SALINITY EFFECT ON GERMINATION, GROWTH AND YIELD PERFORMANCE OF MUNGBEAN (*Vigna radiata* L.)

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CERTIFICATE

*This is to certify that the thesis entitle, "*SALINITY EFFECT ON GERMINATION, GROWTH AND YIELD PERFORMANCE OF MUNGBEAN *(Vigna* radiata*)."submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of bona fide research work carried out by* ***U.S.M. REZOWANA MASUD*** *Registration No.* ***12-04833*** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
Dhaka, Bangladesh

Dr. Nazmun Naher
Professor
Supervisor

Dedicated to

My Beloved Parents

And Family

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ABSTRACT

Salinity is a major abiotic stress limiting mungbean production worldwide including Bangladesh. Since mungbean plant is very sensitive to salt condition, selection of salinity tolerant genotypes becomes important for mungbean improvement. The objective of this study was to evaluate the tolerance of seven mungbean varieties (BARI mung 1, BARI mung 2, BARI mung 4, BARI mung 5, BARI mung 6, BARI mung 7, BARI mung 8) and three germplasms (BMS I, BMS II, BMS III) to salinity at seedling stage under different levels. The pot experiment was conducted at Sher-e-Bangla Agricultural University during September 2017 to December 2017 by RCBD design with 3 salinity levels and 3 replications. The germination test was done at BARI lab by CRD design with 4 salinity treatments and 3 replications. Germination percentage (%) was decreased with the increasing of salinity level in all varieties. BARI Mung 6 gave the tallest (36cm) plant at control while it was 31.16 cm at 8 dS/m salinity level. Like plant height all the other parameters *i.e.* no of branch/plant, no. of leaf, chlorophyll content etc. were also decreased with increasing level of salinity. Maximum number of pods per plant was obtained at control in BMS I (15.02) and decreased in higher salinity. BMS I (9.55) had the highest no. of seed/pod at control and it was decreased to 7.55 at 8 dS/m salinity level. Weight of pod/plant was (22.80g) highest in BMS I among the varieties. Yield contributing characters *i.e.* no of pod/plant, pod length (cm), weight of pod/plant (g), individual pod weight (g), 1000 seed weight (g) etc. were also decreased with the increasing salinity level.

ACRONYMS

% = Percent
^{0}C =Degree Celsius
AEZ =Agro Ecological Zone
AIS =Agriculture Information Service
ANOVA =Analysis of Variance
BARI =Bangladesh Agricultural Research Institute
BBS = Bangladesh Bureau of Statistics
cm =centimeter
cm^2 =Centimeter square
CV =Co-efficient of Variation
DAE =Department of Agricultural Extension
dS/m =deci Siemens per meter
DW =Dry weight
EC =Electrical conductivity
e.g. =For example
et al. =And others
FAO =Food and Agriculture Organization
FAOSTAT =Food and Agriculture Organization Statistics
FW =Fresh weight
g =Gram
K =Potassium
Kg =Kilogram
LSD =Least Significant Difference
m =Metre
mg =Miligram
Mg =Magnesium
mm =Milimeter
mM =Mili mole
m mhos/cm =Milimohos per centimeter
MoA =Ministry of Agriculture
N =North
Na =Sodium
no. =Number
S =South
SAU =Sher-e-Bangla Agricultural University
SI =Serial
viz. =Namely

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CHAPTER I

INTRODUCTION

Salinity is a significant problem affecting agriculture worldwide, including Bangladesh, resulting in substantial losses in crop yield. In Bangladesh, over 30% of the net cultivable areas lie in the coastal area, which approximately 53% are affected by varying degrees of salinity (Haque, 2006). The severity of salinity of this area increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth and reduces yield and in severe cases, total yield is lost. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increasing production of crops.

Bangladesh has 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with EC (Electrical Conductivity) values ranging between 4 and 16 dS/m (Zaman and Bakri, 2003). Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen, 2001). Salinity problems resulting from seawater intrusion are more acute and lands are commonly left fallow as crop production is restricted by the presence of salts in the month of March and April (Mondol, 1997). So, selection of crop or a variety of a crop for saline area considered as an important management option to minimize yield loss due to salinity.

The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman rice. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001). During rabi season large area remain fallow due to lack of irrigation water and higher level of salinity. Again the coastal belts remain inundated with range of 60 cm to 80 cm from May to September limiting the cultivation of crops except some local rice varieties, covering 60% of total cultivated land (Karim *et al.,* 1998).

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. Like other legumes, mungbean fixes atmospheric nitrogen (58–109 kg/ha) in symbiosis with *Rhizobium* which not only meet its own nitrogen need, but also benefits following crops (Ali and Gupta, 2012).

Mungbean (*Vigna radiata* L. Wilczek) is an important eco-friendly short term leguminous crop of dry land agriculture. It is one of the most important pulse crops in Bangladesh belonging to the family Fabaceae. Mungbean is cultivated on over 6 million ha in the warmer regions of the world and is one of the most important pulse crops. It is a short duration (65–90 days) grain legume having wide adaptability and low input requirements (Nair *et al*., 2012). Its edible grain is characterized by good digestibility, flavor, high protein content and absence of any flatulence effects (Ahmed *et al*., 2008). Mungbean grain contains 51% carbohydrate, 26% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981 and Kaul, 1982).

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). Recently, Sehrawat *et al*. (2013a) reviewed that mungbean also encounters the cumulative adverse effects of other environmental factors as insects, pests, and high temperature, pod-shattering along with salinity causing high yield loss. It causes a variety of biochemical, physiological and metabolic changes (Xiong and Zhu, 2002), which may result in oxidative stress and affect plant metabolism, performance and thereby the yield (Shafi *et al*., 2009).

Salinity stress during the entire life cycle of the crop cause considerable yield losses in mungbean (Sunil *et al*., 2012). Salt stress at seedling stage reduces seed germination, fresh and dry biomass, shoot and root lengths, and seedling vigor of mungbean (Sehrawat *et al*., 2014; Dutta and Bera 2014 and Ghosh *et al*., 2015). At saline condition, the seed germination was significantly delayed and there were large differences among genotypes (Hetharie, 2008; Kandil *et al*., 2012, Taufiq *et al*., 2013; Sehrawat *et al*., 2014, El Kafafi *et al*., 2015 and Trustinah *et al*., 2016). Ahmed (2009) observed fewer grains per pod and lower grain weight under salinity stress in mungbean.

Saline condition may effects the Legume-Rhizobium symbiosis in nodulation because of its osmotic and ionic effects. The Salinity reduces the survival of rhizoidal inhibiting the infection process affecting nodule development and function or reducing plant growth (Singleton and Bohlool 1984). The effect of salinity on growth of Mungbean plants has been reported sporadically (Asraf and Rasul 1988; Raptan 2001; Islam 2001and Faruquei 2002). It is reported that salinity reduces nitrogen fixation (Hafeez *et al*. 1988 and Idris *et al.* 1990). NaCl stress had more deleterious effect on roots than shoots, with a sudden dip in root growth associated traits (Friedman *et al*., 2006 and Saha *et al*., 2010).

Selection of salinity tolerant genotypes becomes important for mungbean improvement. The availability of saline-tolerant variety of mungbean is a cheaper and easier technology for farmers in order to anticipate the expansion of the saline area. Salt tolerant mungbean crop may be an alternative for increasing production in these saline soils.

Keeping these considerations in view, the present study has aimed with the following objectives-

- To study the effect of salinity on mungbean during germination stage;
- To study the salinity effect on morphology and physiological parameters of mungbean and
- To observe the changes of yield of mungbean at different salinity level.

CHAPTER II

REVIEW OF LITERATURE

Salinity is one of the most severe environmental stresses which affect crop production. Mungbean is one of the most important pulse crop in Bangladesh and the growth are greatly influenced by salt stress. The aim of this chapter is to describe the review of the past research conducted in line of the major focus of the study.

2.1 Soil salinity

Soil salinity is the term used to designate a condition in which the soluble salt content of the soil reaches a level harmful to crops. Soil with an electrical conductivity of saturation extracts above 4 dS /m is called saline soil. It contains an excess of soluble salts, especially sodium chloride. Soil salinity is a major constraint of food production because it limits crop yield and restricts uses of uncultivated land (Flowers and Yeo, 1995).

Tanji (1990) said that soil salinity is the concentration of dissolved mineral salts present in water and soils on a unit basis or weight.

Flowers (2005) said that salinity can be termed as abiotic stress and comprises all the problems due to salts primarily by an abundance of sodium chloride (NaCl) from irrigation or natural accumulation.

2.2 Soil salinity around the world and in Bangladesh

Soil salinity area is one of the various effects of the changing environment and is rapidly increasing. Around 930 million ha land is affected with salinity worldwide. The severity of the problem can be gauged from the fact that salinity has increased by 6% over the last 45 years, with 77 million ha land becoming saline. In the next 50 years, another 15 million ha is at a risk of becoming saline in Australia (Ghassemi *et al*., 1995 and Munns, 2002).

According to Bradbury and Ahmad (1990), one - third of the worlds land surface is arid or semi - arid, out of which one - half is estimated to be affected by salinity.

According to FAO (2010) the total world wide area of land affected by salinity is about 190 million ha.

Waisal (1972) reported that over four-fifth of the surface of our earth is covered with salt solution containing, among many other constituent approximately 0.5 M NaCl. Millions of hectares of land throughout the world are too saline to produce economic crops and more land is becoming non-productive each year because of salt accumulation. Common salts like carbonates, bicarbonates and sulphates of Na, K, Ca, and Mg are major problems in saline soil.

FAO (2015) reported that salt stress negatively influences 60 million hectares, or round about 20% of the total irrigated land area in the world. Yasin *et al.* (1998) reported that out of 16.2 m ha of land under irrigation, more than 40,000 ha of land is lost to crop production each year in Pakistan.

Bangladesh is highly vulnerable to sea level rise (Brammer *et al.*, 1993). Naher *et al.* (2011) reported that coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degree of salinity. The whole coast runs parallel to the Bay of Bengal, forming 710 km long coastline (CZP, 2005). The area lies at 0.9 to 2.1 meters above mean sea level (Iftekhar and Islam, 2004).

Soil resource development Institute (2000) showed that soil saline area in the country has increased to 1.02 million ha. Agricultural land used in these areas is very poor, which is roughly 50% of the country's average (Petersen and Shireen, 2001). In Bangladesh, coastal areas about 2.86 million ha covered by 30% of the total crop land of the country. Of this, nearly 1.056 million ha are affected by varying degrees of salinity (Karim *et al*., 1990).

The problems of salinization are increasing, either due to bad irrigation drainage or agriculture practices. Despite its relatively small area, irrigated land is estimated to produce one - third of the world food (Munns, 2002). Hasanuzzaman *et al.* (2013) reported that the arable land is continuously transforming into saline (1- 3% per year) either due to primary/natural salinity or secondary/irrigation-associated salinity, and is expected to increase up to 50% land loss by 2050.

According to SRDI (2010), in Bangladesh out of coastal cultivable saline area, about 328 (31%), 274 (26%) and 190 (18%) thousand hectares of land are affected by very slight (2.0-4.0 dS/ m), slight (4.1- 8.0 dS /m) and moderate salinity (8.1-12.0 dS/ m), respectively are scope to successfully crop production.

Table 1. Soil salinity class and area in coastal saline belt of Bangladesh

Land classification	Salinity (dS/m)	Saline area (1000' ha)
Non saline with some very slightly saline	S1 (2.0-4.0)	328
Very slightly saline with some slightly saline	S2 (4.1-8.0)	274
Slightly saline with some moderately saline	S3 (8.1-12)	190
Strongly saline with some moderately saline	S4(12.1-16.0)	162
Very strongly saline with some strongly saline	S5 (>16.0)	102

Source: SRDI, 2010

Salinity is expected to have devastating global effects resulting up to 50% land loss by 2050 as the arable land is continuously transforming into saline (1-3% per year) either due to natural salinity or induced by human in Bangladesh (Mahajan and Tuteja, 2005 and Hasanuzzaman *et al*., 2013).

In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001).

According to the coastal zone policy (CZPo, 2005) of the Government of Bangladesh, 19 districts out of 64 are in the coastal zone covering a total of 147 upazilas of the country. Central coastal zone extends from Feni river estuary to the eastern corner of the Sundarbans, covering Noakhali, Barisal, Bhola and Patuakhali districts. The zone receives a large volume of discharge from the Ganges-Bhrahmputra- Meghna river system, forming high volume of silty deposition. More than 70% of the sediment load of the region is silt; with an additional 10% sand (Allison *et al*., 2003)

Naher *et al*. (2011) found that the lands of coastal area become saline as it comes in contact with sea water by continuous inundation during high tides and ingress of sea water through cracks and sometimes cyclone induced storm surge. The severity of salinity is increasing in the coastal area during winter with the drying of soil.

Salinity causes unfavorable environment and hydrological situation that restrict normal crop production throughout the year. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0–8.4 (Haque, 2006 and Naher *et al*., 2011). Observations in the recent past indicated that due to increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted.

2.3. Fertility status of saline soils

Soil fertility is an important factor for crop production. In general the coastal regions of Bangladesh are quite low in soil fertility. Thus in addition to salinity, plant nutrients in soils affect plant growth.

Soil reaction values (pH) range from 6.0-8.4 with the exception of Chittagong and Patuakhali, where the pH values range from 5.0-7.8. The soils are in general poor in organic matter content with the excepton of Paikgachha upazila of Khulna district, where the top soils contain high organic matter (7%). The organic matter content of the top soils ranges from less than 1% to 1.5%. The low organic content in soils indicates poor physical condition of the coastal soils. The total N contents of the soils are generally low, mostly around 0.1%. The low N content may be attributed to low organic matter contents of most of the soils. Available P status of the soils ranges from 15-25 ppm. Some deficient P soils are also found in Chittagong, Barguna, Satkhira and Patuakhali districts. Widespread Zn and Cu deficiencies have been observed in the coastal regions (Karim *et al.,* 1990 and Naher *et al*., 2011).

2.4. Present scenario of pulse *i.e.* mungbean cultivation

Mungbean (*Vigna radiata* (L.) Wilczek) is an important diploid crop with 2n = 22 chromosomes. 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).

Rahim *et al*. (2010) reported that mungbean is an important leguminous crop mainly cultivated in tropical, subtropical and temperate zones of Asia including Bangladesh, India, Pakistan, Myanmar, Indonesia, Philippines, Sri Lanka, Nepal, China, Korea and Japan. Cultivation of the crop extends across wide range of latitudes (40° N or S) in regions with diurnal temperatures of growing season are > 20°C (Lawn and Ahn, 1985).

Mungbean is one of the important pulse crops in our country. The agro ecological condition of Bangladesh is quite favorable for growing the crop. The demand of grain legumes is increasing day by day in Bangladesh due to increase in consciousness of the nutrition of leguminous food among the common people (BBS, 2012).

According to Rahman and Ali (2007) 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. 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 mostly due to low yield (MoA, 2013).

According to AIS (2017), at present the total land area under pulse crops are 8,85,700 hectares of land and the total production of pulses in our country is 10,05,100 metric tons that is less than the country’s requirement. It also reported that the total mungbean cultivated area of Bangladesh is 2,05,700 ha that produced 2,25,500 tons mungbean in 2015-16 . It holds the 3rd in protein content and 4th in both acreage and production in Bangladesh (MoA, 2014).

2.5. Scocio economic importance of mungbean

Mungbean is an important eco-friendly short term leguminous crop of dry land agriculture. It contains minerals, proteins and also serves as a food filler, resistant starch and dietary fiber (BBS, 2010).

Islam (2001) stated that the cultivation of legume is elbowing to the problematic soils including saline soils as the demand of cereals is higher than pulses in Bangladesh. On the nutritional point of view, mungbean is one of the best among pulses (Khan, 1981). Being protein, mineral and vitamin rich source, it is a crucial ingredient in Bangladesh diets. It is widely used as "Dal" in the country like other pulses.

Mungbean is a summer pulse crop with short duration (70-90 days) and high nutritive value. The seeds contain 22-28 % protein 60-65 % carbohydrates, 1-1.5 % fat, 3.5-4.5 % fibers and 4.5-5.5 ash, it has many effective uses, green pods in cooking as peas, sprout rich in vitamins and amino acids.

Lawn (1985) said that this crop can be used for both seeds and forage since it can produce a large amount of biomass and then recover study was carried out to investigate the varietal after grazing to yield abundant seeds.

Mungbeans are a high source of nutrients like manganese, potassium, foliate, vitamin B etc. Pulse protein is rich in lysine that is deficient in rice. Its edible grain is characterized by good digestibility, flavor, high protein content and absence of any flatulence effects (Ahmed *et al*., 2008). Because of their high nutrient density, mungbeans can defend against several chronic, age-related diseases, including heart diseases**,** cancer**,** diabetes and obesity. It increases immunity and fight against harmful bacteria, viruses, colds, rashes, irritations and more.

El Khimsawy (1998) said that it can be used in broilers diets as a non-traditional feed. Ihsan *et al.* (2013) stated that mungbean contains very low levels of oligosaccharides (sugars influence flatulence), is a good protein source (~23%) with high digestibility and suitable as baby food. It is mostly used as food such as porridge, flour products, beverage products, cakes, noodles, sprouts and a small portion of fodder.

In the existing cropping systems mungbean fit well due to its short duration, low input, minimum care required. It has a symbiotic association with nitrogen-fixing rhizobia present in the root nodules, thus plants do not require external nitrogen sources. Somta and Srinives (2007) reported that the short life span and nitrogen fixing ability make mungbean a valuable crop in cropping systems and sustainable agriculture production.

Limpens and Bisseling (2003) reported that the symbiotic association of mungbean roots and Rhizobia reduces the cost for nitrogen fertilizers. Besides, the crops have the capability to enrich soils through nitrogen fixation (Sharma and Behera, 2009). In favorable condition mungbean can fix atmospheric nitrogen by symbiotic process with the help of microorganism, rhizobium. Legume plants secrets some substance probably lectin which attract root rhizobium and infected root to produce nodules. Mungbean can improve soil nitrogen status in cereal legume crop rotation.

2.6. Physiological mechanisms of salinity stress in plants

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, salinity 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. Plants under high saline unable take up adequate water for metabolic processes or maintain turgidity due to low osmotic potential. Naturally, salt-alkalinized soils are complex that include various ions creating soil-salt-alkalization complex (Läuchli and Lüttge, 2002).

Munns (2002) and Li *et al*. (2012*)* stated that differential response of plants to salt and alkali stresses are largely due to high-pH associated stress. Ge and Li (1990) stated that Salt stress generally involves osmotic stress and ion injury. Munns (2005) and Rozema and Flowers (2008) reported that Salinity stress involves changes in various physiological and metabolic processes, varies with stress severity and its duration and ultimately inhibits crop production .

Initially, soil salinity represses plant growth through osmotic stress, which is then followed by ion toxicity (Rahnama *et al.*, 2010 and James *et al*., 2011). During initial phases, the water absorption capacity of the root system decreases and water loss from leaves is accelerated due to osmotic stress, and therefore salinity stress is also considered hyper osmotic stress (Munns, 2005).

Munns and Tester (2008) and Pang *et al*. (2010) reported that osmotic stress at the initial stage causes various physiological changes, such as interruption of membranes, nutrient imbalance, impaired ability to detoxify reactive oxygen species (ROS), differences in antioxidant enzymes, and decreased photosynthetic activity. Plants develop various physiological and biochemical mechanisms to survive in soils with high salt concentration.

Reddy *et al.* (1992*)* and Roy *et al.* (2014) reported that principal mechanisms include, but are not limited to, ion transport, uptake and compartmentalization biosynthesis of osmo protectants and compatible solutes, activation and synthesis of antioxidant enzymes/ compounds, polyamines and hormonal modulation.

2.7. Effects of salinity on germination and seedling stage

More and Ghonikar (1984) determined that the critical level of salinity in irrigation water to cause injury to seed germination in mungbean was 3.5 m mhos/cm. Bewley and Black (1982) reported that soil salinity affects germination by either an osmotic stress or ion toxic effect.

Ayers (1952) and Naher *et al*. (2010) reported that 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. Most of the mungbean cultivars tolerate salt to an extent of 9–18 m mhos/cm than usual salt concentration of 5–6 m mhos/cm (at germination stage). Paliwal and Maliwal (1980) reported that mungbean seeds could tolerate 6 m mhos/cm salinity, compared to 3 m mhos/cm for black gram.

In one of the study (Phillips and Collins, 1979), callus from mungbean grown in sand culture with Hoagland's nutrient solution supplemented with 0–350 mol/m^3 NaCl, showed tolerance to salt as that of whole plant, suggesting mungbean appears to have salt tolerance at cellular level.

Roychoudhury and Ghosh (2013) studied the physiological and biochemical responses of *Vigna radiata* seedlings to varying concentrations of cadmium chloride ($CdCl_2$) and NaCl. Both chemicals enhanced seedling mortality, notably at higher concentrations. A decline in normal growth, germination percentage, inhibition in root and shoot length and decreased fresh and dry weights of seedlings was observed.

Mahdavi *et al*. (2007) was reported that, salinity stress conditions caused negative effects during germination stages in soy-bean. Hafeez *et al*. (1988) and Idris *et al*. (1990) reported that salinity reduces nitrogen fixation.

In a pot experiment (from Bangladesh), effect of salinity levels (e.g., 0, 0.1, 0.2, 0.3, and 0.4% of NaCl) on germination, growth and nodulation of mungbean varieties (BARI Mung 4, BARI Mung 5 and BARI Mung 6) were observed by Naher *et al*. (2010). Salinity affected germination and root elongation. Root growth was significantly reduced with higher salt and BARI Mung 4 showed better performance than other varieties. All showed similar performance in yield traits at higher NaCl levels. No effect on nodulation at a higher (0.4% NaCl) dose was seen in BARI Mung 5. Howevere reported nodules per plant decreased but not nodule size with increase in salinity.

Under salinity conditions depression of germination percentages is usually takes place by a combined effect of seed imbibitions capacity as a result of low osmotic potential of the soil solutions and specific ion effect (Hassen, 1999).

Increasing concentration of salts reduced the seed germination percentages and growth of many crops were reported by many authors (Kassray and Doering , 1989 ; Al-Zubaydi *et al.*, 1992 ; Nasir 2002 and Al - Seedi , 2004).

Mungbean shows completely inhibited seed germination in NaCl solution with osmotic potential of -1.5 MPa (Murillo-Amamdor *et al*., 2002b).

2.8. Effects of salinity on growth and physiology

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).

Recently, Sehrawat *et al.* (2013a) reviewed that mungbean also encounters the cumulative adverse effects of other environmental factors as insects, pests, high temperature, pod-shattering along with salinity causing high yield loss.

