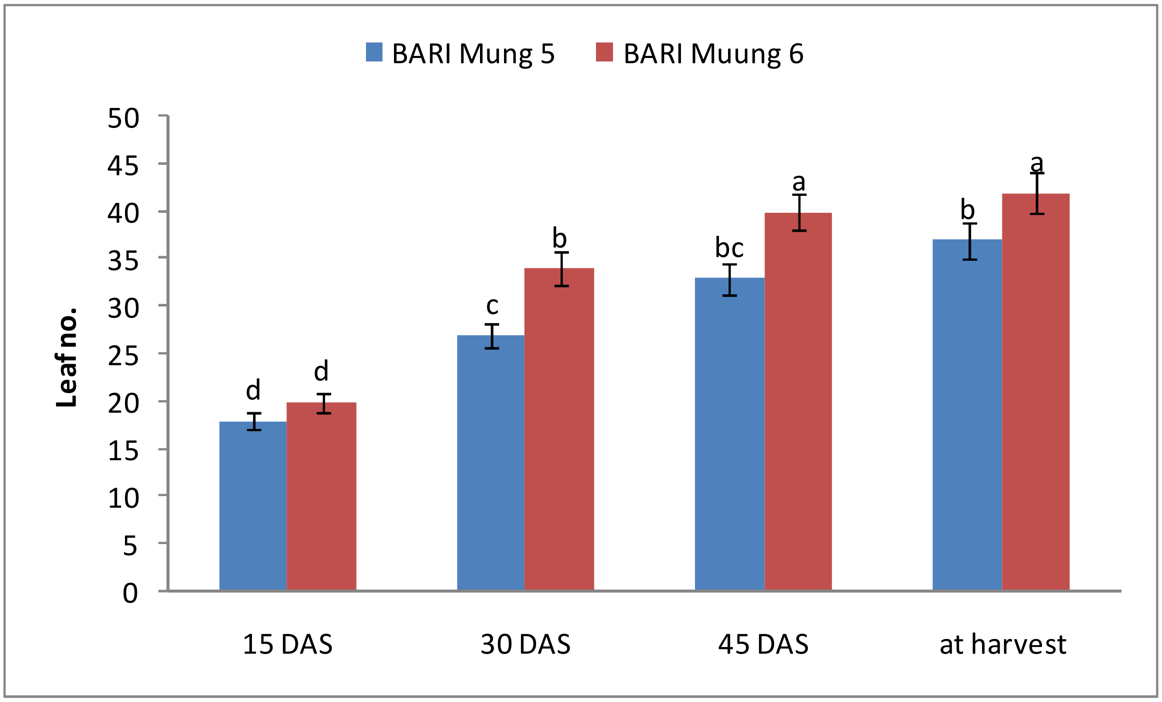

Figure 7: Effect of different varieties (BARI Mung 5and BARI Mung6) on no. of leaves/plant. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ by applying LSD test

4.6.2 Effect of salinity treatments

Number of leaves plant^{-1}of mungbean at 15, 30, 45 DAS and at harvest showed significant variation for different levels of salinity. Maximum no. of leaves plant^{-1}was found from T_0at harvest stage which was statistically similar to 45 DAS old seedlings. With the increasing salinity, no. of leaves plant^{-1} decreased significantly (Figure 8).