Singleton and Bohlool (1984) reported that the salinity reduces the survival of rhizoidal inhibiting the infection process affecting nodule development and function or reducing plant growth.

Elsheikh and Wood (1995) observed that growth and nodulation of soybean was adversely affected by salinity and nodulation was more sensitive than plant growth to salinity.

Mirza and Tariq (1992) reported that salinity decreased the number of nodule per plant but increased the size of nodule in *Sesbania sesbane.*

The effect of salinity on decreasing growth of Mungbean plants has been reported sporadically (Raptan, 2001; Islam, 2001and Faruquei, 2002).

In mungbean seedlings, high salt concentration causes increased H_2O_2 content in both roots and leaves, hence salts should be removed to ensure proper growth and development (Saha *et al*., 2010).

Misra *et al*. (1996) reported that both root and shoot lengths were reduced with increased NaCl concentration, but roots were more damaged, with an increase in number of lateral roots and increase in its thickness, compared to shoots.

Nandini and Subhendu (2002) stated that high salinity results in a decrease in total leaf area and stomatal opening when three species of *Vigna (V. radiata, V.mungo, and*

V. unguiculata) subjected to varied doses of NaCl (50, 75, 100, 125, and 150 mM), and reduction in chlorophyll content, sugar, starchand peroxidase enzyme activity were observed in shoots and roots by Arulbalachandran *et al.*, (2009). Germination %, seedling growth rate, RWC and photosynthesis decreased with increasing NaCl levels in all species. The growth decrease was higher in mungbean than in black gram and cowpea.

Rivera and Heras (1973) was found that the adverse relationship between salinity and growth, that high salinity affected the protein bonds of green pigments and caused a cute decrease on the chlorophyll content. Photosynthetic activity of mungbean is reduced due to reduced function of electron transport and instability of pigment protein complex (Promila and Kumar, 2000).

Parida *et al.* (2005) and Hajier *et al.* (2006) reported that salinity stress results in a clear stunting of plant growth, which results in a considerable decrease in fresh and dry weights of leaves, stems and roots. Increasing salinity is also accompanied by significant reductions in shoot weight, plant height and root length.

Wests and Francios (2004) reported that vegetative growth reduced 9.0% for each unit increase in electrical conductivity of in cowpea.Salinity Stress causes an imbalance in the uptake of mineral nutrients and their distribution within the plants (Grattan and Grieve, 1992 and Glenn *et al.*, 1999)

Singh *et al.*, (1993), reported that the effect of varying levels of soil sodicity on plant height and found that increasing soil sodicity decreased the plant height in lentil.

Chakrabarti and Mukherji (2002) reported that application of NaCl salinity (EC value 4 dSm^{-1}) resulted decrease in total leaf area in mungbean. Plants challenged with salinity display many visual signs of salt injury. Qualitative effects are symptomatic i.e. stunted growth (Srivastave & Jana, 1984), chlorosis of green parts (James, 1988; Pentalone *et al*., 1997 and Husain *et al*., 2003), leaf tip burning (Wahid *et al*., 1999b), scorch (Barroso and Alvarez, 1997) and necrosis of leaves (Volkumar *et al.*, 1998). Quantitative ones include reductions in dry mass, elongation and expansion growth of leaves (Neumann *et al*., 1988), tissue ionic and nutrient contents (Misra *et al.,* 2001) etc. Suppression in growth is usually ascribed to a reduced capacity of the green parts to photosynthesize under salinity (Morant-Manceau *et al.*, 2004), which, in addition to other factors, is more related to increased chlorophyll fluorescence (Murillo-Amamdor *et al*., 2002b) and changes in overall chlorophyll content (Zayed and Zeid 1997 and Husain *et al*., 2003). Appraisal of morphological and physiological criteria of salinity tolerance has proven beneficial in increasing our understanding of salt tolerance in many plant species (Wahid *et al*., 1999b; Murillo-Amamdor *et al*., 2002a and Morant-Manceau *et al*., 2004)

Salt stress alters the membrane properties leading to reduced uptake of various essential nutrients by the roots and transport to the shoots (Promila and Kumar, 2000; Lauchli and Luttge, 2002).

2.9. Effects of salinity on yield

Salinity stress causes a significant reduction in mungbean yield (Abd-Alla *et al.*, 1998 and Saha *et al.*, 2010) through decline in seed germination, root and shoot lengths, fresh mass and seedling vigor and varies with different genotypes (Promila and Kumar, 2000 and Misra and Dwivedi, 2004).

Keatinge (2011) reported that the productivity of mungbean crop is drastically reduced (>70% yield loss) due to salinity stress. It causes a variety of biochemical, physiological and metabolic changes (Xiong and Zhu, 2002), which may result in oxidative stress and affect plant metabolism, performance and thereby the yield (Shafi *et al*., 2009).

The problem of soil salinity which particularly appears in the course of irrigation , leading from seriously diminished yield to a complete loss of land suitability , has a major importance in many areas with arid and semi - arid climatic conditions (Doering *et al.*,1984)

Singh *et al*. (1989) reported that four mungbean cultivars in plots salinized with 2,4, and 6 dS/m gave average seed yield of 906, 504, and 370 kg/ha, respectively.

Salinity-induced reduction in yield was reported in many crops viz., wheat, barley, mungbean and cotton (Keating and Fisher, 1985). Mungbean showed decreased growth, photosynthesis and yield at a high salinity, but postponed pod ripening during the spring resulted in reduced pod shattering (Sehrawat *et al.*, 2013a, d).

Maas *et al*. (1986) exposed two sorghum cultivars to salinity and determined the reduction in dry matter and grain yield. Saline irrigation water applied to soybean significantly reduced the growth and yield, when grown on hill (Beecher, 1994).

Singh *et al*. (1989) reported that four *Vigna radiata* cultivars in plots salinized with 2, 4, and 6 dS/m gave average seed yields of 906, 504, and 370 kg / ha, respectively.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from September, 2017 to December, 2017 to study the effect of salt tolerance capability in mungbean (*Vigna radiata* L.) under salt stress. The materials and methods describes a short description of the experimental site, climatic condition of the culture room, experimental materials, treatments and design, methods of the study, data collection procedure and data analysis. The experiment was conducted at two phase *i.e*. (1). germination in the lab and (2). growth and yield in pot. The detailed materials and methods that were used to conduct the study are presented below under the following headings:

FIRST EXPERIMENT

The experiment was conducted at Pulse Research Centre (PRC) Lab, Bangladesh Agricultural Research Institute (BARI), Gazipur in room temperature on September, 2017. This experiment comprised of seven varieties and three germplasm of mungbean. Seeds of seven mungbean varieties (BARI Mung 1, BARI Mung 2, BARI Mung 4, BARI Mung 5, BARI Mung 6, BARI Mung 7, BARI Mung 8) and three germplasms (BMS I, BMS II, BMS III) were collected from PRC, Gazipur. Four doses of salinity namely control, 4, 8 and 12 dS/m were designated as T_0, T_1, T_2 and T_3 respectively. Experimentally NaCl is widely used for developing salinity and found most toxic and effective in screening technique among other salts used alone or in combination (Aslam *et al.,* 1993). Salt solution was prepared artificially by dissolving calculated amount of commercially available NaCl with tap water to make 40, 80 and 120 Mm NaCl solution. The electrical conductivity (EC) of the respective salt solutions was equivalent to 4, 8 and 12 dS/m (1 dS/M=10 mM NaCl) respectively and 0.30 dS/M for tap water (control). Fourty petridishes (Pyrex) (87 mm diameter, 15mm height) were thoroughly washed with distilled water, rinsed with de-ionized water and dried in an oven. Three layers of Whatman No.2 filter paper were placed in each petridish. These were divided into sub groups for the various salinity treatments. Ten seeds of each mungbean cultivars per treatment were placed in a petridish on filter paper at almost equal distances from each other. An equal volume of salt solution was added to the dishes to maintain the concentration of salt treatment constant. Ten ml of the appropriate solution were applied on alternate days to each petridish. The completely randomized design (CRD) with three replications was followed. Germination percentage and germination rate were determined. Seed germination was evaluated after every 12 hours. After 24 hours seeds had started to germinate (seeds were considered to be germinated with the emergence of the root tip). The germinating seeds were counted at regular intervals until the 6th day from the start of the experiment. Root length and shoot length were measured by slide calipers. A seed was considered germinated when both plumule and radical had emerged >2mm.

Data Collection:

$$\textbf{Germination percentage} = \frac{\text{Total no. of germinated seeds}}{\text{Total no. of germinated and non-germinated seeds}} \times 100$$

The rate of germination (estimated by using a modified Timson index of germination velocity) = $\sum G/t$,
Where G = % seed germination at 2 days interval, and t = germination period.

Shoot length (mm): Shoot length was measured from the shoot base to the tip of the shoot. This was measured at 6th day.

Root length (mm): Root length was measured from the root base to the tip of the shoot. This was measured at 6th day.

$$\textbf{Reduction of shoot length (\%)} = \frac{\text{Shoot length at non-saline} - \text{Shoot length at saline}}{\text{Shoot length at non-saline}} \times 100$$

$$\textbf{Reduction of root length (\%)} = \frac{\text{Root length at non-saline} - \text{Root length at saline}}{\text{Root length at non-saline}} \times 100$$

Root -shoot ratio: Ratio of root to shoot length.

Statistical analysis of data:

The recorded data were analyzed statistically as per the design used. The treatment means were compared by using DMRT/LSD at 5% level of probability following Gomez and Gomez (1984).

SECOND EXPERIMENT

Experimental site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from September 2017 to December 2017. The location of the experimental site was at 23°75′ N latitude and 90°34′ E longitudes with an elevation of 8.45 meter from sea level (Anon, 1989).

Climate

The experimental site was situated in subtropical climate zone, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The soil of the experimental site was collected from SAU field which was sandy loam. There was no rainfall during the experimental period. Rabi season is characterized by plenty of sunshine.

Collection of materials

This experiment comprised of two mungbean varieties and two germplasms (V_1 -BARI Mung 5, V_2 –BARI Mung 6, V_3 -BMS I, V_4 -BMS III) which were collected from Pulse Research Center, BARI, Gazipur. These four varieties were screened out from the first experiment.

Treatments of the experiment

The two factor experiment was conducted in pots. The experiment was conducted following Randomized Complete Block Design (RCBD) with three replications.

Factor A: Mungbean genotypes (two mungbean varieties and two germplasms)

V_1: BARI Mung 5,

V_2: BARI Mung 6,

V_3: BMS I

V_4: BMS III

Factor B: Three levels of salinity dSm^{-1} (deci siemens per meter),

T_0= Control (Tap water),

T_1= 4 dSm^{-1} and

T_2= 8 dSm^{-1}

So, there were 12 treatment combinations such as T_0V_1, T_0V_2, T_0V_3, T_0V_4, T_1V_1, T_1V_2, T_1V_3, T_1V_4, T_2V_1, T_2V_2, T_2V_3 and T_2V_4.

Pot preparation

Top soil was collected from experimental field and then pulverized. The inert materials, visible insects, pests and plant propagates were removed. Then the soil was dried thoroughly. Compost (1/4th of the soil volume) and 0.20 g Urea, 0.4 g TSP and 0.12g of MP per pot were incorporated uniformly into the soil. Clean and dried plastic pots of 10 liter size were used for each variety. Each pot was then filled with 8 kg previously prepared growth media (soil and cow dung mixture). Treatments were replicated three times. Salt solution was prepared to give the same concentration levels, and was added as irrigation water to plastic pots, in addition to distill water treatment was applied as a control. Ten seeds had chosen and sowed in each pot at a depth of 1 cm. Intercultural operation, weeding and other measures were taken when necessary.

Salinity development

Three salinity levels of 0 mM NaCl (Control), 40 mM NaCl (T_1), and 80 mM NaCl (T_2) were prepared artificially by dissolving calculated amount of commercially available sodium chloride in the water used for irrigation to impose salt stress. The control treatment (0 mM NaCl) was without sodium chloride. The EC of the respective salt solution was equivalent to 4 and 8 d S/m respectively and 0.3 d S/m for tap water(control). Pots were maintained at field capacity until seed sowing.

Plate1: Pot preparation

Plate 2. Preparation of salt solution in lab

Plate 3: Application of saline water in mungbean plant

Plate 4. Field visit of respected supervisor

Mungbean seedlings were subjected to salinity at vegetative stage after establishment (20 DAS) with sufficient quantities of salt solutions in the treated pot. Salt solutions were applied once in a week to impart salt stress. The plants provided with equal volume of water without NaCl were used as control (C).

Plant materials

Two mungbean varieties and two germplasm *i.e.* BARI Mung 5, BARI Mung 6, BMS I, and BMS III were compared under salt conditions with 3 replications, each pot consisted of 6 plants.

Plant sampling

Plant samples were collected from the pot at different stages of the crop. During the course of experiment 3 plants were sampled randomly from each pot for data collection. The plant samples then separated into stem, leaf and reproductive organs at harvest. After recording growth characters these samples were oven dried to a constant weight and the dry wt. of the different parts was recorded separately.

Data collection

Plant height

Plant height was recorded at two stages. Height was measured by scale. Plant height was measured from base to the tip of the plant. Height of 3 plants from each plot was recorded.

No. of leaves/plant

Numbers of leaves of 3 randomly selected plants were counted at vegetative and fruiting stage. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of 3 plants gave the number of leaves per plant

No. of branches/plant

Number of branches of 3 randomly selected plants were counted at vegetative and pod filling stage. Only the smallest young branches at the growing point of the plant were

Plate 5: Measurement of plant height

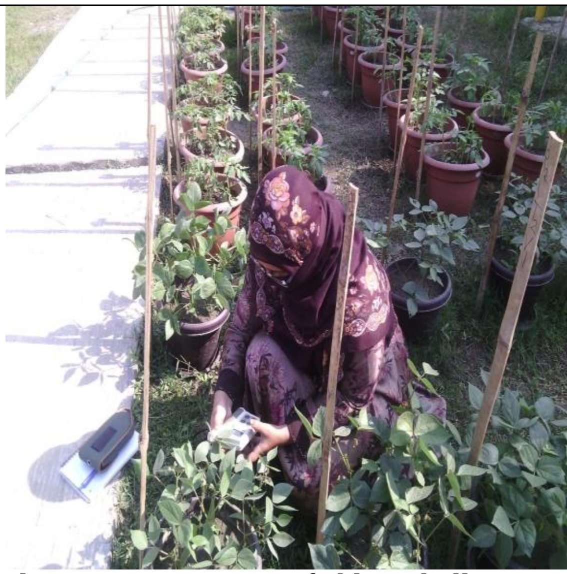


Plate 6: Measurement of chlorophyll content by using SPAD 502 chlorophyll meter

Plate 7: Measurement of EC of soil

Plate 8: Measurement of seed weight

excluded from counting. The average number of branches of 3 plants gave number of branches per plant.

Length and width of leaves (cm)

Three plants from each pot were randomly selected at vegetative and pod filling stage for collecting data on length and width of leaves. Length and width of leaves were measured by scale.

Chlorophyll content in leaf (SPAD Unit)

Chlorophyll content of leaf was measured by SPAD meter (SPAD 502 chlorophyll meter). Data was recorded from 3 leaves of each sampling plant and at three stages *i.e* vegetative stage, flowering stage and pod filling stage.

EC

Electrical conductivity (EC) of soil samples from the root zone was measured by using a conductivity meter (Field scout soil and water EC meter).

Total no. of pod/pot

Total number of pod in each pod was counted from the three replications. The numbers of total pod per pot were obtained from the average value.

No. of pod/plant

Number of pod per plant was counted from the three replications. The numbers of total pod per plant were obtained from the average value.

No. of seed per pod

Three pods were selected randomly for counting the no of seed and average value was taken for obtaining no. of seed per pod.

Pod length (cm)

Three pods were selected randomly from each replications and length was measured by a scale.

Pod breadth (cm)

Three pods were selected randomly from each replications and length was measured manually.

Fresh wt. of one pod (g)

Three pods were selected randomly from each treatment immediately after harvest. Then these were placed on the digital balance for the calculation of fresh weights.

Dry wt. of one pod (g)

Three pods were selected randomly from each treatments and were put into envelop and placed in oven and dried at 60°C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then final weight of the sample was taken.

1000 seed wt. (g.)

100 seeds were weighted by digital balance and it was converted into 1000 seed weight.

Wt. of pod/pot and wt. of pod/plant (g)

Total wt of pod/pot and pod/plant were taken by digital balance.

Statistical analysis

The data obtained for different parameters were statistically analyzed to observe the significant difference among the treatment. The mean value of all the parameters was calculated and analysis of variance was performed. The recorded data on different parameters were statistically analyzed by using SPSS version 16 software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by Dancan test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

In this experiment, efforts were made to find out the effect of salt stress on germination, growth and yield contributing parameters of four mungbean genotypes. Data on different parameters were analyzed statistically and the results have been presented in this chapter.

4.1. Effect of salinity on seed germination

4.1.1. Mean effects of salinity on germination percentage

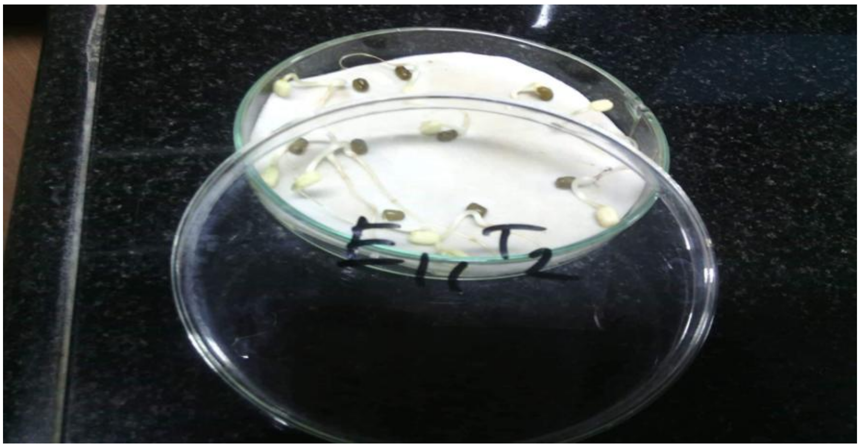
Figure (1) shows that the high germination percentage was recorded in distill water at a control treatment, whereas gradual decreases on the percentages of germination were noticed with the increase of salt concentrations at all treatments**.** From figure (1), it was observed that at control condition maximum varieties showed higher germination percentage except BARI Mung 4 (30%).

A decreasing trend was observed in all the varieties with the increasing of salinity. At 12 dS/m germination percentage were decreased significantly in all varieties. In BARI Mung 2 and BARI Mung 4 germination percentage was zero. That means no seed were germinated in these two varieties whereas BMS III had a germination percentage of 90% even in 12 dS/m salinity.

The results of decreasing germination percentage under salt stress are in agreement with Kannan *et al*. (2002). Germination reduction under salinity stress might be due to this fact that dormancy increases in crop seeds as well under salinity stress (Khajeh-Hoosseini *et al*., 2003). Seed germination may be affected by salinity through either creating external osmotic potential or toxic effect of Na^+ and Cl^- ions as reported by Yang *et al.* (2007) and Murillo-Amador *et al*. (2002). High accumulation of sodium and chloride ions produced an outside osmotic potential that avoids adequate water uptake or toxic effect of Na^+ and Cl^- ions in saline environment resulted in poor

Control

4 dS/m



8 dS/m

Plate 9. Germination of mungbean at different salinity level

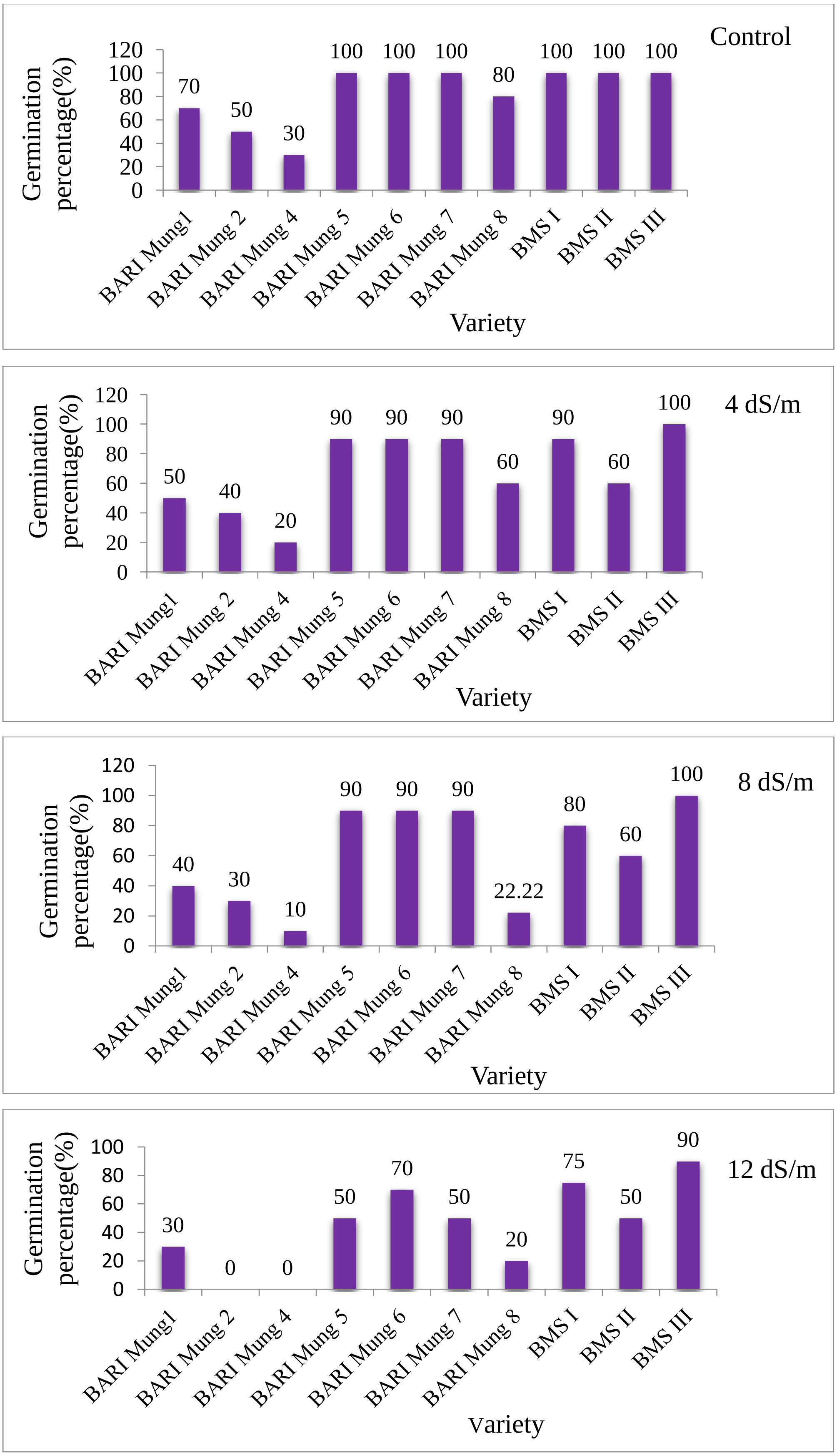


Figure 1. Effect of NaCl concentration on germination percentage (%) of ten mungbean varieties (CV - 3.68%)

activation of the hydrolytic enzymes and further reduced the seed germination (Murillo-Amador *et al*., 2002; Khajeh-Hoosseini *et al.*, 2003 and Mohammed 2007). Mudgal *et al*. (2010) reported that during germination under saline conditions, high osmotic pressure of saline water is created due to capillary rise leading to more salts density at seed depth than at lower soil profile, which reduces time and rate of germination.

4.1.2 Mean effects of salinity on root length

Root length is an important characteristic of plant. The highest root growth was found at control treatment which was followed by the higher concentration of salinity treatment. In control condition, root length ranged from 29.16 to 60.35 mm with an average of 41.46 mm. On the contrary, the ranges were 22.06 to 44.88 mm with an average of 32.30 mm in 4 dS/m salinity level. At 8 dS/m root length ranged from 15.35 to 34.29 mm with mean value 23.51 mm (Figure 2). No growth was found at 12 dS/m salinity level.

This result revealed that root length was gradually decreased with the increasing of salinity levels. This result is in agreement with the findings of Nag (2005) who reported significant reduction of root length of mustard and rapeseed genotypes with increase of salinity level.

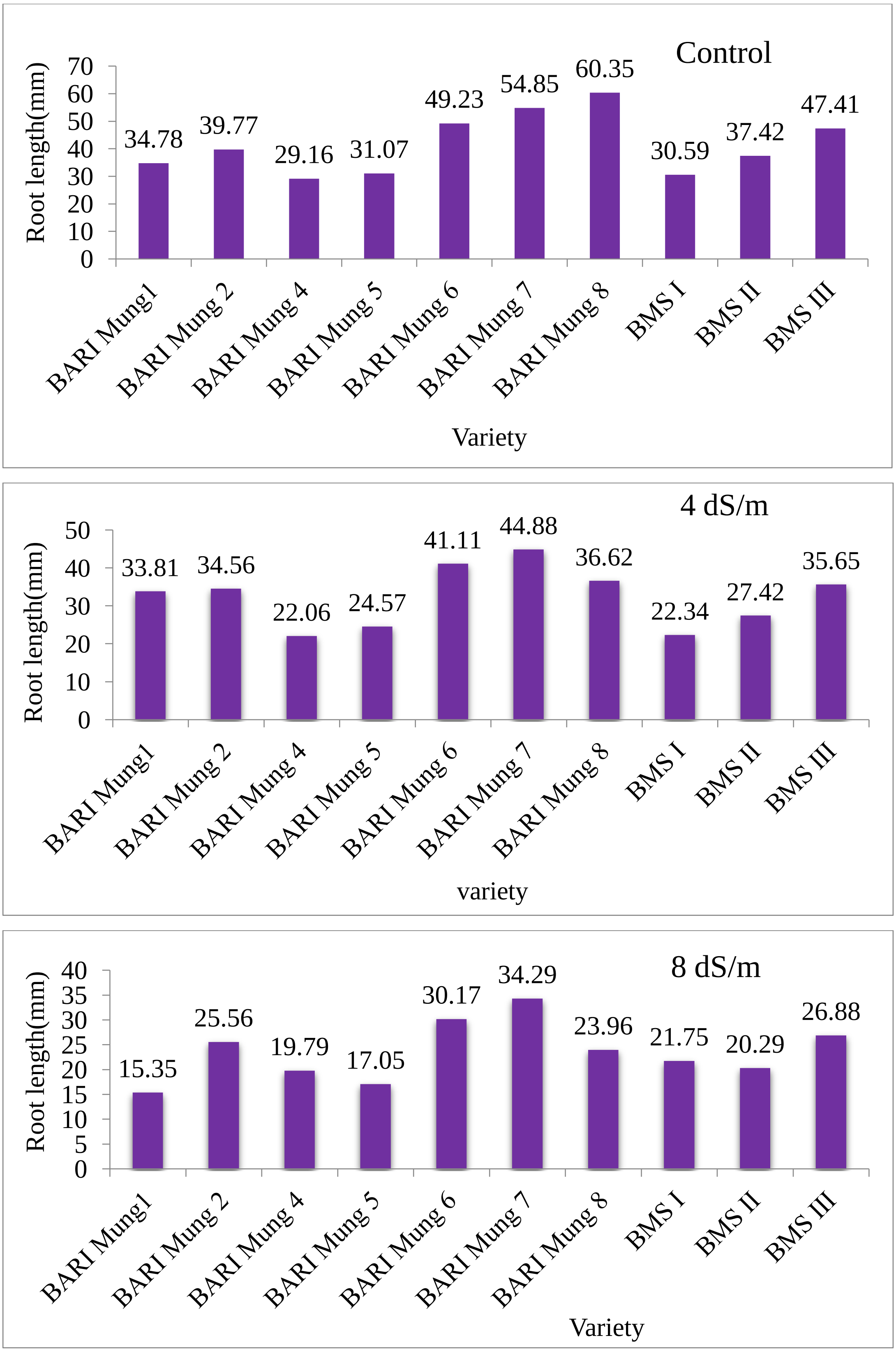


Figure 2. Root length (mm) of ten mungbean varieties at 6^{th} day at different salinity level (CV- 4.3%)

4.1.3. Mean effects of salinity on shoot length

Shoot length decreased significantly with increasing salinity levels from 0 to 4 and 8 dS/m. The highest root growth was found at control treatment. It was observed that shoot length ranged from 23.38 to 116.74 mm with a mean value of 81.07 mm at control condition. On the other hand, the ranges at 4 dS/m and 8 dS/m salinity level varied from 20.59 to 56.02 mm and 39.78 to 13.82 mm with the mean values of 36.87 mm and 26.56mm. At 12 dS/m salinity level, it was ranged from 0 to 9.12 mm with a mean value 5.03 mm.It suggests that shoot length decreased significantly with the increase of salinity level (Figure 3).

Significant decreases of shoot length in rapeseed and mustard with increase of salinity level was also reported by Nag (2005).Such reduction may be due to decrease water entry ratio into plant since under saline condition root pressure is reduced causing a decrease in water flow. That means less water is taken up by the roots and transported into shoots. Consequently, less water is available for normal growth and development (Satti and Lopez 1996).

Specific effect of salt stress due to particular ions toxicity to the crops and a general effect due to rise of osmotic pressure of the soil solution in and around the root regime of the crop. In the long run belonged transpiration brings about large amount of salt into the shoot, especially into the old leaves that level to senescence.

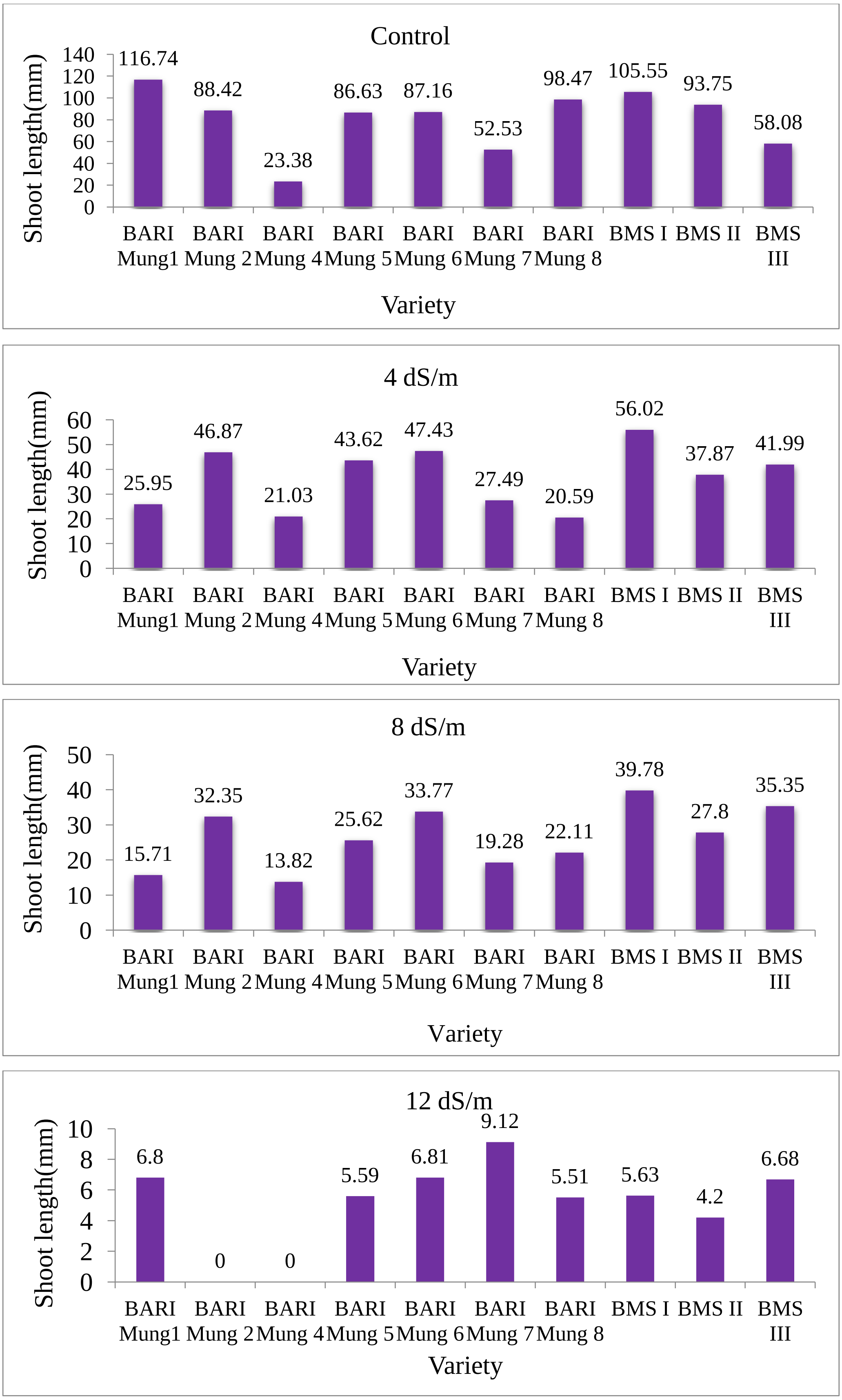


Figure 3. Shoot length (mm) of ten mungbean varieties at 6th days at different salinity level (CV – 4.68%)

4.1.4. Mean effects of salinity on reduction of root length

A significant differences on the reduction of root length between a control treatment and the salt treatments (4 and 8dS/m) were noticed. At 4 dS/m salinity level reduction of root length ranged from 4.85% to 52.73% and the average value was 21.8%. At 8 dS/m reduction of root length ranged from 22.61% to 73.29% with mean value 41.45% (Table 2). The result indicates that root reduction rate increased with the increase of salinity levels.

Table 2. Effect of various salinity levels on the percent reduction of root length of ten mungbean varieties

Mungbean Varieties	Salinity level	
	4 dS/m	8 dS/m
BARI Mung 1	4.85	36.00
BARI Mung 2	24.23	38.08
BARI Mung 4	24.35	32.13
BARI Mung 5	8.20	45.32
BARI Mung 6	14.69	42.00
BARI Mung 7	25.15	34.29
BARI Mung 8	52.73	73.29
BMS I	13.38	22.61
BMS II	26.78	45.82
BMS III	23.64	44.92
CV(%)	9.46	
SE(±)	1.74	

Salt stress caused low intra-cellular water potential and water scarcity around the root zone due to which roots failed to absorb sufficient water and nutrients for adequate plant growth (Mohammed, 2007; Sunil et al., 2012). A decrease in root and shoot growth under saline environment caused reduced total plant growth (Sehrawat *et al.*, 2013b; 2013c). Growth inhibition under salt stress may be due to the diversion of energy from growth to maintenance (Greenway and Gibbs, 2003).

4.1.5. Mean effects of salinity on reduction of shoot length

Significant variation among the varieties was observed in reduction of shoot length. From the table (3) it was observed that the reduction rate of shoot length ranged from 8.36 to 56.68% with mean value 35% at control. On the other hand, the ranges at 8 dS/m and 12 dS/m salinity level varied from 38.3 to 77.62% and 76.83 to 100% with the mean values of 57.06 % and 89.56% respectively. The result also indicates that shoot reduction rate increased with the increase of salinity levels.

Balasubramanian and Sinha (2006) reported that root growth was more sensitive to increase in salt stress both cowpea and mungbean. Both root and shoot lengths were reduced with increased NaCl concentration, but roots were more damaged, with an increase in number of lateral roots and increase in its thickness, compared to shoots (Misra *et al*., 1996).

Table 3. Effect of various salinity levels on the percent reduction of shoot length of ten mungbean varieties

Mungbean varieties	Salinity level		
	4 dS/m	8 dS/m	12 dS/m
BARI Mung 1	52.66	77.62	88.13
BARI Mung 2	38.21	61.26	100
BARI Mung 4	0	0	100
BARI Mung 5	35.74	59.77	88.59
BARI Mung 6	8.36	41.7	76.83
BARI Mung 7	49.59	67.23	86.42
BARI Mung 8	56.68	76.54	86.42
BMS I	25.83	39.64	89.71
BMS II	54.17	67.54	93.96
BMS III	18.69	38.3	85.31
CV(%)	5.99		
SE(±)	3.24		

The reduction in root and shoot development may be due to toxic effects of the NaCl used as well as unbalanced nutrient uptake by the seedlings. The water absorption capacity of the root system decreases and water loss from leaves is accelerated due to osmotic stress, and therefore salinity stress is also considered hyper osmotic stress (Munns, 2005).

High salinity may inhibit root and shoot elongation due to slowing down the water uptake by plant (Werner *et al*, 1995). There may be another reason for this decrease. Neumann indicated that salinity can rapidly inhibit root growth and hence capacity of water uptake and essential mineral nutrition from soil.

4.1.6. Mean effects of salinity on root - shoot ratio

Root - shoot ratio indicates the root and the shoot growth pattern of a crop. The high root shoot ratio means the higher root growth while the lower ratio means the higher shoot growth. The analyses of variance showed that the differences among the varieties were significant. Mean root - shoot ratio of the varieties was the highest at control (2.07) condition, 1.19 at 4 dS/m salinity and 1.12 at 8 dS/m. At control condition, root - shoot ratio of the varieties ranged 0.81 to 3.45. On the other hand, the ranges at 4 dS/m and 8 dS/m salinity level varied from 0.56 to 2.51 and 0.56 to 1.83 (Figure 4). The decreasing trend of the root - shoot ratio indicates the higher shoot growth than root growth.

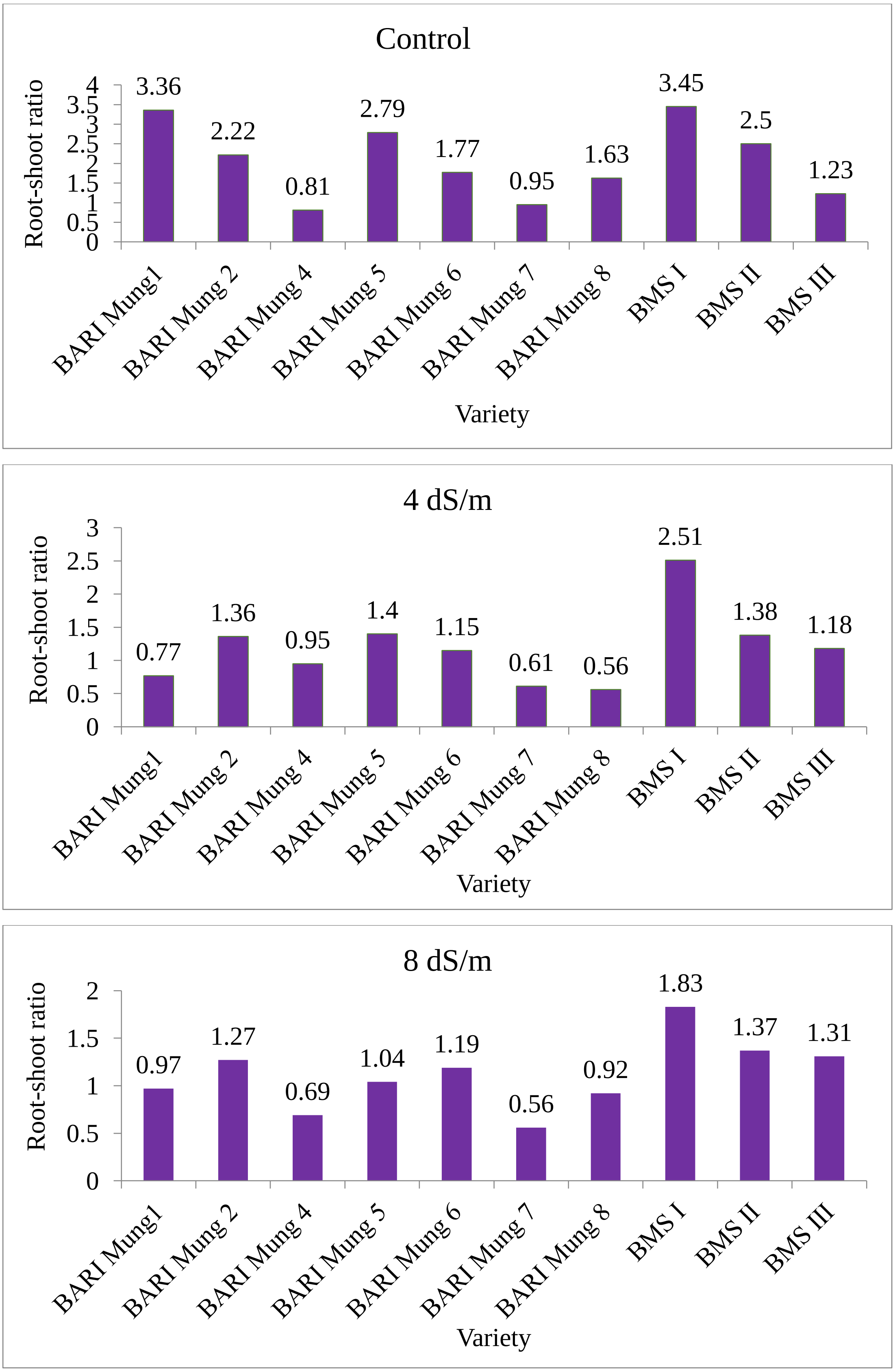


Figure 4. Root-shoot ratio of ten mungbean varieties at different salinity level (CV-10.27%)

4.2. Effect of salinity on growth and morphological / physiological chararteristics

The second experiment was conducted at SAU field to evaluate growth and yield performance. Mungbean genotypes were selected on the basis of germination percentage obtained from first experiment. Among the 10 genotypes, BMS III (90%), BMS I (75%) and BARI Mung 6 (70%) had higher germination percentage. BARI Mung 5 and BARI Mung 7 had same (50%) germination percentage but BARI Mung 5 showed better performance in terms of root and shoot growth. So BARI Mung 5 was selected between the two varieties.

4.2.1. Effect of salinity level on Plant height

Effects of salinity

Plant height is an important growth index of plant. The height of four mungbean plants was measured at different stage. The effect of salinity on plant height was statistically significant (P>0.05) at vegetative and fruiting stage (Figure 5). Plant height decreased with increasing of salinity at different levels of harvest. At vegetative stage the tallest plant (21.58 cm) was obtained from control followed by 4

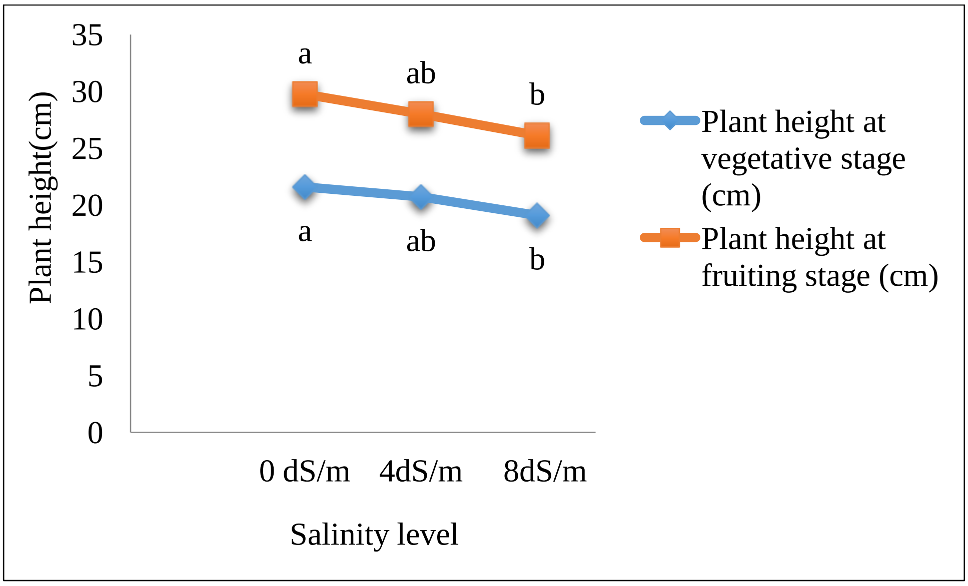


Figure 5. Effect of salinity level on plant height (cm) of mungbean genotype ($LSD_{(0.05)}$ -2.05 (vegetative stage) and 2.66 (fruiting stage).

dSm^{-1} salinity level. The shortest plant (19.08 cm) was recorded from the salinity at 8 dSm^{-1}. At fruiting stage the tallest plant (29.75cm) was obtained from control followed by 4 dSm^{-1}. The shortest plant (26.12 cm) was recorded from the salinity of 8 dS/m. The gradual decrease of plant height might be due to decrease nutrients availability caused by the increased salinity. Salinity had direct effect on plant height. Egeh and Zamora (1992) reported that plant height of mungbean genotypes were decreased by salinity.