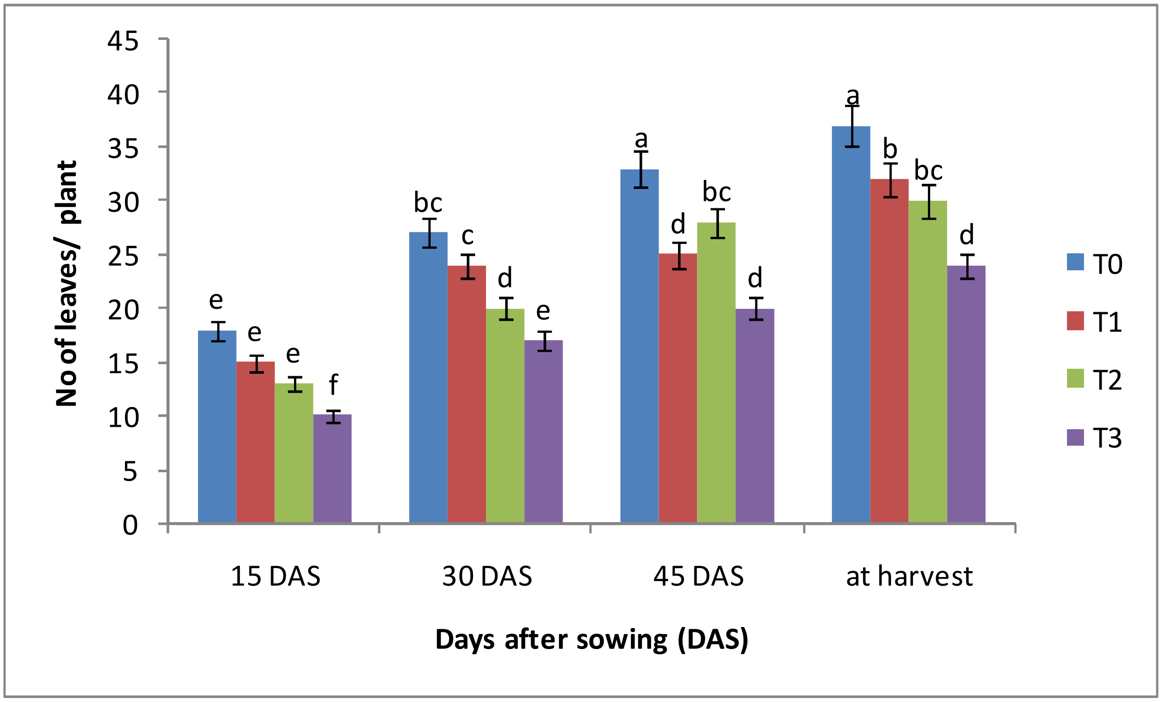

Figure 8: Effect of salinity on no. of leaves/plantof BARI Mung 5and BARI Mung6. Mean (SD) was calculated from three replicates for each treatment. Bars with different letters are significantly different at P ≤ 0.05 by applying LSD test

*T_0: 0 (control), T_1: 50 mM salt, T_2: 75 mM salt, T_3: 150 mM salt

4.6.3: Interaction effect of variety and salinity treatments

Number of leaves plant^{-1} of mungbean at 15, 30, 45 DAS and at harvest showed significant variation for different levels of salinity. At 15, 30, 45 DAS and at harvest, the maximum number of leaves plant^{-1} was found from V_1T_0 and V_2T_0, and these two treatments showed statistically similar to V_1T_1, $V_1T_{2,}$ V_2T_1 and V_2T_2. At 30 DAS sampling date, the treatment combination V_1T_1 showed statistically similar no. of leaves with V_1T_0 and V_2T_0 combination On the other hand, the minimum number of leaves plant^{-1}was observed from $V_1T_4$and V_2T_4 (Table 3). Amira and Abdul (2010) reported that growth parameters were significantly reduced with high salinity level.

The decrease of leaf numbers may be due to the accumulation of sodium chloride in the cell walls and cytoplasm of the older leaves. At the same time, their vacuole sap cannot accumulate more salt and, thereby decreases the concentration of salt inside the cells, which ultimately leads to their quick death and cut down (Munns, 2002).

Table 3. Interaction effect of different varieties and salinity levels on number of leaves/ plant ofmungbean

Treatments	Number of leaves plant^{-1} at			
	15 DAS	**30 DAS**	**45 DAS**	**Harvest**
V_1T_0	10.5 b	28.50 a	34.00 b	41.00 a
V_1T_1	8.00 bc	25.70 ab	33.00 b	38.70 b
V_1T_2	8.00 bc	21.00 c	30.7 c	33.00 bc
V_1T_3	5.30 d	21.20 c	26.20 cd	29.00 c
V_2T_0	12.20 a	30.10 a	39.33 a	41.00 a
V_2T_1	10.10 b	26.00 bc	36.33 bc	35.00 bc
V_2T_2	7.3 b-d	26.00 bc	33.10 bc	34.33 cd
V_2T_3	6.40 d	19.10 d	26.40 d	29.33 d
LSD(0.05)	**1.259**	**2.791**	**3.806**	**3.152**
CV(%)	**5.94**	**7.67**	**8.10**	**5.88**

Where, V_1: BARI Mung-5 T_0: 0 (control)

V_2: BARI Mung-6 T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

4.7 Pods/ plant

Reproductive growth of mungbean was also affected by different variety and salinity as the number of pod per plant, pod length and seed per pod substantially decreased with the increasing salinity levels.