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 6). At vegetative stage the highest plant height was recorded in BARI Mung 6 (24.06cm) and lowest was in BMS III (19.67 cm) followed by BARI Mung 5 and BMS III. At

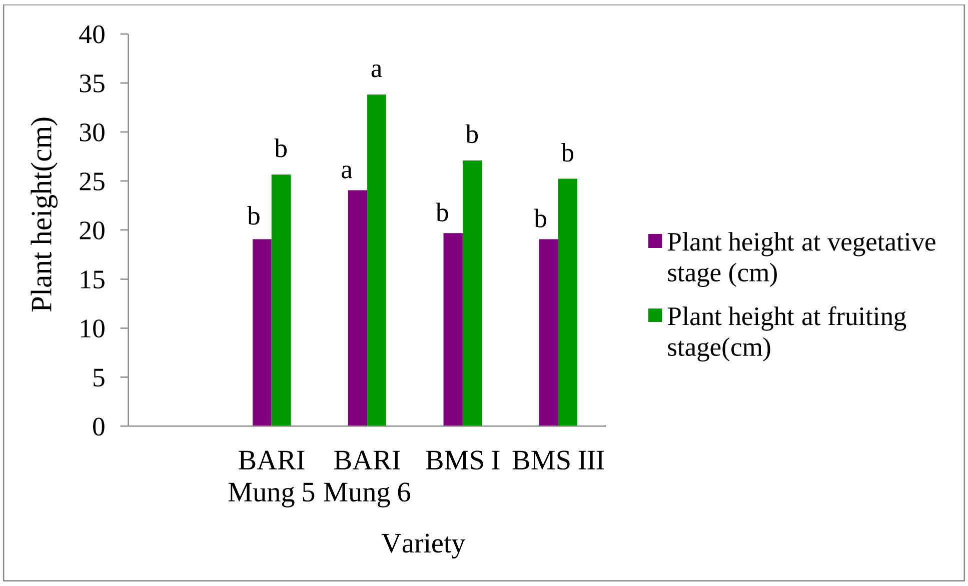


Figure 6. Varietal effect of saline on plant height (cm) [$LSD_{(0.05)}$ -2.26 (vegetative stage and 3.39 (fruiting stage)].

fruiting stage the highest plant height was recorded in BARI Mung 6 (33.83cm) and lowest was in BMS III (25.22 cm) followed by BARI Mung 5 and BMS I. The variation of plant height among the varieties might be due to different genetic makeup of the varieties.

Interaction effect of salinity level and genotype

The interaction effect on plant height between varieties and salinity levels was found significant. From the Table 4, it was observed that the tallest plant was found (36 cm) in BARI Mung 6 at control at fruiting stage and the shortest plant (18 cm) was found in BMS III at 8 d/Sm salinity level at vegetative stage.

In all the varieties, there were decreasing trend in plant height with increasing salinity levels. Similar trends were also reported by Hossain *et al*. (2008), Qados (2011) and Velmani *et al*. (2012) in *Vigna* spp and Bakht *et al* (2011) in *Zea mays*. Wests and Francios (2004) reported that vegetative growth reduced 9.0% for each unit increase in electrical conductivity of in cowpea.

Table 4**.** Interaction effect of salinity level and genotype on plant height (cm)

treatment	Plant height at vegetative stage (cm)	Plant height at fruiting stage (cm)
salinity ×Variety		
Control ×BARI Mung 5	19 bc	23.66 c-e
Control ×BARI Mung 6	26.5 a	36 a
Control ×BMS I	19.66 bc	26 c-e
Control ×BMS III	21.16 a-c	28 b-e
4 dS/m× BARI Mung 5	20.16 bc	30.33 a-d
4 dS/m× BARI Mung 6	24.66 ab	34.33 ab
4 dS/m× BMS I	20 bc	27 b-e
4 dS/m× BMS III	18 c	25.66 c-e
8 dS/m× BARI Mung 5	18 c	23 de
8 dS/m× BARI Mung 6	21 a-c	31.16 a-c
8 dS/m× BMS I	19.33 bc	28.33 a-e
8 dS/m× BMS III	18 c	22 e
SE(±)	1.6345	2.1139
$LSD_{(0.05)}$	5.94	7.69

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

These results suggested that vegetative growth of these species was the most sensitive to salinity compared to other growth stages. The reduction of the plant height due to reduction in intermodal distance with increased salinity may be a result of a combination of osmotic ion effects of Na and Cl (Zhu *et al.* 2001). Similar results were found by Singh *et al*. (1993). They reported that the effect of varying levels of soil salinity on plant height and found that increasing soil salinity decreased the plant height.

4.2.2. Effect of salinity level on number of branch

Effects of salinity

Data in Figure 7 indicated that the use of saline water for irrigation resulted significant effect in number of branches/plant. The number of branches decreased with increasing of salinity at different levels of harvest. At vegetative stage the highest number of branch (4.67) was obtained from control. The lowest number of branch (3.98) was recorded from the salinity at 8 dSm^{-1}. At fruiting stage the highest number of branch (5.99) was obtained from control. The lowest number of branch (5.29) was recorded at 8 dS/m the salinity.

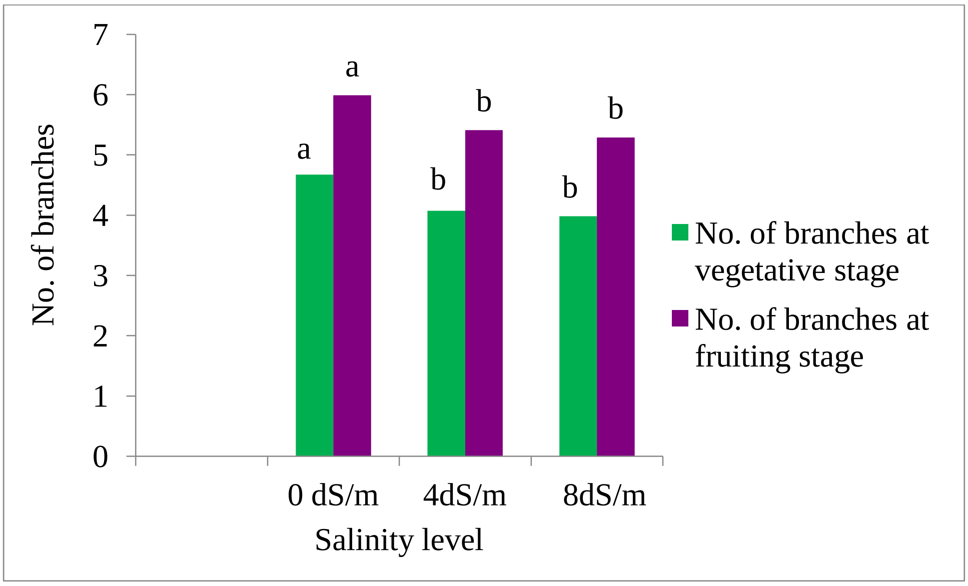


Figure 7. Effect of salinity level on number of branch of mungbean genotypes ($LSD_{(0.05)}$ -0.19 (vegetative stage), 0.49 (fruiting stage).

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 8). At vegetative stage the highest number of branches ware recorded in BMS I (5.55) and lowest was in BARI Mung 6 (3.53). At fruiting stage the highest number of branches ware recorded in BMS I (7.00) and lowest was in BARI Mung 6 (4.95) followed by BARI Mung 5 and BMS I.

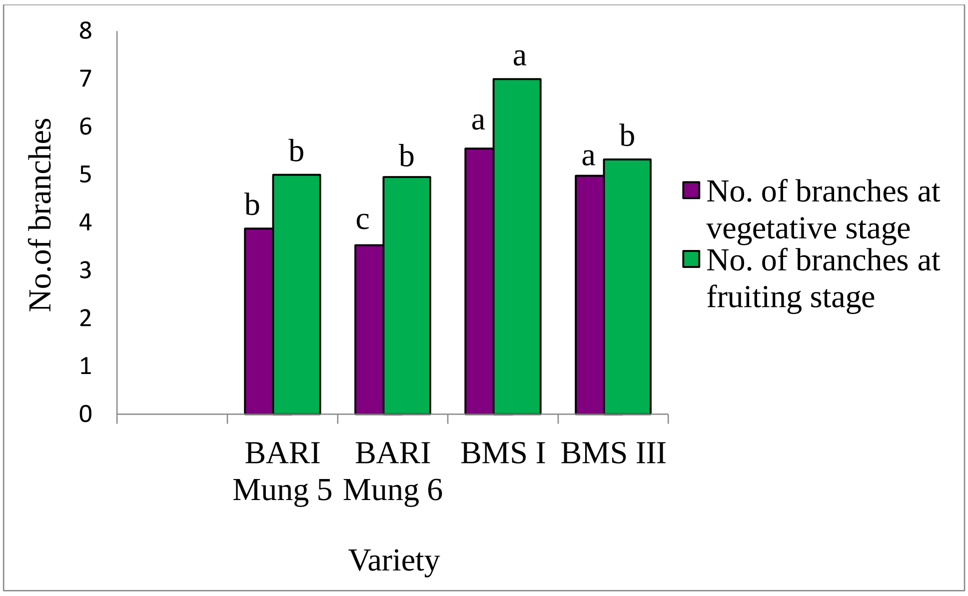


Figure 8. Varietal effect of saline on number of branch [$LSD_{(0.05)}$ -0.25 (vegetative stage) and 0.63 (fruiting stage)].

Interaction effect salt stress and genotype

The interaction effect on number of branch between varieties and salinity levels was found significant. From the Table 5, it was observed that the highest number of branch

Table 5. Interaction effects between salinity level and genotypes on number of branch

treatment	No. of branches at vegetative stage	No. of branches at fruiting stage
salinity ×Variety		
Control ×BARI Mung 5	4.66 c	5.66 b-d
Control ×BARI Mung 6	6.66 a	5.66 b-d
Control ×BMS I	5.66 b	8 a
Control ×BMS III	4.33 cd	5.63 b-c
4 dS/m× BARI Mung 5	4 d	5.33 c-e
4 dS/m× BARI Mung 6	3.3 e	4.33 de
4 dS/m× BMS I	4.33 cd	7 ab
4 dS/m× BMS III	4.3 cd	6 bc
8 dS/m× BARI Mung 5	3 e	4 e
8 dS/m× BARI Mung 6	3.3 e	4.83 c-e
8 dS/m× BMS I	4 d	6 bc
8 dS/m× BMS III	3.33 e	4.33 de
SE(±)	0.1584	0.3918
$LSD_{(0.05)}$	0.58	1.42

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

was found in BMS I (8) at control and the lowest number of branch was found in BARI Mung 5 (4) followed by BMS III at 8 dSm-1salinity level at fruiting stage. The number of branches plant^{-1} was higher in control condition that is decreased with imposing salt stress reported by Mohamed and Kramany (2005). These results are in line with those of Raptan *et al*. (2001).

4.2.3. Effect of salinity level on number of leaf

Effects of salinity

Salinity adversely affected the production of leaf number in mungbean plants. The influence of salt stress on the number of leaves plant^{-1} was significant (Figure 9) at vegetative and fruiting stage. At vegetative stage, the highest (14.09cm) number of leaves were found at control treatment and the lowest (12cm) one was found at highest salinity (8 dS m^{-1}). Similar decreased trend was also found at fruiting stage.

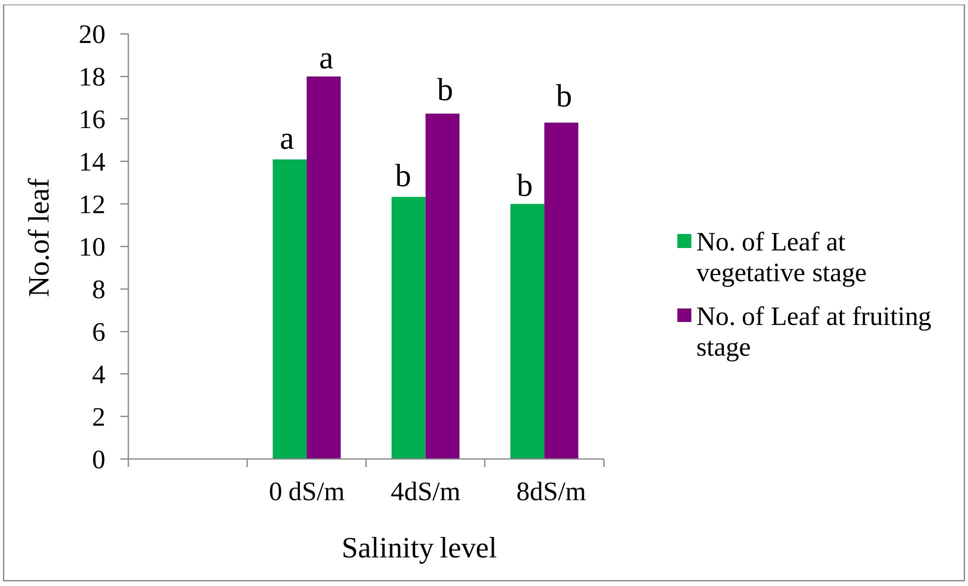


Figure 9. Effect of salinity level on number of leaf of mungbean genotypes [$LSD_{(0.05)}$ - 1.94 (vegetative stage), 0.64 (fruiting stage)].

This result showed that number of leaves plant^{-1} decreased gradually with increasing salinity in comparison to that control.

Effects on mungbean varieties

Among the genotypes, number of leaves plant^{-1} under different salinity stress was statistically significant (Figure 10) at vegetative and fruiting stage. At vegetative stage BMS I produced the maximum (16.78) number of leaves and BARI Mung 6 produced the lowest (10.67) leaf number followed by BMS III and BARI mug 5. At fruiting stage BMS I produced the maximum (21.11) number of leaves and BARI Mung 6 produced the lowest (14.67) leaf number followed by BMS III and BARI Mung 5.

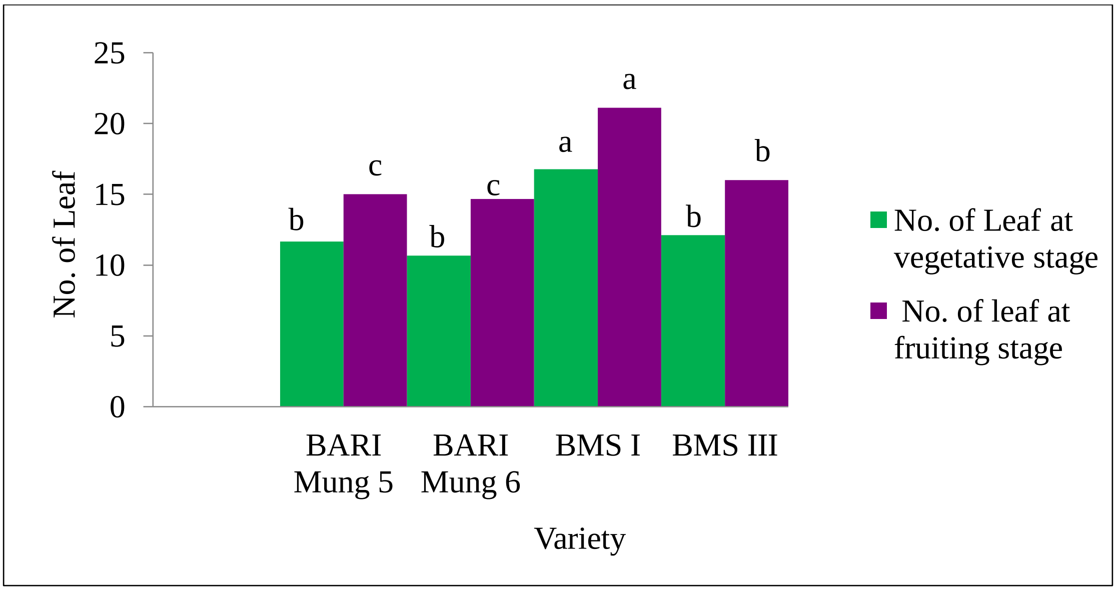


Figure 10. Varietal effect on number of leaf of four mungbean plants grown under different saline conditions [$LSD_{(0.05)}$ - 1.93 (vegetative stage), 0.81(fruiting stage)].

Interaction effect of salt stress and genotype

The interaction effect on number of leaf between varieties and salinity levels was found significant. From the Table 6, it was observed that the highest number of branch was found in BMS I (20.33) at control and the lowest number of branch was found in BARI Mung 5 (9) followed by BMS III at 8 dS/m salinity level at fruiting stage.

Reduction in no. of leaves per plant is a common phenomenon under salinity stress in various species (Zhu *et al*., 2001). Hassine and Lutts (2010) and Bakht *et al*. (2011) investigated the *Solanum tuberosum*, *Atriplex halimus* and *Zea mays*, respectively

Table 6. Interaction effect of salinity level and genotype on the number of leaf

treatment	No. of Leaf at vegetative stage	No. of Leaf at fruiting stage
Salinity ×Variety		
Control ×BARI Mung 5	14 bc	17 cd
Control ×BARI Mung 6	12 cd	17 cd
Control ×BMS I	20.33 a	24.33 a
Control ×BMS III	13.33 b-d	17 cd
4 dS/m× BARI Mung 5	12 cd	16 d
4 dS/m× BARI Mung 6	10 cd	13 ef
4 dS/m× BMS I	17 ab	18 c
4 dS/m× BMS III	13 b-d	18 c
8 dS/m× BARI Mung 5	9 d	12 f
8 dS/m× BARI Mung 6	10 cd	14 e
8 dS/m× BMS I	13 b-d	17 cd
8 dS/m× BMS III	10 cd	13 ef
SE(±)	1.2087	0.5063
$LSD_{(0.05)}$	4.39	1.84

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

under saline conitions and found a marked reduction in intermodal distance in response to salt stress. This reduction in intermodal distance and no of leaves may be due to the reduction in turgid potential, necessary for cell elongation (Iqbal and Ashraf, 2005) and turger pressure, which were reduced under salt stress(Ashraf and harris, 2004).

4.2.4. Effect of salinity level on leaf width

Effects of salinity

Leaf width was decreased with increasing levels of salinity. The leaf width was significantly affected by salt stress during both vegetative and fruiting stage given in Figure 11. At vegetative stage the highest leaf width (3.78cm) was obtained from control which was statistically similar to 4dS/m and lowest (2.54cm) was recorded from the salinity of 8 dS/m. At fruiting stage the highest leaf width (4.5cm) was obtained from control and lowest (3.96cm) was recorded from the salinity of 8 dS/m.

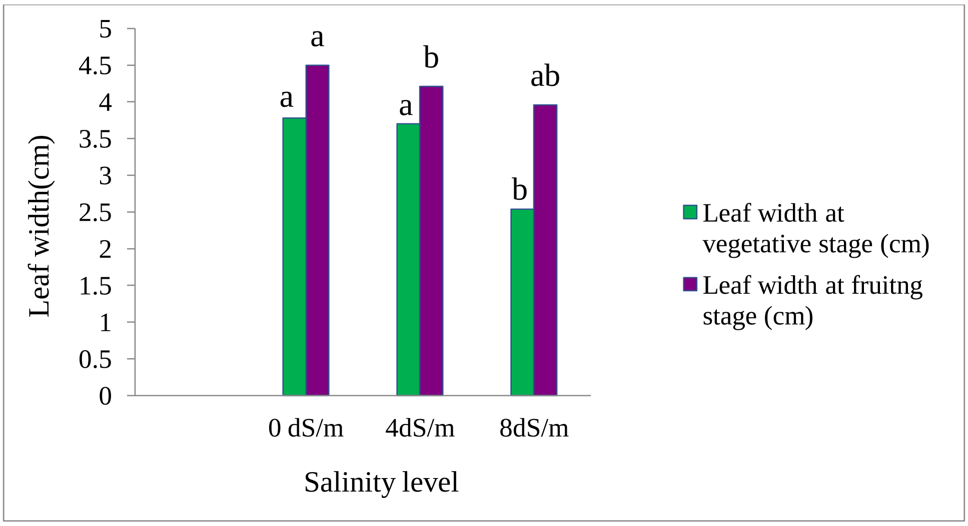


Figure 11. Effect of salinity level on leaf width (cm) of mungbean genotypes [LSD$_{(0.05)}$ - 0.14 (vegetative stage), 0.31 (fruiting stage)].

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 12). At vegetative stage the maximum leaf width was in BARI Mung 5 (4.47cm) and minimum was in BMS III (2.93cm) which was statistically similar to BMS I. At fruiting stage the maximum width was recorded in BARI Mung 5 (5.10cm) which was statistically similar to BARI Mung 6 and minimum was in BMS III (3.45cm).

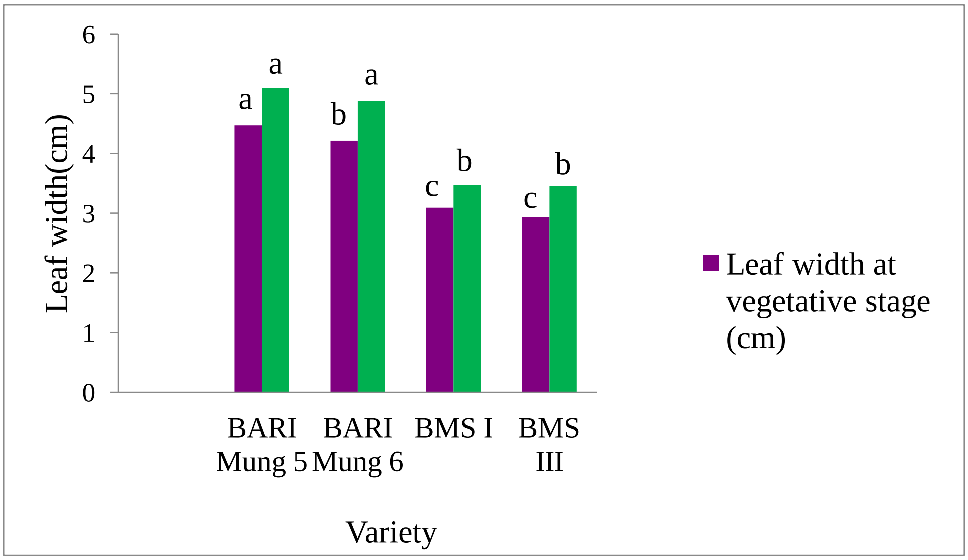


Figure 12. Varietal effect of saline on leaf width (cm) [LSD$_{(0.05)}$ - 0.18 (vegetative stage), 0.40 (fruiting stage)].

Plate 10. Effect of salinity on plant (T_0= Control (Water), T_1= 4 dSm^{-1} and T_2= 8 dSm^{-1}, V_1= BARI Mung 5, V_2= BARI Mung 6, V_3= BMS I and V_4= BMS III).

Interaction effect on salinity levels and genotype

The interaction effect on leaf width between varieties and salinity levels was found significant. From the Table 7, it was observed that the maximum leaf width was found in BARI Mung 5 (6.28cm) at control in fruiting stage and minimum leaf width was found in BMS III (2.52cm) at 8 dSm-1salinity level which was statistically similar to BARI Mung 5 at vegetative stage.

4.2.5. Effect of salinity level on leaf breadth

Effects of salinity

The leaf breadth was significantly affected by salt stress during both vegetative and fruiting stage given in Figure 13. At vegetative stage leaf breadth was insignificant. At fruiting stage the highest leaf breadth (6.27cm) was obtained from control and lowest (5.98cm) was recorded from the salinity 8 dS/m.

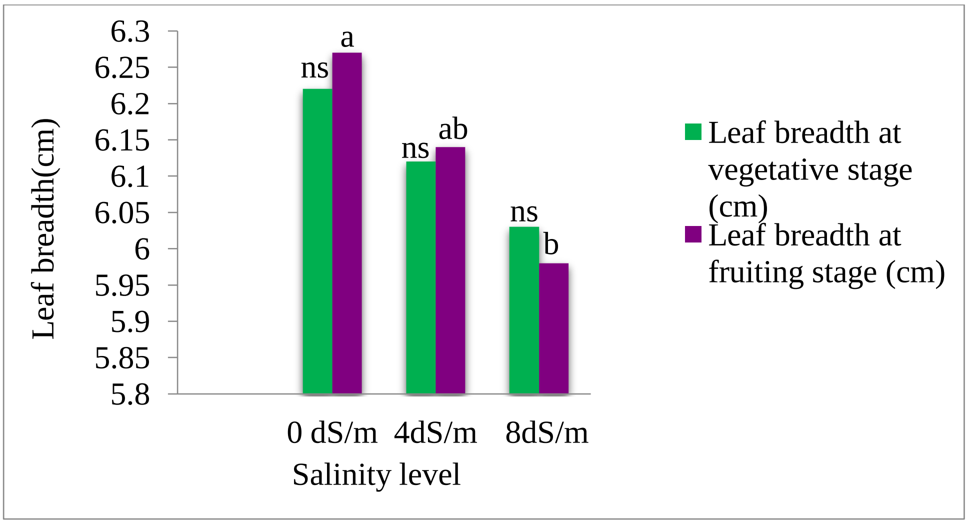


Figure 13. Effect of salinity level on leaf breadth (cm) of mungbean genotypes [$LSD_{(0.05)}$ - 0.34 (vegetative stage), 0.27 (fruiting stage)].

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 14). At vegetative stage the maximum leaf breadth was in BARI Mung 5(7.08cm) followed by BARI Mung 6 and minimum was in BMS III (5.35cm) which was statistically similar to BMS I. At fruiting stage the maximum breadth was recorded in BARI Mung 5 (7.25cm) and minimum was in BMS III (5.26cm).

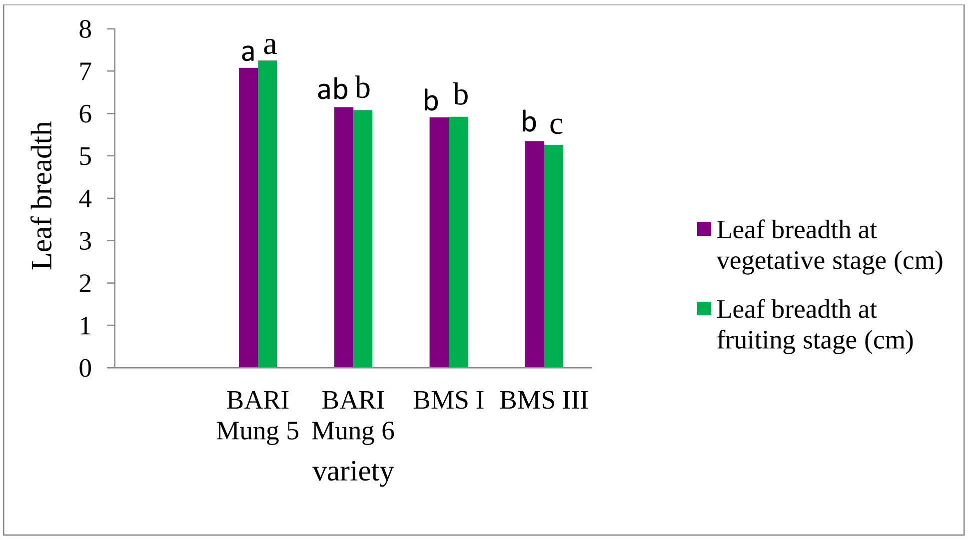


Figure14. Varietal effect of saline on leaf breadth (cm) [$LSD_{(0.05)}$ - 1.01 (vegetative stage), 0.27(fruiting stage)].

Interaction effect of salt stress and genotype

The interaction effect on leaf breadth between varieties and salinity levels was found significant. From the Table 7, it was observed that the maximum leaf breadth was

Table 7**.** Interaction effect of salinity level and genotype on the leaf width and leaf breadth (cm)

treatment	Leaf width at vegetative stage (cm)	Leaf width at fruitng stage (cm)	Leaf breadth at vegetative stage (cm)	Leaf breadth at fruiting stage (cm)
Salinity ×Variety				
Control ×BARI Mung 5	4.75 a	6.28 a	7.41 a	8.18 a
Control ×BARI Mung 6	4.17 b	4.45 cd	6.25 ab	5.71 de
Control ×BMS I	3.08 d	3.4 e	5.5 ab	5.8 c-e
Control ×BMS III	3 d	3.6 de	5.4 ab	5.91 c-e
4 dS/m× BARI Mung 5	4.5 0a	4.4cd	7.33 a	6.5 bc
4 dS/m× BARI Mung 6	4.58 a	4.68 bc	6.25 ab	5.83 c-e
4 dS/m× BMS I	2.52 e	3.36 e	5.41 ab	5.56 e
4 dS/m× BMS III	3.25 d	3.66 de	5.81 ab	5.51 e
8 dS/m× BARI Mung 5	4.08 b	4.63bc	6.5 ab	7.06 b
8 dS/m× BARI Mung 6	3.88 bc	5.5 ab	5.96 ab	6.71 b
8 dS/m× BMS I	3.66 c	3.63 de	6.83 ab	6.4 b-d
8 dS/m× BMS III	2.55 e	3.08 e	4.83 b	4.36 f
SE(±)	0.1103	0.2502	0.6300	0.2148
$LSD_{(0.05)}$	0.40	0.91	2.29	0.78

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

found in BARI Mung 5 (8.18cm) at control in fruiting stage and minimum leaf width was found in BMS III (4.36cm) at 8 dSm^{-1} salinity level.

4.2.6. Effect of salinity level on chlorophyll content

Effects of salinity

Salinity caused reduction in chlorophyll content of leaf. The effect of salinity on chlorophyll content was statistically significant (Figure 15). At vegetative stage the maximum chlorophyll content (48.46) was obtained from control followed by 4 dS/m salinity level and lowest was (44.87) in 8 dS/m salinity level. In flowering stage highest (56.34) chlorophyll content was in control treatment and lowest (49.32) in 8 dS/m salinity level. In fruiting stage the maximum chlorophyll content (50.05) was obtained from control followed by 4 dS/m salinity level and lowest was (36.45) in 8 dS/m salinity level.

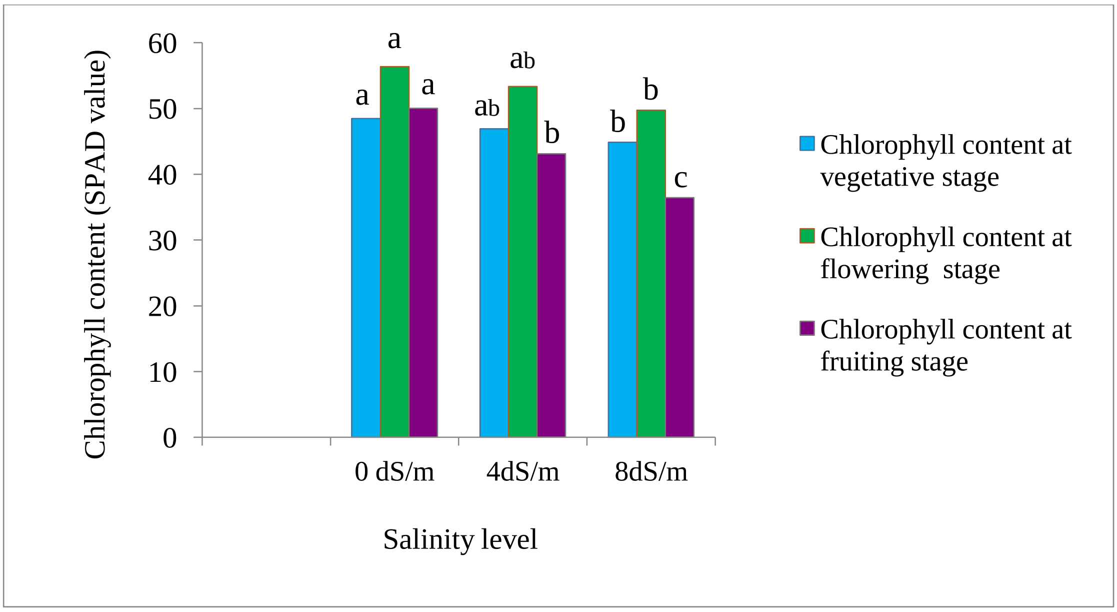


Figure 15. Effect of salinity level on of mungbean genotypes on chlorophyll content [$LSD_{(0.05)}$ - 2.9-3 (vegetative stage), 6.5(flowering stage) and 2.53(fruiting stage)].

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 16). At vegetative stage the highest chlorophyll content was recorded in BARI Mung 6 (50.23) and lowest was in BMS III (44.81) followed by BARI Mung 5 and BMS III. At flowering stage chlorophyll content of leaf was insignificant. Among four variety

BMS I was produced higher (55.41) chlorophyll than other variety. At fruiting stage the highest chlorophyll content was recorded in BARI Mung 6 (49.73) and lowest was in BMS III (36.83) followed by BARI Mung 5 and BMS I.

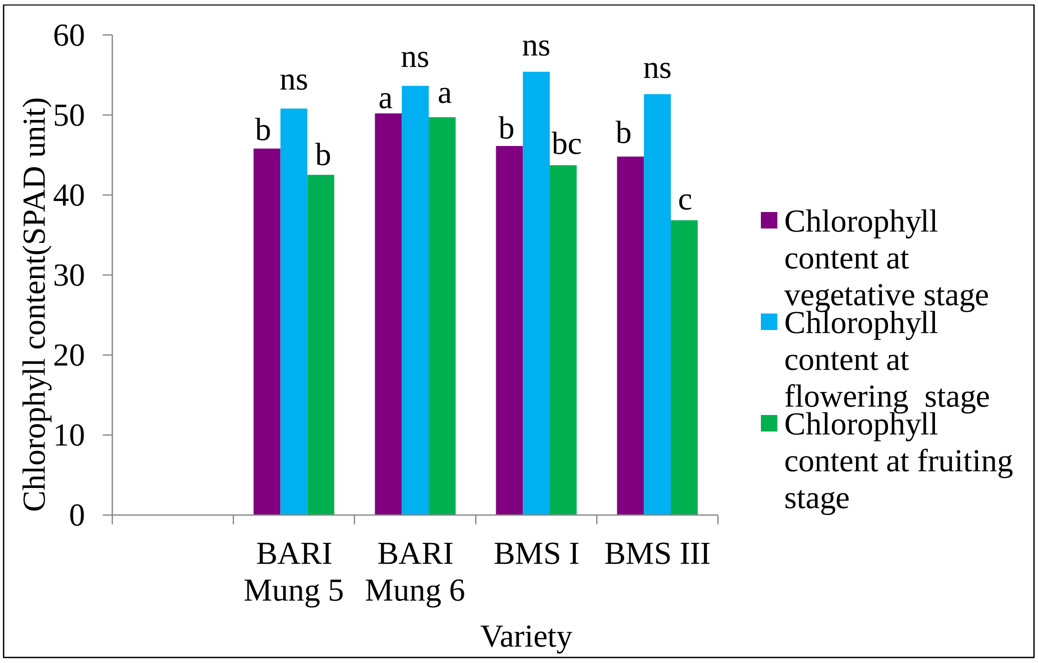


Figure 16. Varietal effect of saline on chlorophyll content [$LSD_{(0.05)}$ -3.7-3.87 (vegetative stage), 8.3 (flowering stage) and 3.23 (fruiting stage)].

Interaction effect of salt stress and genotype

The interaction effect was statistically significant (Table 8). The interaction effect on chlorophyll content between varieties and salinity levels was found significant. From the Table 8, it was observed that the maximum chlorophyll content was found in BARI Mung 6 (59.13) at control in fruiting stage and minimum chlorophyll content was found in BMS III (39.1) at 8 dS/m salinity level which was statistically similar to BARI Mung 5 at vegetative stage. At flowering stage it was insignificant.

Table 8**.** Interaction of salt stress and genotype on the chlorophyll content

treatment	Chlorophyll content at vegetative stage (SPAD unit)	Chlorophyll content at flowering stage (SPAD unit)	Chlorophyll content at fruiting stage (SPAD unit)
Salinity ×Variety			
Control ×BARI Mung 5	49.88 ab	53.63	48.43 b
Control ×BARI Mung 6	48.38 ab	56.30	59.13 a
Control ×BMS I	49.29 ab	60.27	48.26 b
Control ×BMS III	46.28 ab	55.17	44.4 bc
4 dS/m× BARI Mung 5	45.65 ab	52.03	44.26 bc
4 dS/m× BARI Mung 6	52.61 a	54.17	47.93 b
4 dS/m× BMS I	44.74 ab	54.17	43.76 b-d
4 dS/m× BMS III	43.99 b	52.93	36.46 d-f
8 dS/m× BARI Mung 5	41.84 b	46.8	34.93 ef
8 dS/m× BARI Mung 6	49.7 ab	50.43	42.13 b-e
8 dS/m× BMS I	43.77 b	51.80	39.1 c-e
8 dS/m× BMS III	44.17 b	49.87	29.63 f
SE(±)	2.30	5.18	2.01
$LSD_{(0.05)}$	8.41-9.48	ns	7.33

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Salinity stress caused swelling of membranes in chloroplasts of sensitive plants which affected their chlorophyll content, or it occurred due to excess ions (Na^+ and Cl^-) in leaves which induced loss of chlorophylls (Wahid *et al*., 2004 and Arulbalachandran *et al*., 2009). Accumulation of toxic ions under salinity stress reduced the water and osmotic potential that further caused disturbances in photosynthetic processes (Khan *et al*., 2010). Reduction in chlorophyll content is probably due to the inhibitory effect of the accumulated ions of various salts on the biosynthesis of the different chlorophyll fractions. Loss of chlorophyll content caused chlorosis of leaves that later turned into necrosis. These adverse effects finally caused senescence and plant death. The results are in agreement with the earlier findings on mungbean (Sehrawat *et al*., 2013b; 2013c).

4.3. Effect of salinity on yield and yield components

4.3.1. Effect of salinity level on pod length

Effects of salinity

Effect of salinity on pod length of mungbean was insignificant (Figure 17). The pod length decreased with increasing of salinity at different levels of harvest. The highest pod length (4.59cm) was obtained from control. The lowest pod length (3.70) was recorded from the salinity of 8 dS/m.

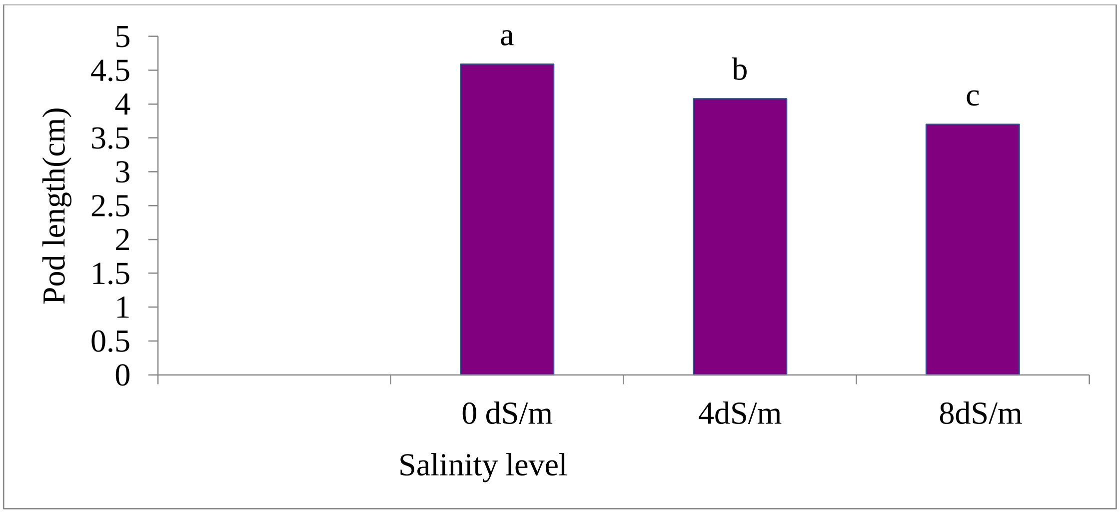


Figure 17. Effect of salinity level on pod length (cm) of mungbean genotypes [$LSD_{(0.05)}$ -0.08].

Effects on mungbean varieties

Effect of salt stress on different genotypes was statistically significant (Figure 18). The highest pod length ware recorded in BARI Mung 6 (4.51) which was statistically similar to BMS I and lowest was in BARI Mung 5 (3.57).

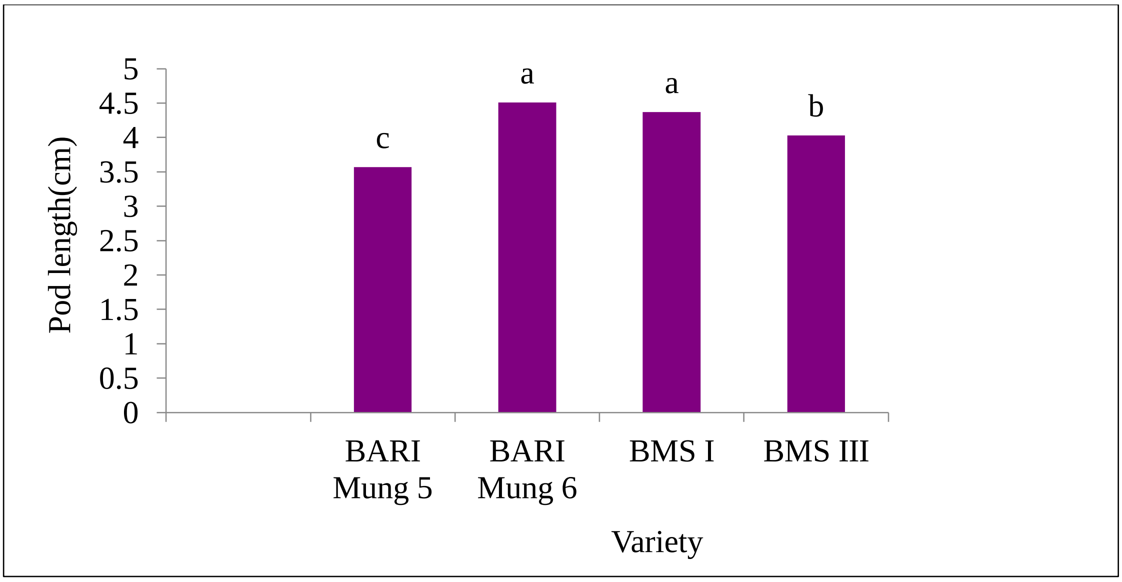


Figure 18. Varietal effect of saline on pod length (cm) [$LSD_{(0.05)}$ - 0.20].

Interaction effect on salinity level and genotype

The interaction effect on pod length between varieties and salinity levels was found significant. From the Table 9, it was observed that the highest pod length (4.82 cm) was found in BARI Mung 6 which was statistically similar to BMS I (4.81cm) followed by BARI Mung 5 at control.

Table 9**.** Interaction effect of salinity level and genotype on the pod length (cm)

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	4.35 ab	4.82 a	4.81 a	4.38 ab
4 dS/m	3.57 d	4.47 ab	4.26 a-c	4.02 b-d
8 dS/m	2.8 e	4.24 a-c	4.04 b-d	3.69 cd
SE(±)	0.1652			
$LSD_{(0.05)}$	0.60			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

The lowest pod length was found in BARI Mung 5 (2.5) at 8 dS/m salinity level. Ahmed (2009) found that pod length in mungbean exponentially reduced by salt stress.

4.3.2. Effect of salinity level on pod breadth

Effects of salinity

Statistical analysis for the pod breath indicated significant ($p<0.05$) differences among the genotypes with increased salinity. The highest (1.90cm) pod breadth was found in control treatment and lowest (1.61cm) was at 8dS/m which was statistically similar to 4 dS/m (Figure 19).

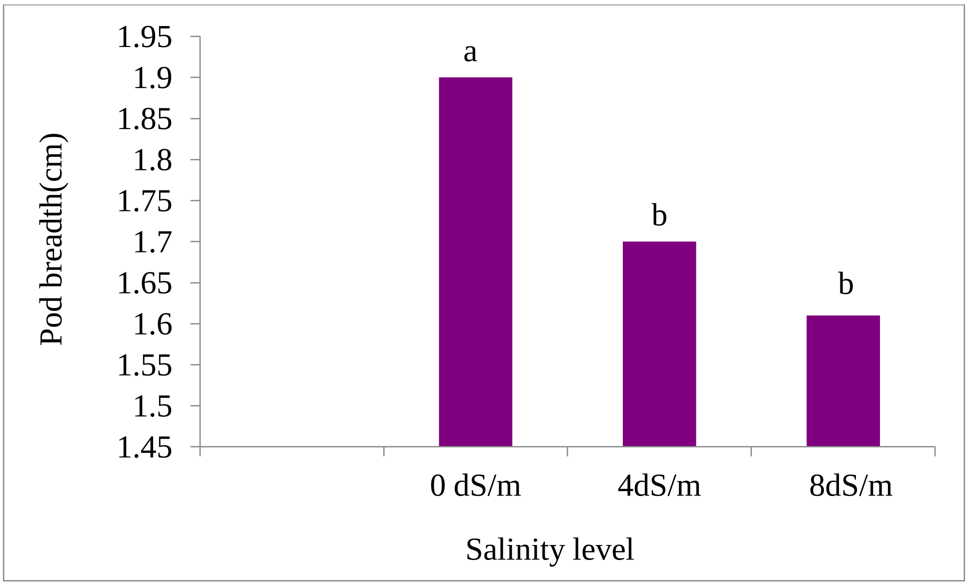


Figure 19. Effect of salinity level on pod breadth (cm) of mungbean genotypes ($LSD_{(0.05)}$ - 0.11).