4.7.1 Effect of variety

Experimental data showed that there have statistically no significant differences between two varieties.The higher number of pods plant^{-1} (10.05) was recorded from V_2 which was statistically similar (9.590) to V_1(Table 4).

4.7.2 Effect of salinity levels

In case of different salinity levels number of pods plant^{-1} of mungbean showed statistically significant variation. The highest number of pods plant^{-1} (8.50) was found from T_0. The lowest number (4.03) was observed from T_3. Treatments T_1 and T_2showed no significant differences in case of number of pods plant^{-1}(Table 4).

4.7.3 Interaction effect of variety and salinity treatments

In case of interaction effect,V_1T_0 and V_2T_0 treament combinations showed higher pods per plant. number of pods plant^{-1}decreased with increased salinity level. The lowest pod per plant were observed in V_1T_3 treatment (Table 4). Earlier study also shown similar trend. Ahmed (2009)in chickpea andRaptan (2001) in mungbean. They observed that increasing salinity significantly reduced pods per plant.

4.8 Pods length

4.8.1 Effect of variety

In terms of pod length varieties of mungbean varied significantly. The higher pod length (10.05 cm) was recorded from V_2, while the lower pod length (7.79 cm) was recorded from V_1 (Table 4).

4.8.2 Effect of salinity levels

There have significant differences upon exposure to salinity in terms of pod length. The highest pod length (8.50 cm) was found from T_0 while the lowest pod length (5.75 cm) was observed from T_3. Treatments T_1 and T_2 showed statistically similar results (Table 4).

4.8.3 Interaction effect of variety and salinity treatments

In case of interaction effect, pods length found to decrease significantly with increasing salinity levels. The higher pod length was observed inV_1T_0, and V_2T_0treatment while lower pod length was recorded in $V_1T_3$and V_2T_3 (Table 4).

4.9 Seeds/ pod

4.9.1 Effect of variety

There have no significant differences among varieties in respect of Seeds/ pod attribute. The higher number of seeds pod^{-1} (11.5) was recorded from V_2 which was followed (10.3) by V_1(Table 4).

4.9.2 Effect of salinity levels

Number of seeds pod^{-1} of mungbean showed significant variation for different levels of salinity. The highest number of seeds pod^{-1} (10.20) was found from T_0 which was statistically closely followed by T_1(7.50). The lowest number (5.70) was observed from T_3(Table 4). Higher saltinity level showed significant differences in case of seeds/ pod attribute.

4.9.3 Interaction effect of variety and salinity treatments

Statistically significant variation was recorded in terms of number of seeds pod^{-1} due to the interaction effect of mungbean varieties and levels of salinity. The highest number of seeds pod^{-1}(10.67) was recorded fromV_2T_0while the lowest number (3.26) was recorded from V_1T_3 treatment combination (Table 4)**.**

One of the attributes for reduced yield may be a reduction in pod and seed production by the plant. The pods/ plant, pods length, and seeds/ pod of mungbeancrops is adversely affected under salt stress (Sarin*et al.*, 1975). Gill (1979) reported similar result of effect of soil salinity on yield in barley. Furthermore, mungbean under present investigation differed widely in yield and its component attributes under normal as well as under saline conditions. This may ultimately lead to reduce seed yield under salinity and consequent lower economic yield.