Effects on mungbean varieties

Effect of salinity on pod breadth of mungbean was statistically significant (Figure 20). The highest (2.03cm) pod breadth was in BARI Mung 5 and lowest (1.54) was in BMS III followed by BMS I.

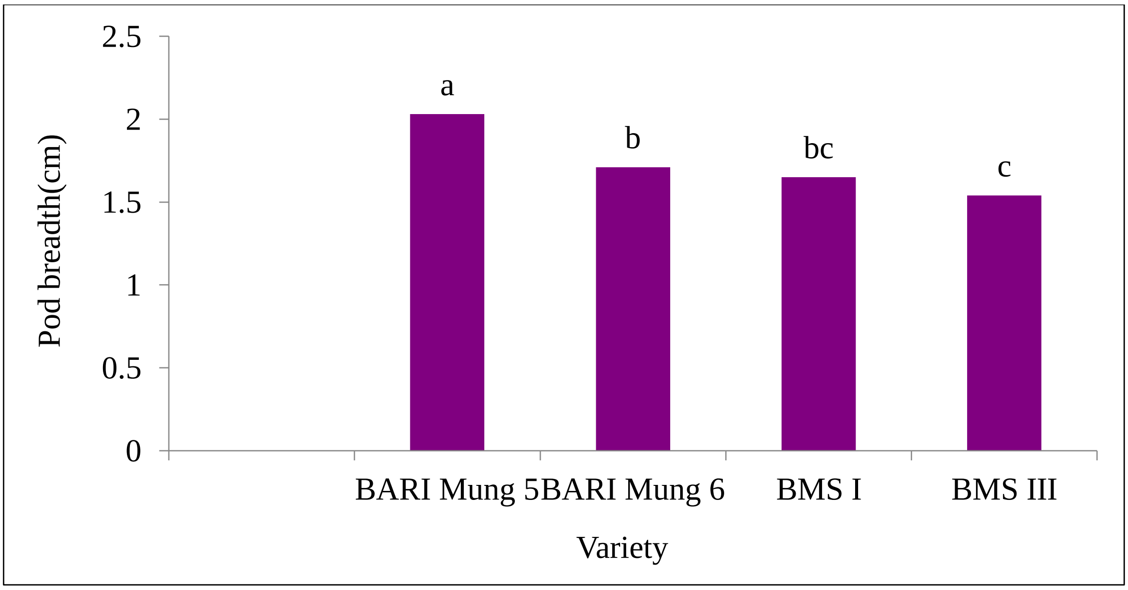


Figure 20. Varietal effect of saline on pod breadth (cm) ($LSD_{(0.05)}$ - 0.15).

Interaction effect on salinity level and genotype

From interaction between varieties and salinity levels it was found that BARI Mung 5 gave highest (2.37cm) pod breadth in control condition while BMS III gave lowest (1.45cm) result (Table 10).

Table 10. Interaction effects between salinity level and genotypes on pod breadth (cm)

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	2.37 a	1.89 bc	1.70b-e	1.64 b-e
4 dS/m	1.91 b	1.71 b-e	1.64 b-e	1.53 de
8 dS/m	1.83 b-d	1.55 c-e	1.6 b-e	1.45 e
SE(±)	0.0926			
$LSD_{(0.05)}$	0.34			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

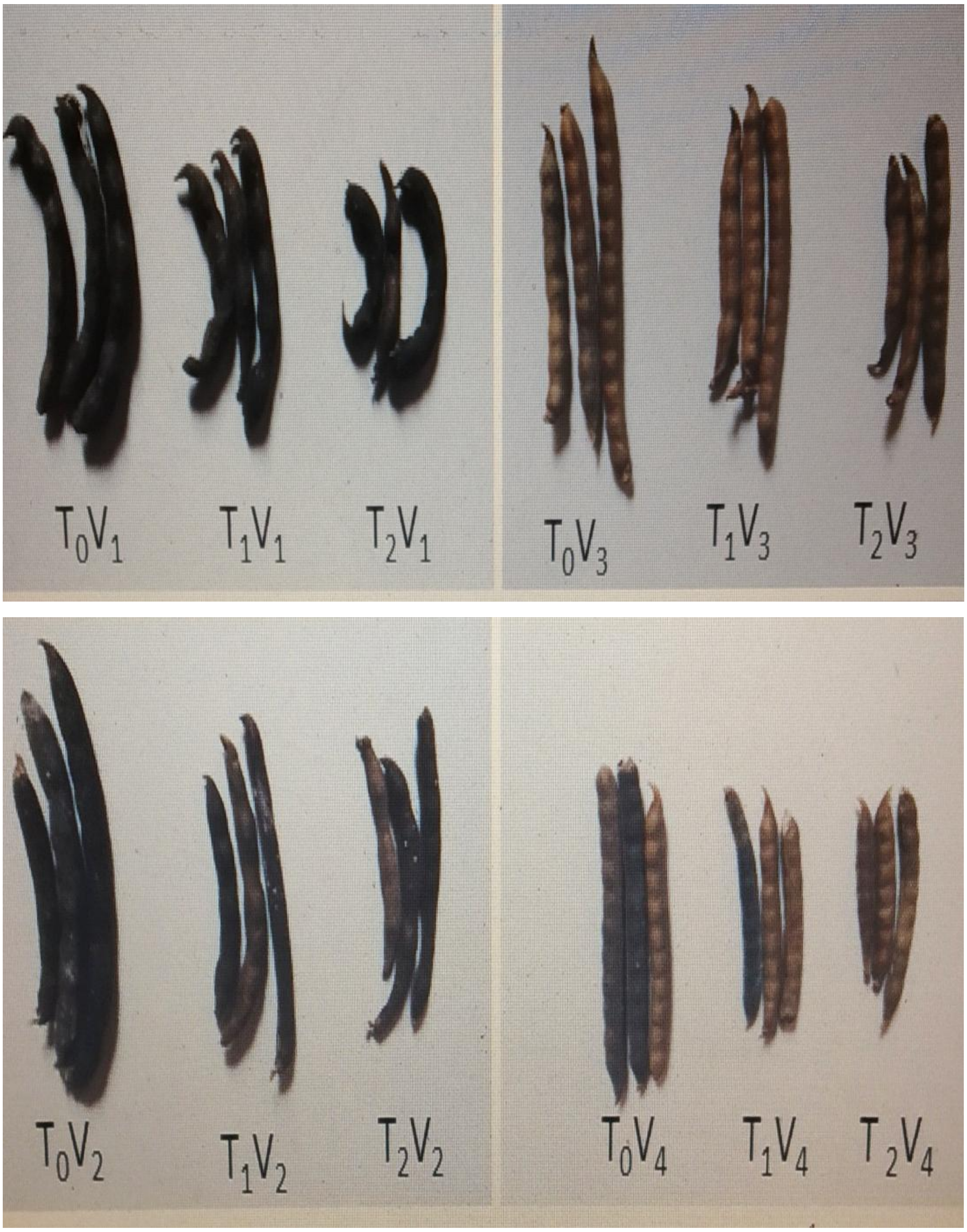


Plate 11. Effect of salinity on pod (T_0= Control (Water), T_1= 4 dSm^{-1} and T_2= 8 dSm^{-1}, V_1= BARI Mung 5, V_2= BARI Mung 6, V_3= BMS I and V_4= BMS III)

4.3.3. Effect of salinity level on Number of pod per plant

Effects of salinity

Increasing salinity level resulted in a significant reduction in number of pods per plant (Figure 21). The highest (9.33) number of pods per plant was obtained from control treatment which was significantly different from other two salinity levels. Application of 4 dS/m salinity proved to be better than 8 dS/m salinity for the character.

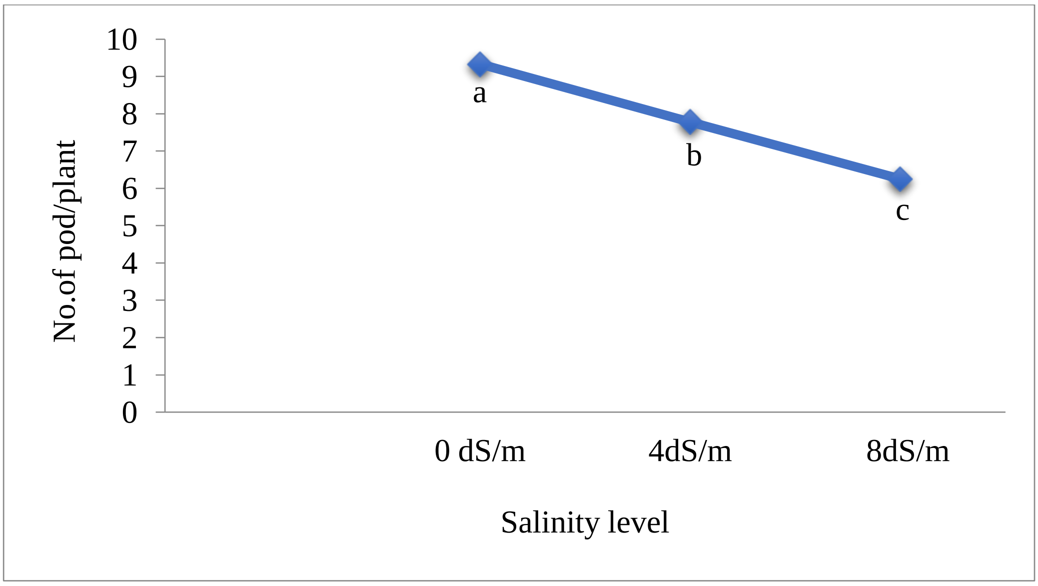


Figure 21. Effects of salinity levels on no. of pod/plant ($LSD_{(0.05)}$ - 0.76).

The lower (6.25) number of pods per plant was recorded under 8 dS/m which was significantly different from two treatments. Small number of pods under salinity might be due to translocation of assimilates towards reproductive organ.

Effects on mungbean varieties

The variations of number of pods plant^{-1} among the genotypes were significant for different salinity levels (Figure 22). The highest number of pods plant^{-1} (12.77) was in the BMS I and the lowest (4.24) was in the BARI Mung 5. The highest number of pods plant^{-1} (12.77) was in the BMS I and the lowest (4.24) was in the BARI Mung 5.

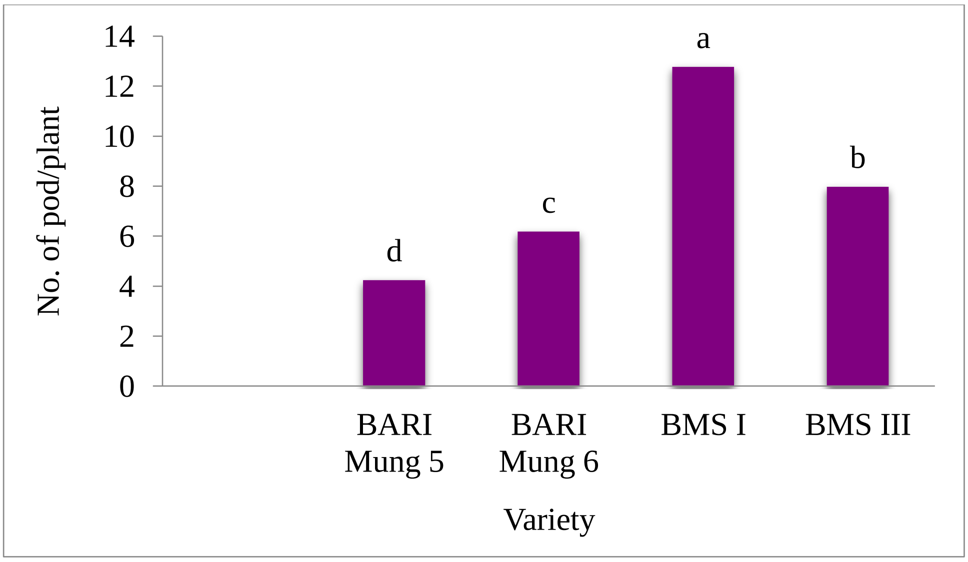


Figure 22. Varietal effect of saline on number of pod/plant ($LSD_{(0.05)}$ - 0.97).

Interaction effect on salinity level and genotype

The interaction effect of salinity levels and genotypes in relation to number of pods per plant was found significant ($P<0.05$) (Table 11). The maximum number of pods per plant was obtained at control BMS I (15.02) and the minimum number of pod per plant was found in BARI Mung 5 at (3.24) at 8 dS/m salinity level.

Table 11. Interaction effects between salinity level and genotypes on number of pod/plant

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	5.38 f-h	7.17 ef	15.02 a	9.78 cd
4 dS/m	4.11 gh	6.22 fg	12.37 b	8.43 de
8 dS/m	3.24 h	5.15 f-h	10.9 bc	5.70 fg
SE(±)	0.6060			
$LSD_{(0.05)}$	2.20			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

The results showed that the number of pod per plant growth of mungbean was also affected by salinity substantially decreased with the increasing salinity levels. Ram *et al*. (1989) in chickpea and mungbean and Raptan (2001) in mungbean observed that increasing salinity significantly reduced pods per plant.

4.3.4. Effect of salinity level on number of seeds pod^{-1}

Effects of salinity

The effect of salinity on the number of seeds pod^{-1}, data in Figure 23 indicated that increasing the level of salinity water from tap water to 8 dS m^{-1}, significantly decreased no. of seeds per pod. The highest number of seeds pod^{-1} (8.22) was recorded at control condition and the lowest (6.30) was recorded at 8 dS m^{-1} level of soil salinity.

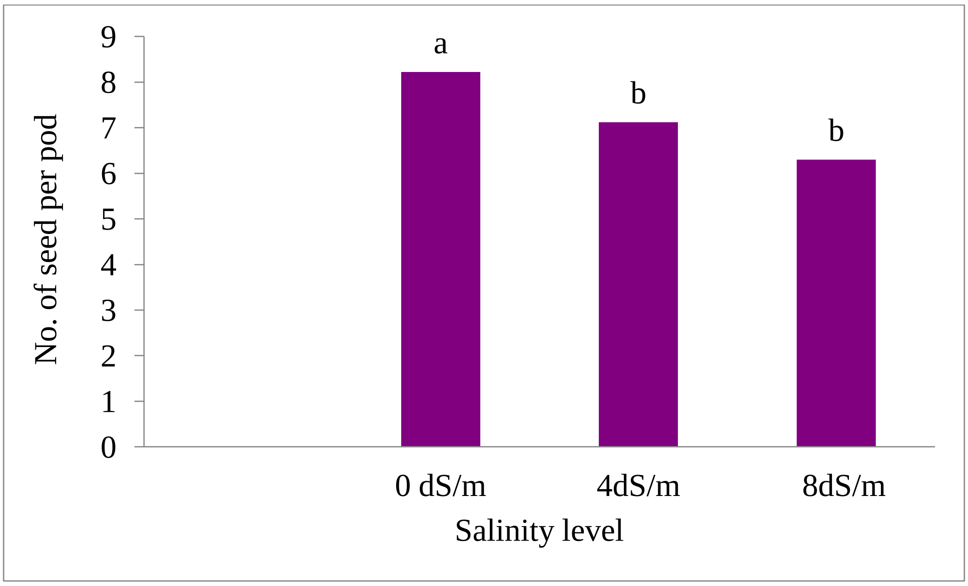


Figure 23. Effect of salinity level on number of seed/pod of mungbean genotypes ($LSD_{(0.05)}$ - 0.87).

Effects on mungbean varieties

Among the genotypes, number of seeds pod^{-1} was significant (Figure 24). The highest number of seeds pod^{-1} (8.59) in BMS I and the lowest (5.55) was in BARI Mung 5.

According to Gill (1979) lengthening the time required for seed filling under salt stress pushed 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. Thus, it may be concluded that reduced yield 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 per pod/or plant and dry matter yield of individual seed. Delayed maturity due to salt stress pushes the plant also to desiccation stress causing shriveled seeds.

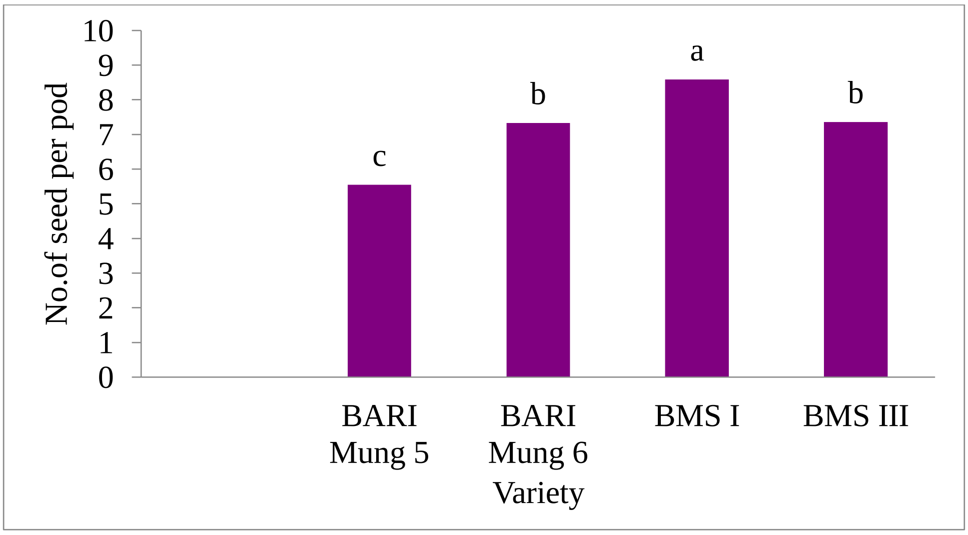


Figure 24. Varietal effect of saline on number of seeds/pod ($LSD_{(0.05)}$ - 1.11).

Interaction effect of salt stress and genotype

The interaction effect on number of seeds pod^{-1} between varieties and salinity levels was found significant. From the Table 12, it was observed that the highest number of seeds pod^{-1} was found in BMS I (9.55) at control and the lowest number of seeds pod^{-1} was found in BARI Mung 5 (4) followed by BMS III at 8 dS/m salinity level.

Table 12**.** Interaction effect of salinity level and genotype on the number of seed/pod

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	6.33 c-f	8.11 a-d	9.55 a	8.88 ab
4 dS/m	5.33 ef	7.22 a-f	8.66 a-c	7.22 a-f
8 dS/m	5 f	6.66 a-e	7.55 a-e	6 d-f
SE(±)	0.6938			
$LSD_{(0.05)}$	2.25			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

These results were supported with the findings obtained by Fauzia *et al.* (1988), who reported that number of grains/pod was 4.1, 3.7 and 3.5 when the plants were grown in 1.4, 5.0 and 7.5 ds/m of soil salinity, respectively. Also, Raptan *et al.* added that the reduction in number of seeds per pod of the plants which irrigated with 100 mm NaCl was 50% as compared to the plants which irrigated with tap water.

4.3.5. Effect of salinity level on total number of pod per pot

Effects of salinity

The effect of salinity on the number of pods per pot was statistically significant ($P < 0.05$) (Figure 25). The highest (56.02) number of pods per pot was obtained from control treatment which was significantly different from other two salinity levels. Application of 4 dS/m salinity proved to be better than 8 dS/m salinity for the character. The lower (37.50) number of pods per pot was recorded under 8 dS/m which was significantly different from two treatments. Small number of pods under salinity might be due to translocation of assimilates towards reproductive organ.

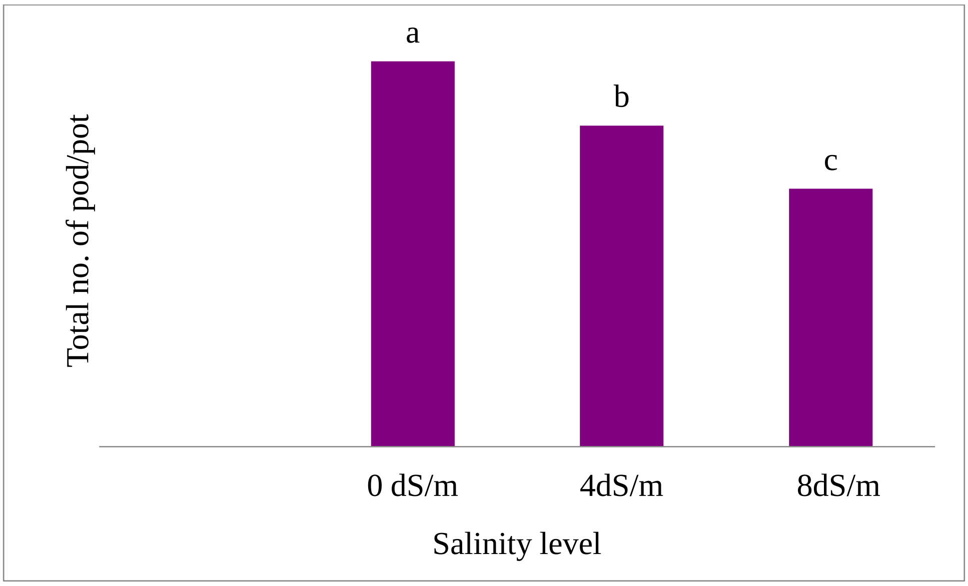


Figure 25. Effect of salinity level on number of pod per pot of mungbean genotypes ($LSD_{(0.05)}$ - 4.58).

Effects on mungbean varieties

The variations of number of pods per pot among the genotypes were found significant for different salinity levels (Figure 26). The highest number of pods per pot (76.57) was found in the BMS I and the lowest (37.08) was in the BARI Mung 5.

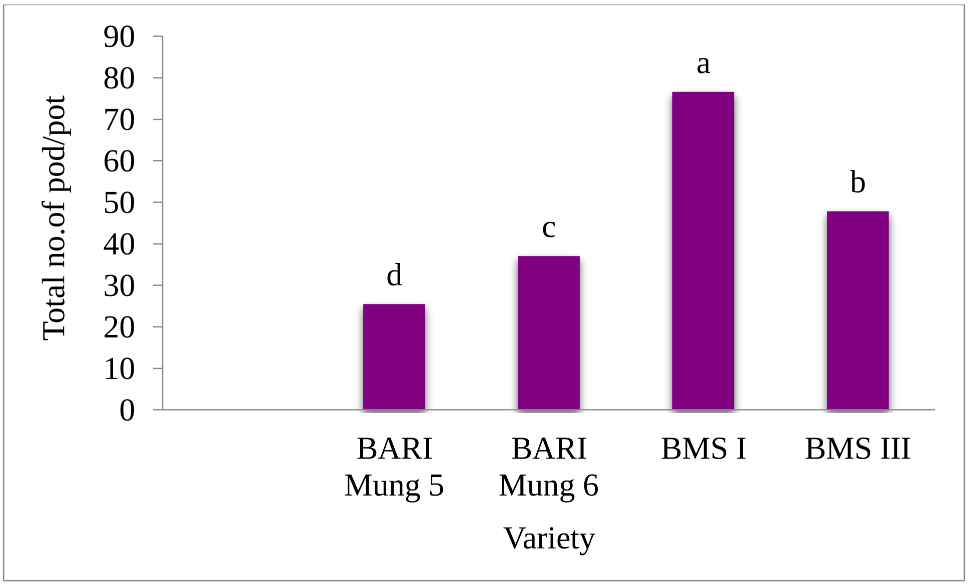


Figure 26. Varietal effect of saline on number of pod per pot ($LSD_{(0.05)}$ - 5.84).

Interaction effect on salinity level and genotype

The interaction effect of salinity levels and genotypes in relation to number of pods per pot was found significant (P<0.05) (Table 13). The maximum number of pods per pot was obtained at control BMS I (90.01) and the minimum number of pod per pot was found in BARI Mung 5 (19.47) at 8 dSm^{-1} salinity level.

Table 13. Interaction effects between salinity level and genotypes on number of pod per pot

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	32.25 f-h	43 ef	90.1 a	58.72 cd
4 dS/m	24.67 gh	37.33 fg	74.21 b	50.58 de
8 dS/m	19.47 h	30.90 f-h	65.40 bc	34.22 fg
SE(±)	2.47			
$LSD_{(0.05)}$	13.23			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

4.3.6. Effect of salinity level on weight of individual pod

Effects of salinity

Significant effect of salinity levels was found on individual fruit weight. Individual pod weight was taken in both fresh and dry condition. The highest (0.37g) pod weight per plant was obtained from control treatment and lowest (0.28g) from 8 dS/m salinity level in fresh condition. In dry condition highest (0.33g) pod weight per plant was obtained from control treatment and lowest (0.25g) from 8 dS/m salinity level (Figure 27).

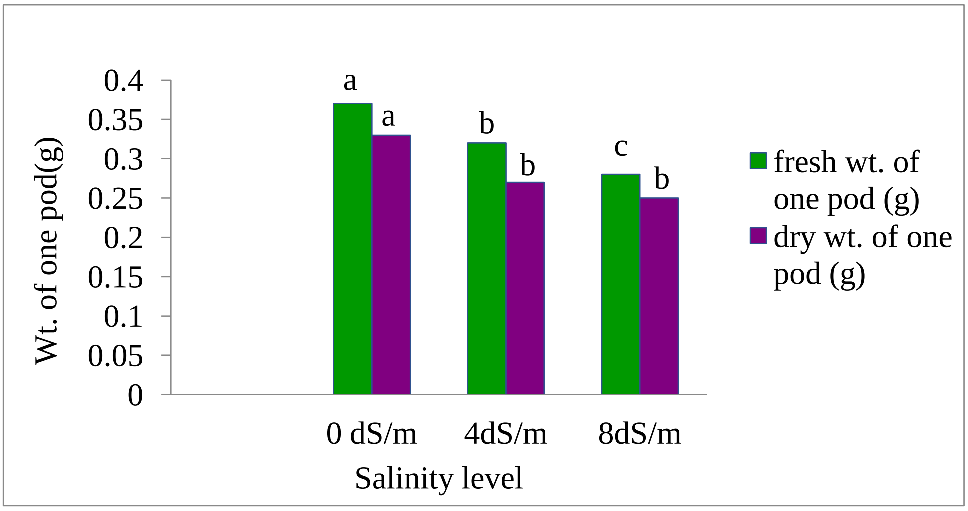


Figure 27. Effect of salinity level on individual pod weight (g) of mungbean genotypes ($LSD_{(0.05)}$ - 0.02(fresh), 0.03 (dry).

Effects on mungbean varieties

Among the genotypes, individual pod weight was found significant ($P<0.05$) (Figure 28). The highest (0.38) fresh weight was in BARI Mung 5 which was statistically similar to BARI Mung 6 and lowest (0.25g) was in BMS III. The highest (0.33g) dry

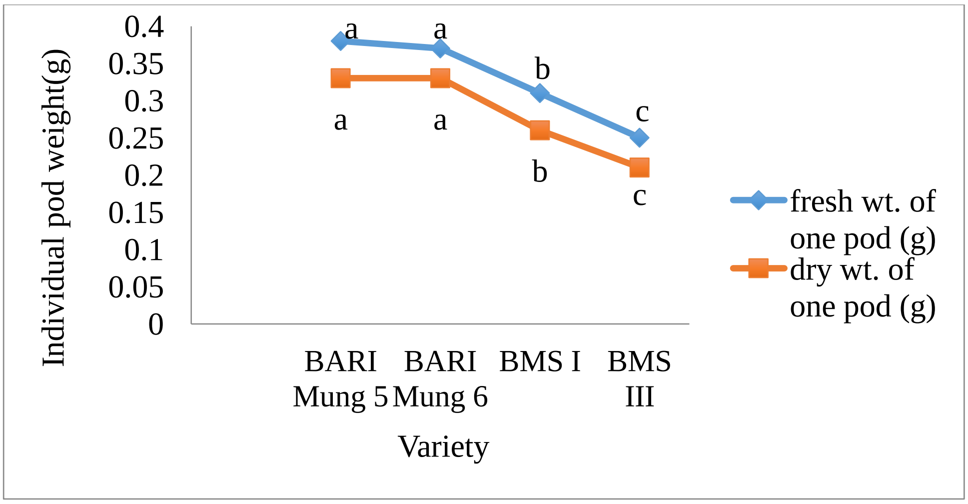


Figure 28. Varietal effect of saline on individual pod weight [$LSD_{(0.05)}$ - 0.02(fresh) and 0.04(dry)].

weight was in BARI Mung 5 which was statistically similar to BARI Mung 6 and lowest (0.21g) was in BMS III.

Interaction effect of salt stress and genotype

The interaction effect of salinity stress and genotypes on individual pod weight was also varied significantly (Table 14). The highest individual fresh pod weight was found in BARI Mung 5 (0.43g) at control condition which was followed by BARI Mung 6 and BMS I and was the lowest (0.22g) in BMS III at 8 dSm^{-1} followed by BMS III. BARI Mung 5 produced the highest (0.37g) dry weight followed by BARI Mung 6 in control condition and lowest (0.18g) in BMS I at 8 dS/m followed by BMS III.

Table 14. Interaction effects between salinity level and genotypes on individual pod weight (g)

Treatment	Individual pod weight(g)	
	fresh wt. of one pod (g)	dry wt. of one pod (g)
Salinity ×Variety		
Control ×BARI Mung 5	0.43 a	0.38 a
Control ×BARI Mung 6	0.4 ab	0.37 ab
Control ×BMS I	0.38 ab	0.32 a-c
Control ×BMS III	0.29 ef	0.24 c-e
4 dS/m× BARI Mung 5	0.36 bc	0.32 a-c
4 dS/m× BARI Mung 6	0.38 bc	0.29 b-d
4 dS/m× BMS I	0.3 d-f	0.26 c-e
4 dS/m× BMS III	0.25 fg	0.21 de
8 dS/m× BARI Mung 5	0.32 c-f	0.28 cd
8 dS/m× BARI Mung 6	0.35 b-d	0.32 a-c
8 dS/m× BMS I	0.25 fg	0.21 de
8 dS/m× BMS III	0.22 g	0.18 e
SE(±)	0.0152	0.0240
$LSD_{(0.05)}$	0.06	0.08

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

4.3.7. Effect of salinity level on weight of pod/pot

Effects of salinity

The effect of salinity on pod weight per pot was statistically significant ($P<0.05$) (Figure 29). The highest (33.16g) pod weight per pot was obtained from control treatment. The lowest (14.06g) pod weight was found from 8 dS/m salinity level which indicated that with the increased salinity levels the pod weight gradually decreased.

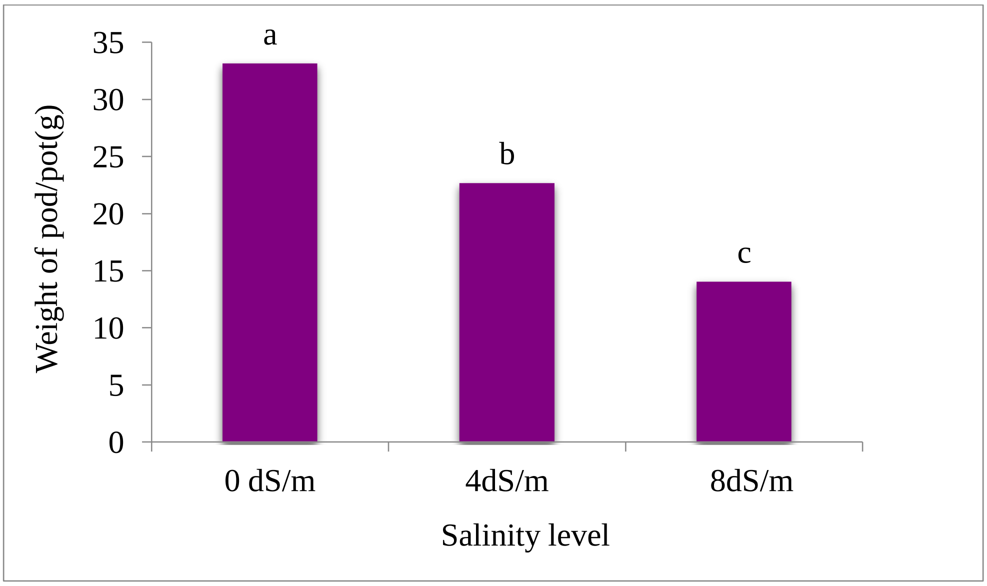


Figure 29. Effect of salinity level on pod weight per pot of mungbean genotypes ($LSD_{(0.05)}$ - 0.90).

Effects on mungbean varieties

Among the genotypes the pod weight per pot was statistically significant ($p<0.05$) (Figure 30). The maximum pod weight (38.20g) per pot was observed in BMS I and the minimum (11.21g) in BARI Mung 5.

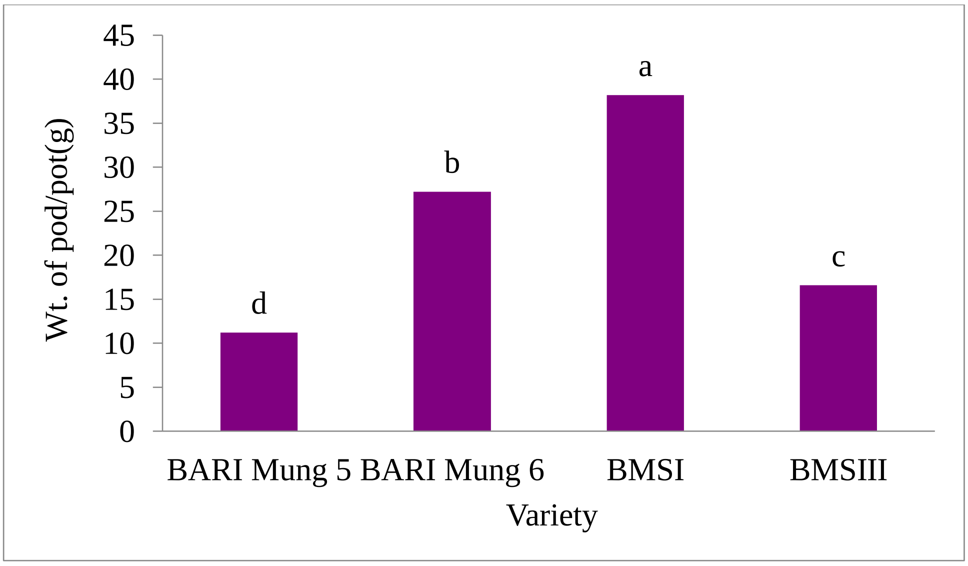


Figure 30. Varietal effect of saline on pod weight (g) per pot ($LSD_{(0.05)}$ - 1.16).

Interaction effect on salinity levels and genotype

The interaction effect of salinity levels and genotypes in relation to pod weight per pot was found significant ($P<0.05$). From Table 15, the maximum pod weight (56.13g) per pot was observed in BMS I at control and the minimum pod weight (6.37g) was observed in BMS III at 8 dS/m salinity which was statistically similar to BARI Mung 5.

Table 15. Interaction effects between salinity level and genotypes on pod weight per pot (g)

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	16.53 f	35.62 b	56.13 a	24.36 cd
4 dS/m	10.04 g	26.00 c	35.68 b	19.02 ef
8 dS/m	7.07 h	20.01 e	22.80 d	6.37 h
SE(±)	0.7196			
$LSD_{(0.05)}$	2.62			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

4.3.8. Effect of salinity level on weight of pod/plant

Effects of salinity

The effect of salinity on pod weight per plant was statistically significant ($P<0.05$) The highest (5.51g) pod weight per plant was obtained from control treatment. The lowest (2.35g) number of pod weight was found from 8 dS/m salinity level (Figure 31). That means, pod weight gradually decreased with the increasing of salinity level.

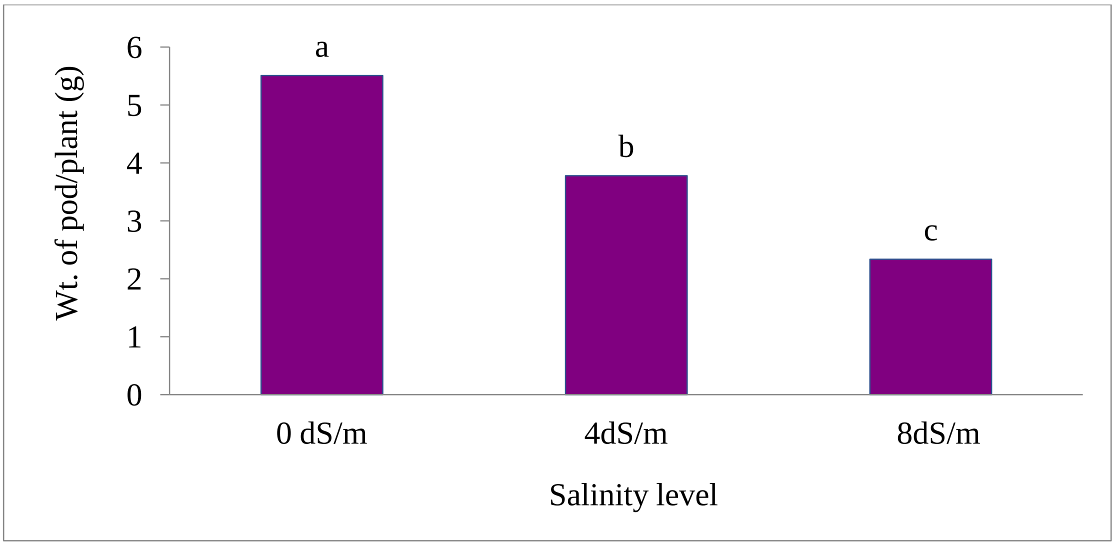


Figure 31. Effect of salinity level on wt. of pod/plant (g) of mungbean genotypes ($LSD_{(0.05)}$ - 2.59).

Effects on mungbean varieties

Among the genotypes the pod weight per plant was statistically significant ($p<0.05$) (Figure 32). The maximum pod weight (6.36g) per plant was observed in BMS I and the minimum (1.87g) in BARI Mung 5.

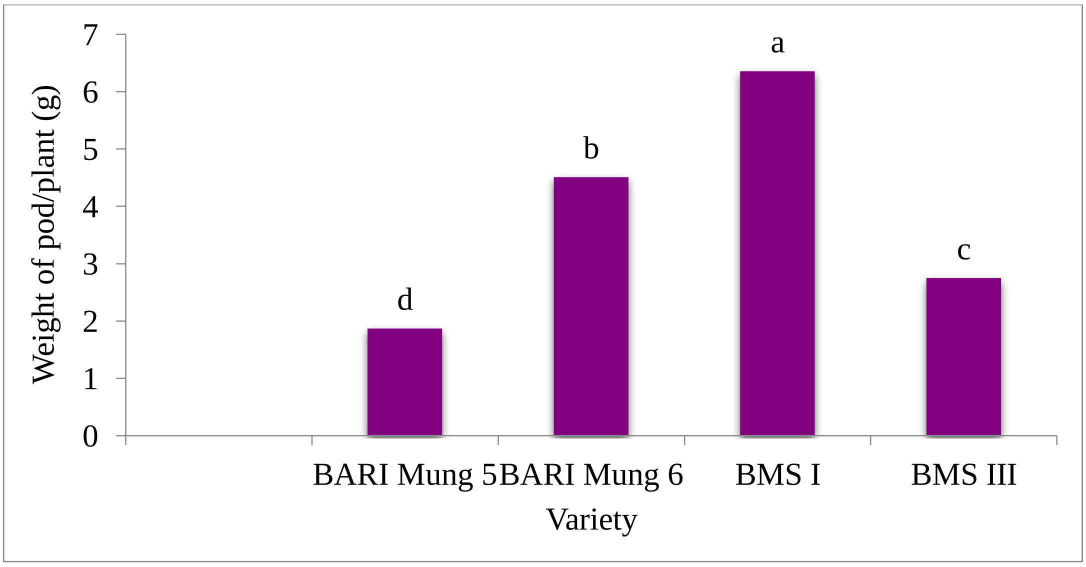


Figure 32. Varietal effect of saline on wt. of pod/plant (g) ($LSD_{(0.05)}$ - 2.59).

Interaction effect on salt levels and genotype

The interaction effect of salinity levels and genotypes in relation to pod weight per plant was found significant ($P<0.05$) (Table 16).The maximum pod weight (9.35g) per plant was observed in BMS I at control and the minimum pod weight (1.06g) was observed in BMS III at 8 dS/m salinity followed by BARI Mung 5.

Table 16. Interaction effects between salinity level and genotypes on wt. of pod/plant (g)

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	2.76 e	5.87 b	9.35 a	4.06 c
4 dS/m	1.66 f	4.33 c	5.94 b	3.15 e
8 dS/m	1.18 fg	3.33 de	3.80 cd	1.06 g
SE(±)	0.1610			
$LSD_{(0.05)}$	0.59			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Islam *et al*. (2006) reported that grain yield plant-1 gradually decreased with the increasing of salinity levels. Mungbean produced the lower grain yield per plant under salt stress as compared to control was reported by Hossain *et al*. (2008), Ahmed (2009) and Golezani *et al*. (2012).

4.3.9. Effect of salinity level on 1000 seed weight

Effects of salinity

The effect of salinity on 1000 seed weight (g) was varied significantly. Thousand seed weight represents grain size of a variety. The highest 1000 grain weight (35.67g) was obtained from control, followed by 4 dSm^{-1} salinity level (32.80g). The lowest 1000 grain weight (29.94g) was recorded from 8 dSm^{-1} salinity level (Figure 33). Salinity stress influenced the size of the seeds. Seed size was reduced with increased salinity stress.

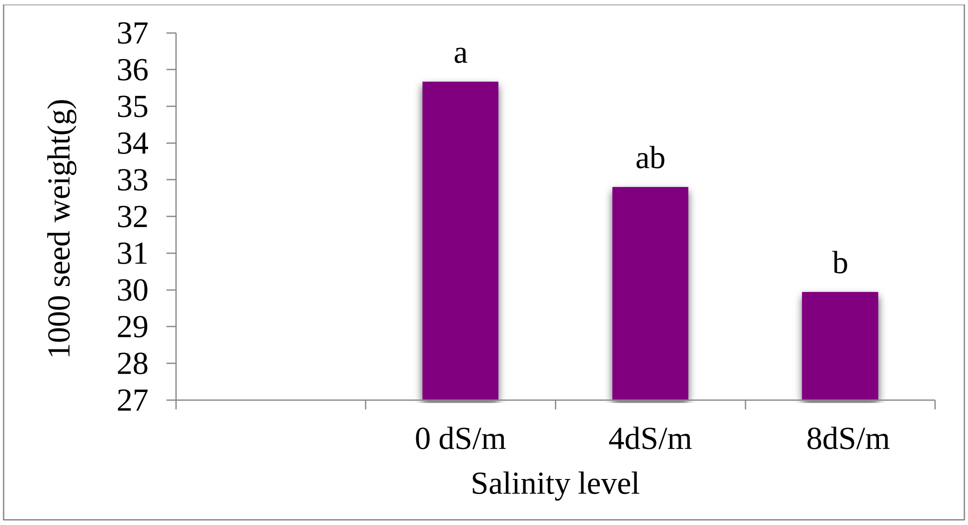


Figure 33. Effect of salinity level on 1000-seed weight of mungbean genotypes ($LSD_{(0.05)}$ - 4.26).

Effects on mungbean varieties

Among the genotypes, 1000-seed weight was significant ($P<0.05$). Among the genotypes, BARI Mung 6 produced the maximum (39.76g) seed weight which was statistically similar to BARI Mung 5 (37.27g) and BMS III produced the lowest (24.17g) seed weight (Figure 34).

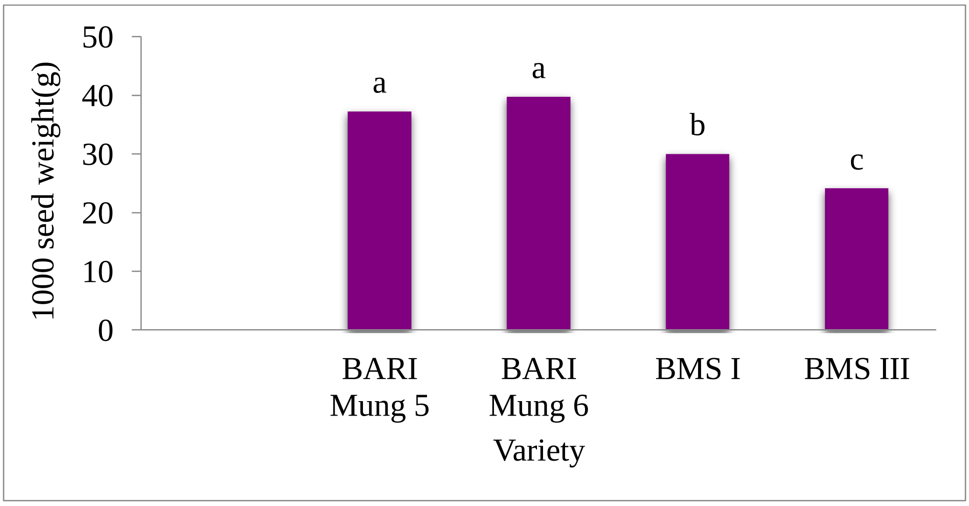


Figure 34. Response of mungbean varieties on 1000-seed weight (g) ($LSD_{(0.05)}$ - 5.43).