Table 4. Effect of different varieties, salinity level and interaction effect on pod/ plant, pod length, seeds/ pod ofmungbean

Treatments	Pod/ plant (no)	Pod length (cm)	Seeds/ pod (no.)
Variety			
V_1	9.9 a	7.79 b	10.3 a
V_2	10.05 a	10.05 a	11.5 a
LSD(0.05)	1.788	1.741	0. 641
Salinity level			
T_0	10.25 a	8.50 a	10.20 a
T_1	7.50 b	5.75 b	7.50 a
T_2	6.50 b	5.10 b	5.61 b
T_3	4.00 c	4.03 c	4.50 b
LSD(0.05)	3.798	1.636	1.983
Interaction between varieties and salinity levels			
V_1T_0	9.50 a	7.80 b	10.0 a
V_1T_1	6.90 a	5.30 c	6.71 a
V_1T_2	5.38 b	5.00 c	5.29 b
V_1T_3	3.10 c	4.12 d	3.26 b
V_2T_0	11.0 a	9.50 a	10.67 a
V_2T_1	8.50 a	6.10 b	7.00 b

V_2T_2	7.34 b	5.4 bc	5.69 b
V_2T_3	5.0 bc	4.08 c	4.55c
LSD(0.05)	**1.783**	**2.504**	**0.584**
CV (%)	**21.52**	**13.31**	**17.64**

Where, V_1: BARI Mung-5 — T_0: 0 (control)

V_2: BARI Mung-6 — T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

4.10 Weight of 1000 seeds

4.10.1 Effect of variety

The experimentaldata showed significant differences among different mungbean variety.The highest weight of 1000 seeds (54.05 g) was recorded from V_2,while the lowest weight of 1000 seeds (48.11 g) was recorded from V_1(Table 5).

4.10.2 Effect of salinity levels

Significant variation was also found in respect of weight of 1000 seeds of mungbean under different levels of salinity. The highest weight of 1000 seeds (49.16 g) was found from T_0 which was statistically similar (49.17 g and 48.84 g) to T_1 and T_2 while the lowest weight of 1000 seeds (36.12 g) was observed from T_3 (Table 5).

4.10.3 Interaction effect of variety and salinity treatments

Statistically significant difference was also observed in case of interaction effect of different varieties and salt treatment in respect of 1000- seed weight (Table 4). Control treatments V_1T_0andV_2T_0showed higher 1000 seed weight where weight of 1000 seeds decreased significantly with increased salinity (Table 5).Similar trends was also observed by Hossain *et al.* (2008).

4.11 Seed yield plant^{-1}

4.11.1 Effect of variety

There have no significant differences betweenvariety in case of seed yield plant^{-1}. The highest seed yield plant^{-1} (8.95 g) was recorded from V_2,while the lowest Seed yield plant^{-1}(88.65 g) was recorded from V_1(Table 5).

4.11.2 Effect of salinity levels

Significant variation was found in respect of seed yield plant^{-1} of mungbean under different levels of salinity. The highest seed yield plant^{-1} (8.32 g) was found from T_0 which was statistically significant from (7.50 g and 6.23 g) to T_1 and T_2 while the lowest weight of 1000 seeds (3.53 g) was observed from T_3(Table 5).

4.11.3 Interaction effect of variety and salinity treatments

The interaction effect between mungbeanvarietiesand salt stress on seed yield/ plant was significant. Control treatments V_1T_0 and V_2T_0 showed the higher value over the salinity treated plants. The highest seed yield was observed in was observed $V_2T_0$and lowest seed yield was observed in V_1T_3(Table 5). Similar results was also observed by Naher*and Alam,* (2010).

4.12 Stover yield plant^{-1}

4.12.1 Effect of variety

There have statistically significant differences between two mungbean varieties. Higher Stover yield plant^{-1} (13.87g) was recorded from V_2 while the lowest Seed yield plant^{-1} (12.11 g) was recorded from V_1 (Table 5).

4.12.2 Effect of salinity levels

In terms of Stover yield plant^{-1} of mungbean under different levels of salinity, there have significant differences. The highest stover yield plant^{-1} (13.14 g) was found from T_0which was statistically similar to T_1 (11.10g). The lowest stover yield plant^{-1} (6.87 g) was observed from T_3 (Table 5).

4.11.3 Interaction effect of variety and salinity treatments

Significant variation was observed in the Interaction effect of variety and salinity treatments of two mungbean varieties in terms of stover yield. Stover yield was higher in V_2T_0over the all other treatments. With the increased salinity stover yield decreased and lower stover yield was found in V_1T_3 (Table 5).

4.13 Harvest index %

4.13.1 Effect of variety

Due to higher seed yield and stover yield, harvest index was significantly higher in V_2 (47.11%). Lower harvest index was recorded from V_1 (41.90%)(Table 5).

4.13.1 Effect of salinity levels

Harvest index of mungbean showed significant variation for different levels of salinity. The highest harvest index (45.22%) was found from T_0, which was statistically similar (40.45%) to T_1 and closely followed (36.51%) by T_2, while the lowest harvest index (34.81%) was observed from T_3 (Table 5).

4.13.3 Interaction effect of variety and salinity treatments

The interaction effect between salt stress and mungbean varieties on harvest index was significant. In following experiment highest harvest index was observed in V_2T_0while the lowest harvest index was observed in V_1T_3(Table 5). Increased salt concentration caused lower harvest index in the mungbean which is similar to earlier findings of Sadeghipour (2008).

Table 5. Effect of different varieties, salinity level and interaction effect onweight of 1000 seeds, seed yield, stover yield and harvest index of mungbean

Treatments	Weight of 1000-seeds (g)	Seed yield (g plant^{-1})	Stover yield (g plant^{-1})	Harvest Index (%)
Variety				
V_1	48.11 b	8.65 a	12.11 b	41.90 b
V_2	54.05 a	8.95 a	13.87 a	47.11 a
LSD(0.05)	1.82	2.120	1.315	1.50
Salinity level				
T_0	49.16 a	8.32 a	13.14 a	45.22 a
T_1	46.13 a	7.50 b	11.10 a	40.45 a
T_2	45.55 a	6.23 b	8.84 ab	36.51 ab
T_3	36.12 b	3.53 c	6.87 b	34.81 b
LSD(0.05)	2.220	0. 971	2.017	2.308
Interaction between varieties and salinity levels				
V_1T_0	49.10 ab	8.60 ab	12.11 b	41.52 b
V_1T_1	46.19 b	8.02 ab	10.23 bc	39.94 bc
V_1T_2	45.11 b	6.70 c	8.82 c	36.91 c
V_1T_3	38.97 c	3.11 e	5.31 d	33.93 d
V_2T_0	54.28 a	9.21 a	14.81 a	48.34 a
V_2T_1	51.21 ab	7.78 b	11.68 b	40.97 b
V_2T_2	48.09 ab	6.42 c	9.61 c	37.04 c
V_2T_3	42.17 bc	4.10 d	5.75 d	35.62 cd
LSD(0.05)	**2.898**	**0.833**	**1.207**	**3.843**
CV (%)	**5.66**	**8.82**	**6.92**	**6.79**

Where, V_1: BARI Mung-5 T_0: 0 (control)

V_2: BARI Mung-6 T_1: 50 mM salt

T_2: 75 mM salt

T_3: 150 mM salt

CHAPTER V
SUMMARY AND CONCLUSION

The experiment salinity based study onmungbean adaptable to salineagriculture in Bangladesh was conducted at the Agronomy Research Farm of Shere-Bangla Agricultural University (SAU), Dhaka during the period from August to November 2017. The experiment consisted of two factors: Factor A: Differentmungbean variety (2 varieties)- V_1: BARI Mung-5, V_2: BARI Mung-6, and Factor B: Different levels of salinity (4 levels)-T_0: 0mM (control), T_1: 50 mM, T_2: 75 mM, T_3: 150 mM.The twofactors experiment was laid out in CompletelyRandomized Design (CRD)with three replications.

In case of germination attributes like germination percentage, vigour index and coefficient of velocity were higher in BARI Mung 6 (94%) and lower in BARI Mung 5. In terms of interaction effect, higher germination percentage and vigour index was found in V_2T_0 and lower in V_1T_3 respectively. With the increase of salt concentration germination attributes decreased significantly.