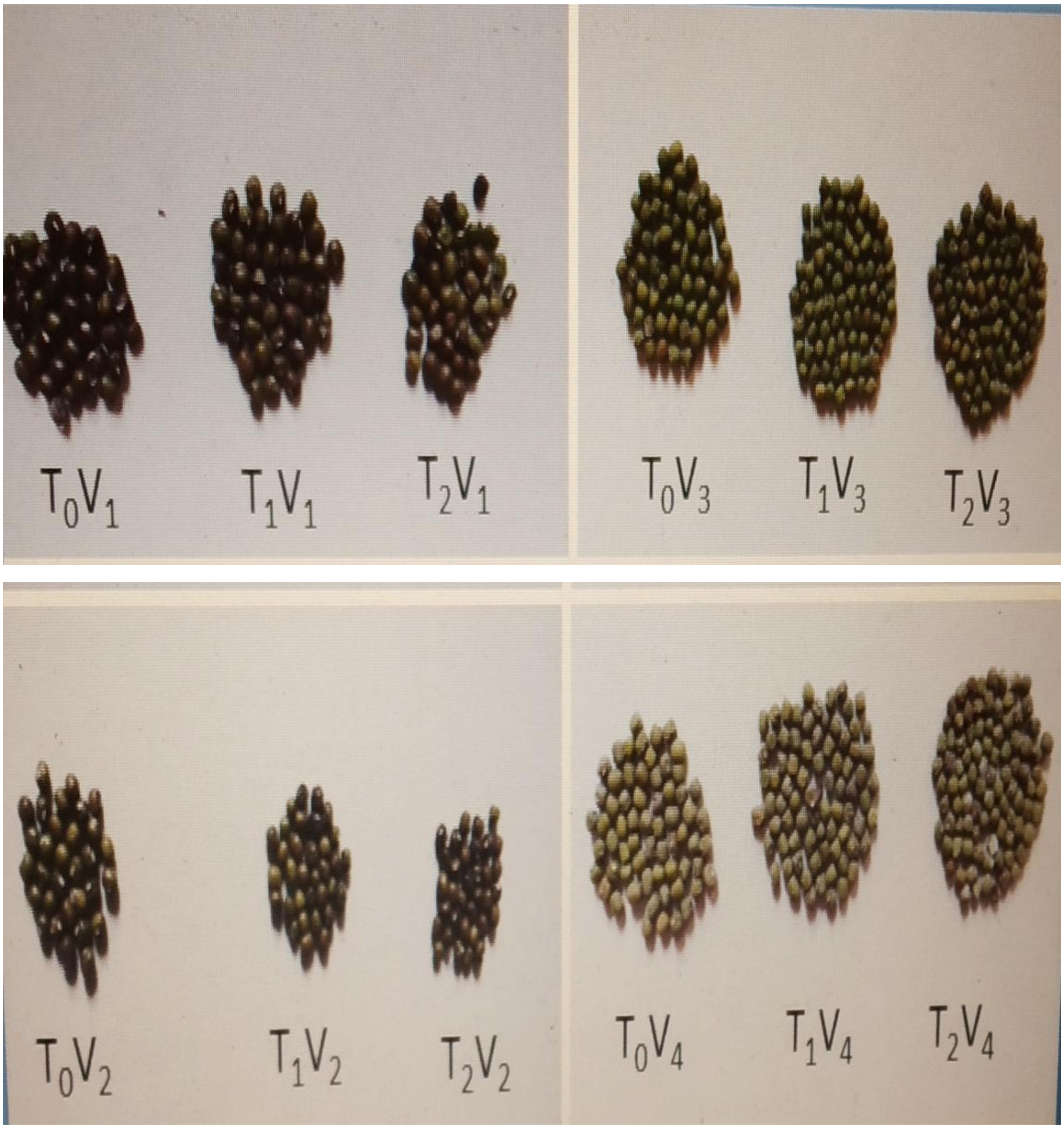


Plate 12. Effect of salinity on seed (T_0= Control (Water), T_1= 4 dSm^{-1} and T_2= 8 dSm^{-1}, V_1= BARI mug 5, V_2=BARI mug 6, V_3= BMS I and V_4= BMS III)

Interaction effect on salinity levels and genotype

The interaction effect of salinity levels and genotypes on 1000-seed weight was also varied significantly (Table 17). The highest 1000-seed weight was found in BARI Mung 6 (42g) at control condition which was followed by at 4 dS/m with same variety and its lowest value (20.26g) was recorded in BMS III at 8 dS/m.

Table 17. Interaction effects between salinity level and genotypes on 1000-seed weight (g)

Salinity level	Varieties			
	BARI Mung 5	BARI Mung 6	BMS I	BMS III
Control	39.14 a-c	42 a	33.43 a-d	28.13 c-e
4 dS/m	37.26 a-c	40.7 ab	29.13 b-e	24.1 de
8 dS/m	35.4 a-d	36.6 a-c	27.5 c-e	20.26 e
SE(±)	3.3885			
$LSD_{(0.05)}$	12.32			

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

With the increased salinity levels the 1000-grain weight gradually decreased. Similar result was reported by Ayoub (1976). He reported that seed yield of lentil was reduced to 50% at soil salinity level of 3.5 mmhos/cm. The yield and yield components of black gram and mungbean (number of seed per plant, 1000 seed weight and seed yield per plant) reduced due the imposition of salt stress reconfirms by Ahmed (2009), Hossain *et al.* (2008). Dua (1992) studied that the 1000 seed weight was less affected by salinity level. Such decrease in the 1000-seed weight was expected because salinity as an environmental stress decreases the days to maturity and consequently decreases the periodof seed development and affected seed filling that means that the plants of the control treatment set their pods and filled their seeds under favorable condition, compared to those plants subjected to salinity stress.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment germination test was done at Pulse Research Centre Lab, Bangladesh Agricultural Research Institute (BARI), Gazipur in room temperature. This experiment comprised of seven mungbean varieties (BARI Mung1, BARI Mung 2, BARI Mung 4, BARI Mung 5, BARI Mung 6, BARI Mung 7, BARI Mung 8) and three germplasm (BMS I, BMS II, BMS III). Four doses of salinity namely control, 4, 8 and 12 dS/m were designated as T_0, T_1, T_2 and T_3 respectively. These varieties were evaluated in petridishes with NaCl solutions to observe the effect of saline on seed germination and root shoot growth. Germination was gradually decreased with increasing of salinity. Germination was delayed at higher salt stress. Root and shoot length were reduced at higher salinity. A significant variation of reduction of root length and shoot length were observed among all varieties but root length was more affected than shoot length specially in higher salinity. The decreasing trend of root shoot ratio indicated the higher shoot growth than root growth. From the ten genotypes, four varieties (BARI Mung 5, BARI Mung 6, BMS I, BMS II, BMS III) were chosen in terms of germination percentage at 12 dS/m for the next experiment. At 12 dS/m, BARI Mung 5 and BARI Mung 7 had the same germination percentage (50%) but root length and shoot length were more in BARI Mung 5.

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from September 2017 to November 2017 to evaluate growth and yield was attributing character. Significant variations and adaptability among stressed and non-stressed plants were observed in all varieties. The data recorded from different characters were statistically analysed to find out the significance of difference of different levels of salinity on growth and yield contributing characters of mungbean.

The tallest plant (29.75 cm) during fruiting stage was recorded in control condition and the shortest (26.12 cm) was recorded in the 8 dS/m salinity. The highest number of branch per plant was recorded at control treatment which was 5.99 and the lowest one is recoded at 8 dS/m salinity which was (5.29). Maximum number of leaves per plant at harvest (18.00) was recorded in control treatment and minimum (15.83) was recorded in the 8 dS/m salinity. Maximum leaf length, leaf breadth, chlorophyll content was recorded in control condition. The highest (9.33) number of pods per plant was obtained from control treatment. The highest number of seeds pod^{-1} (8.22) was recorded at control condition and the lowest (6.30) was recorded at 8 dS m^{-1} level of soil salinity. Similar results were found in case of total no of pod/pot, pod length (cm), pod breadth (cm). The pod weight was gradually decreased with the increased salinity levels. Weight of pod/pot (g), pod/plant (g), individual pod weight (g), 1000 seed weight (g) all were highest in control condition and lowest at 8 dS/m.

BARI Mung 6 was produced the tallest (33.83cm) plant. The highest number of branches ware recorded in BMS I (7.00) and lowest was in BARI Mung 6 (4.95). Among four varieties BMS I was produced higher (55.41) chlorophyll content than other variety. BMS I produced highest no of pod/pot, pod/plant, pod length (cm), no. of seed /pod. Weight of pod/pot (g) and pod/plant (g) was also higher in BMS I.

The interaction effect of salinity and variety was statistically significant in all the maximum parameter. In 8 dS/m salinity, tallest (31.16cm) plant was observed in BARI Mung 6. No. of branch and no. of leaf was higher in BMS I. BMS I produced higher no of pod/pot (65.40), pod/plant (10.9) and seed/pot (7.55) in 8 dS/m salinity. Weight of pod/pot was (22.80g) higher in BMS I than the other variety. In maximum cases BMS III produced lower growth and yield.

CONCLUSION

Salinity stress is one of the most atrocious environmental factors restricting the productivity of mungbean in arid and semiarid regions. Considering the findings of the present experiment following conclusions may be drawn-

- Germination % was higher in most of the variety at control and decreased with increasing salinity level. At 12 dS/m germination percentage was highest in BMS III.
- Tallest plant was found in BARI Mung 6 (36 cm) and shortest was in BMS III (18cm) at 8 dS/m salinity.
- Maximum number of pods per plant obtained from BMS I (15.02) at control and the minimum was in BARI Mung 5 at (3.24) at 8 dS/m salinity level.
- The highest 1000-seed weight -BARI Mung 6 (42g) at control condition and the lowest - in BMS III (20.26g) at 8 dS/m.
- The BMS I was more salinity tolerant than BARI Mnug 6, BARI Mung 5 and BMS III.

Therefore, BMS I and BARI Mnug 6 can be added in the existing cropping pattern in saline area.

CHAPTER VI

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from September 2017 to December 2017

Month	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
September	35	25	81	25
October	26.5	19.4	81	22
November	25.8	16.0	78	00
December	22.4	13.5	74	00

Source: Bangladesh Meteorological Department (Climate and weather division), Agargoan, Dhaka- 1212

Appendix III. List of necessary tables for result and discussion.

Table 1. Effect of salinity level on plant height (cm) of mungbean genotypes

treatment	Plant height at vegetative stage	Plant height at fruiting stage
Control	21.58 a	29.75 a
4 dS/m	20.70 ab	28.00 ab
8 dS/m	19.08 b	26.12 b
SE(±)	0.8173	1.0569
$LSD_{(0.05)}$	2.05	2.66

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 2.Varietal effect of saline on plant height (cm)

treatment	Plant height at vegetative stage	Plant height at fruiting stage
BARI Mung 5	19.06 b	25.67 b
BARI Mung 6	24.06 a	33.83 a
BMS I	19.67 b	27.11 b
BMS III	19.06 b	25.22 b
SE(±)	0.9437	1.2204
$LSD_{(0.05)}$	2.26	3.39

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 3. Effect of salinity level on number of branch of mungbean genotypes

treatment	No. of branches at vegetative stage	No. of branches at fruiting stage
Control	4.67 a	5.99 a
4 dS/m	4.07 b	5.41 b
8 dS/m	3.98 b	5.29 b
SE(±)	0.0792	0.1959
$LSD_{(0.05)}$	0.19	0.49

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 4. Varietal effect of saline on number of branch

treatment	No. of branches at vegetative stage	No. of branches at fruiting stage
BARI Mung 5	3.88 b	5.00 b
BARI Mung 6	3.53 c	4.95 b
BMS I	5.55 a	7.00 a
BMS III	4.98 b	5.32 b
SE(±)	0.0915	0.2262
$LSD_{(0.05)}$	0.25	0.63

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 5. Effect of salinity level on number of leaf of mungbean genotypes

treatment	No. of Leaf at vegetative stage	No. of Leaf at fruiting stage
Control	14.09 a	18.00 a
4 dS/m	12.33 b	16.25 b
8 dS/m	12.00 b	15.83 b
SE(±)	0.6043	0.2531
$LSD_{(0.05)}$	1.94	0.64

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 6. Varietal effect on number of leaf of four mungbean plants grown under different saline conditions

treatment	No. of Leaf at vegetative stage	No. of Leaf at fruiting stage
BARI Mung 5	11.67 b	15.00 c
BARI Mung 6	10.67 b	14.67 c
BMS I	16.78 a	21.11 a
BMS III	12.11 b	16.00 b
SE(±)	0.6978	0.2923
$LSD_{(0.05)}$	1.93	0.81

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 7. Effect of salinity level on leaf width (cm) of mungbean genotypes

treatment	Leaf width at vegetative stage (cm)	Leaf width at fruitng stage (cm)
Control	3.70 a	4.50 a
4 dS/m	3.78 a	3.96 b
8 dS/m	2.54 b	4.21 ab
SE(±)	0.0552	0.1251
$LSD_{(0.05)}$	0.14	0.31

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 8. Varietal effect of saline on leaf width (cm)

treatment	Leaf width at vegetative stage (cm)	Leaf width at fruitng stage (cm)
BARI Mung 5	4.47 a	5.10 a
BARI Mung 6	4.21 b	4.88 a
BMS I	3.09 c	3.47 b
BMS III	2.93 c	3.45 b
SE(±)	0.0637	0.1445
$LSD_{(0.05)}$	0.18	0.40

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 9. Effect of salinity level on leaf breadth (cm) of mungbean genotypes

treatment	Leaf breadth at vegetative stage (cm)	Leaf breadth at fruiting stage (cm)
Control	6.12	6.27 a
4 dS/m	6.22	6.14 ab
8 dS/m	6.03	5.98 b
SE(±)	0.3150	0.1074
$LSD_{(0.05)}$	0.34	0.27

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 10. Varietal effect of saline on leaf breadth (cm)

treatment	Leaf breadth at vegetative stage (cm)	Leaf breadth at fruiting stage (cm)
BARI Mung 5	7.08 a	7.25 a
BARI Mung 6	6.15 ab	6.08 b
BMS I	5.91 b	5.92 b
BMS III	5.35 b	5.26 c
SE(±)	0.3637	0.1240
$LSD_{(0.05)}$	1.01	0.27

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 11. Effect of salinity level on of mungbean genotypes on chlorophyll content

treatment	Chlorophyll content at vegetative stage	Chlorophyll content at flowering stage	Chlorophyll content at fruiting stage
Control	48.46 a	56.34 a	50.05 a
4 dS/m	46.91ab	53.32 ab	43.10 b
8 dS/m	44.87 b	49.72 b	36.45 c
SE(±)	1.1500	2.5899	1.0072
$LSD_{(0.05)}$	2.9-3	6.5	2.53

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 12. Varietal effect of saline on chlorophyll content

treatment	Chlorophyll content at vegetative stage	Chlorophyll content at flowering stage	Chlorophyll content at fruiting stage
BARI Mung 5	45.79 b	50.82	42.54 b
BARI Mung 6	50.23 a	53.65	49.73 a
BMS I	46.15 b	55.41	43.71 b
BMS III	44.81 b	52.65	36.83 c
SE(±)	1.3279	2.9905	1.1630
$LSD_{(0.05)}$	3.7-3.87	8.3	3.23

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 13. Effect of salinity level on pod breadth and pod length of mungbean genotypes (cm)

treatment	Pod length (cm)	Pod breadth(cm)
Control	4.59 a	1.90 a
4 dS/m	4.08 b	1.70 b
8 dS/m	3.70 c	1.61 b
SE(±)	0.0826	0.0463
$LSD_{(0.05)}$	0.08	0.11

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 14. Varietal effect of saline on pod breadth and pod length (cm)

treatment	Pod length (cm)	Pod breadth(cm)
BARI Mung 5	3.57 c	2.03 a
BARI Mung 6	4.51 a	1.71 b
BMS I	4.37 a	1.65 bc
BMS III	4.03 b	1.54 c
SE(±)	0.0954	0.0535
$LSD_{(0.05)}$	0.20	0.15

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 15. Effects of salinity levels on no. of pod/plant

treatment	no. of pod/plant
Control	9.33 a
4 dS/m	7.78 b
8 dS/m	6.25 c
SE(±)	0.3030
$LSD_{(0.05)}$	0.76

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 16. Varietal effect of saline on number of pod/plant

treatment	no. of pod/plant
BARI Mung 5	4.24 d
BARI Mung 6	6.18 c
BMS I	12.77 a
BMS III	7.974 b
SE(±)	0.3499
$LSD_{(0.05)}$	0.97

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 17. Effect of salinity level on number of seed/pod of mungbean genotypes

treatment	No. of seed per pod
Control	8.22 a
4 dS/m	7.12 b
8 dS/m	6.30 b
SE(±)	0.3469
$LSD_{(0.05)}$	0.87

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 18. Varietal effect of saline on number of seeds/pod

treatment	No. of seed per pod
BARI Mung 5	5.55 c
BARI Mung 6	7.33 b
BMS I	8.59 a
BMS III	7.36 b
SE(±)	0.4006
$LSD_{(0.05)}$	1.11

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 19. Effect of salinity level on number of pod per pot of mungbean genotypes

treatment	Total no. of pod/pot
Control	56.02 a
4 dS/m	46.69 b
8 dS/m	37.50 c
SE(±)	1.24
$LSD_{(0.05)}$	4.58

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 20. Varietal effect of saline on number of pod per pot

treatment	Total no. of pod/pot
BARI Mung 5	25.46 d
BARI Mung 6	37.08 c
BMS I	76.57 a
BMS III	47.84 b
SE(±)	1.43
$LSD_{(0.05)}$	5.84

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 21. Effect of salinity level on individual pod weight (g) of mungbean genotypes

treatment	individual pod weight(g)	
	fresh wt. of one pod (g)	dry wt. of one pod (g)
Control	0.37 a	0.33 a
4 dS/m	0.32 b	0.27 b
8 dS/m	0.28 c	0.25 b
SE(±)	7.596	0.0120
$LSD_{(0.05)}$	0.02	0.03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 22. Varietal effect of saline on individual pod weight (g)

treatment	individual pod weight(g)	
	fresh wt. of one pod(g)	dry wt. of one pod(g)
BARI Mung 5	0.38 a	0.33 a
BARI Mung 6	0.37 a	0.33 a
BMS I	0.31 b	0.26 b
BMS III	0.25 c	0.21 c
SE(±)	8.771	0.0139
$LSD_{(0.05)}$	0.02	0.04

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 23. Effect of salinity level on pod weight (g) per pot of mungbean genotypes

treatment	Wt. of pod/pot (g)
Control	33.16 a
4 dS/m	22.69 b
8 dS/m	14.06 c
SE(±)	0.3598
$LSD_{(0.05)}$	0.90

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 24. Varietal effect of saline on pod weight (g) per pot

treatment	Wt. of pod/pot (g)
BARI Mung 5	11.21 d
BARI Mung 6	27.21 b
BMS I	38.20 a
BMS III	16.59 c
SE(±)	0.4154
$LSD_{(0.05)}$	1.16

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 25. Effect of salinity level on wt. of pod/plant (g) of mungbean genotypes

treatment	Wt. of pod/plant(g)
Control	5.5133 a
4 dS/m	3.7758 b
8 dS/m	2.3458 c
SE(±)	0.0805
$LSD_{(0.05)}$	0.20

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 26. Varietal effect of saline on wt. of pod/plant (g)

treatment	Wt. of pod/plant(g)
BARI Mung 5	1.87 d
BARI Mung 6	4.51 b
BMS I	6.36 a
BMS III	2.75 c
SE(±)	0.0930
$LSD_{(0.05)}$	2.59

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Table 27. Effect of salinity level on 1000-seed weight (g) of mungbean genotypes

treatment	1000 seed wt. (g)
Control	35.67 a
4 dS/m	32.80 ab
8 dS/m	29.94 b
SE(±)	1.6943
$LSD_{(0.05)}$	4.26

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly

Table 28. Response of mungbean varieties on 1000-seed weight (g)

treatment	1000 seed wt. (g)
BARI Mung 5	37.27 a
BARI Mung 6	39.76 a
BMS I	30.02 b
BMS III	24.17 c
SE(±)	1.9564
$LSD_{(0.05)}$	5.43

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly.

Appendix III: Analysis of variance tables

Table 1: Analysis of variance on germination percentage (%)

Source	**DF**	**SS**	**MS**	**F**	**P**
replication	2	1167	583.5		
variety	9	91558	10173.1	1705.53	0.0000
treat	3	17627	5875.7	985.07	0.0000
variety*treat	27	12426	460.2	77.16	0.0000
Error	78	465	6.0		
Total	119	123243			
Grand Mean 66.306					
CV 3.68					

Table 2: Analysis of variance root length (mm) at 6th day

Source	DF	SS	MS	F	P
replication	2	147.0	73.52		
variety	9	4772.7	530.30	493.98	0.0000
treat	3	24551.7	8183.90	7623.30	0.0000
variety*treat	27	5588.9	206.99	192.82	0.0000
Error	78	83.7	1.07		
Total	119	35144.1			
Grand Mean	23.594				
CV	4.3				

Table 3: Analysis of variance shoot length (mm) at 6th day

Source	DF	SS	MS	F	P
replication	2	303	151.5		
variety	9	10846	1205.1	420.97	0.0000
treat	3	101898	33965.9	11865.51	0.0000
variety*treat	27	17360	643.0	224.61	0.0000
Error	78	223	2.9		
Total	119	130630			
Grand Mean	36.129				
CV	4.68				

Table 4: Analysis of variance reduction of root length (%)

Source	DF	SS	MS	F	P
replication	2	56.5	28.26		
variety	9	8775.1	975.01	687.39	0.0000
treat	3	23321.0	7773.67	5480.47	0.0000
variety*treat	27	10953.7	405.69	286.02	0.0000
Error	78	110.6	1.42		
Total	119	43217.0			
Grand Mean	12.585				
CV	9.46				

Table 5: Analysis of variance reduction of shoot length (%)

Source	**DF**	**SS**	**MS**	**F**	**P**
replication	2	522	260.8		
variety	9	29600	3288.8	529.41	0.0000
treat	3	100647	33549.0	5400.45	0.0000
variety*treat	27	18473	684.2	110.14	0.0000
Error	78	485	6.2		
Total	119	149726			
Grand Mean	41.622				
CV	5.99				

Table 6: Analysis of variance root shoot ratio

Source	**DF**	**SS**	**MS**	**F**	**P**
replication	2	1.196	0.5978		
variety	9	21.226	2.3585	150.52	0.0000
treat	3	100.071	33.3569	2128.82	0.0000
variety*treat	27	34.113	1.2634	80.63	0.0000
Error	78	1.222	0.0157		
Total	119	157.828			
Grand Mean	1.2185				
CV	10.27				