Comapring between two varieties, there have no significant variance in respect of plant height.Interacting effect of mungbean varieties and level of salinity at 15, 30 and 45 DAS and at harvest the tallest plant was recorded (19.44 cm, 29.80 cm, 39.39 cm and 43.80 cm respectively) was recorded from $V_2T_0$and shortest plant was recorded (9.43 cm, 15.20cm, 22.66 cm, and 28.78 cm respectively) from $V_1T_{3.}$

The highest relative water content was recorded from BARI Mung 6at 15, 30 and 45 DAS which was statistically similar to BARI Mung 5. Higherrelative water content was recorded from control treatmentsV_1T_0 andV_2T_0in terms of interaction effect.

In case of variety, BARI Mung 6 (84.35%) recorded higher leaves/ plant compared to BARI Mung 5 (77.3%). In case of interaction effect, the maximum number of leaves/ plant was recorded from$V_2T_0$and lowest number recorded in V_1T_3.

In case of variety,the higher number of pods plant^{-1} (10.05), pod length (10.05 cm), seeds pod^{-1} (11.5) was recorded from V_2. In case of interaction effect, highest pod/ plant, pod length, and seeds/ pod (11 pod/ plant, 9.50 cm and 10.67 seeds/ pod respectively) was recorded from V_2T_0.

Interaction effect of different varieties of mungbeanand salinity levels on weight of 1000 seeds, seed yield, stover yield and harvest index was higher (54.28 gm, 9.21g plant^{-1}, 14.81 g plant^{-1}, and 48.34% respectively) in $V_2T_0$and lower in 38.97 gm, 3.11 g plant^{-1}5.31 g plant^{-1}, and 33.93% respectively.

From these experiment it's clearly found that BARI Mung6 is more salt stress tolerant than BARI Mung5. Considering the situation of the present experiment, further studies in the followingareas may be suggested:

I. Others mungbean varieties may be used for further study.

II. Another experiment may be carried out under other abiotic stresses and

III. BARI Mung6 can be used for further variety development against different abiotic stresses.

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APPENDICES

AppendixI. Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207

The map of Bangladesh showing experimental site

AppendixII: Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Characteristics	Value
Particle size analysis	
%Sand	27
%Silt	43
%Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

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

AppendixIII. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from September 2016 to November 2016

Months	**Air temperature** *		**Relative humidity*** **(%)**	**Total rainfall (mm)** *
	Maximum	**Minimum**		
September, 2016	32.10	20.88	58.18	1.56
October, 2016	29.36	19.21	54.3	0.63
November, 2016	25.17	18.46	64.02	0.10

Source:* Monthly average,

Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

AppendixIV. Analysis of variance of the data on plant height of mungbean as influenced by different variety and levels ofsalinity

Source of variation	Degrees of freedom (n-1)	Mean square			
		Plant height (cm) at			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	0.166	0.758	0.390	0.323
Treatments	7	3.554*	3.181*	7.254*	14.235*

** Significant at 0.01 level of probability;* Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on leaf number/ plant of mungbean as influenced by different variety and levels ofsalinity

Source of variation	Degrees of freedom (n-1)	Mean square			
		Leaf number/ Plant			
		15 DAS	30 DAS	45 DAS	At harvest
Replication	2	0.067	0.356	0.822	0.622
Treatments	7	1.350*	10.328**	25.561**	13.539**

** Significant at 0.01 level of probability;* Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the dataon number of pods plant^{-1}, number of seedspod^{-1} and pod length of mungbean as influenced by different variety and levels of salinity

Source of variation	Degrees of freedom (n-1)	Mean square		
		No. of pods/ plant	No. of seeds/ pod	Pod length
Replication	2	0.122	0.044	0.043
Treatments	7	4.784**	1.161**	1.583**

** Significant at 0.01 level of probability;* Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on weight of 1000 seeds, seed yield, stover yield and harvest index ofmungbean as influenced by different variety and levels of salinity

Source of variation	Degrees of freedom (n-1)	Mean square			
		weight of 1000 seeds	seed yield	stover yield	harvest index (%)
Replication	2	0.122	0.044	0.043	0.762
Treatments	7	4.784**	1.161**	1.583**	32.963**

** Significant at 0.01 level of probability;* Significant at 0.05 level of probability