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# Germination and early seedling growth of mungbean (*Vigna radiata* L.) as influenced by salinity

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**ABSTRACT**

Five genotypes of mungbean under three salinity levels (0, 75 and 150 mM) were tested to investigate the germination traits of this crop under salt stress. BARI Mung-5 showed the lowest (GP) reduction (18.18% to control) while the highest reduction of GP (34.78%) was recorded in BARI Mung-2 at high level of salt stress (150 mM NaCl).At high salt stress the GR reduced more (34.77%) in BARI Mung-2 while the reduction was only 18.17% in BARI Mung-5. The coefficient of velocity of germination (CVG) of BARI Mung-2 diminished more but comparatively less inhibition was recorded in BARI Mung-5 under both salt stresses. The highest and the lowest mean germination time (MGT) were observed in BARI Mung-2 and BARI Mung-5, respectively. At 150 mM NaCl conditions, the lowest reduction in shoot length was recorded (40.81%) in BARI Mung-5 and dry weight, shoot length, root length, shoot fresh and dry weight, vigor index and salt tolerance index significantly reduced in all varieties under saline condition. Based on above all these parameters we can arranged all the varieties in such way in salt tolerance BARI Mung-5 > BARI Mung-6 > BARI Mung-4 > BARI Mung-3 > BARI Mung-2. From germination test, it can be declared that BARI Mung-5 and BARI Mung-2 are the most salt tolerant and most susceptible varieties at early growth stages, respectively among all the studied varieties.

## INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) is an important grain legume among the pulses in Bangladesh. It's contributed 6.5% of the total pulse production in our country. In Bangladesh, total production of mungbean was 225,500 tons from an area of 205700 hectares in 2015-16 (AIS 2017). Mungbean seed contains 1-3% fat, 5.4% carbohydrates, 25.67% protein, 3.5-4.5% fibers and 4.5-5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque et al. 2000). It is highly nutritious and the green pods are eaten as vegetable. Being a legume, it enriches soil health through biological N fixation and is the cheapest source of dietary protein for human and livestock. Mungbean helps to reduce the cost for nitrogen fertilizers through symbiotic association of roots and rhizobia as reported by Limpens and Bisseling (2003). Although mungbean is a significant grain crop in South East Asian countries like Bangladesh, India, Pakistan, Nepal, Sri Lanka and Bhutan but its genetic potential is not yet obtained at the field due to different biotic and abiotic stresses.

Environmental stresses adversely affect growth and productivity of plants, particularly those which are sensitive to salinity and alkalinity (Islam 2011). The loss of potentially cultivable land is likely to increase over the next 20 years and threats the world food supply (Islam 2012). One of the main reasons of the reducing arable land is either due to natural salinity or induced by human activities (Mahajan and Tuteja 2005; Hasanuzzaman et al. 2013). Salinity stress cause severe changes in growth, physiology and metabolism of plants, thus threatening the cultivation of plants around the globe (Lunde et al. 2007). Salinity causes a reduction in growth rate, yield and quality of crops (EL Sabagh et al.

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2015a,b,c; Abd el-wahed et al. 2015; Hasan et al. 2017), as well as changes in plant metabolic processes (Munns 2002). Furthermore, it decreases plant growth and yield, depending on the plant species, salinity levels, and ionic composition of the salts (Yadav et al. 2010). Saline stress is one of the main factors limiting legume productivity in arid and semi-arid regions (Luch et al. 2007). Salinity adversely affects the plant growth and development, hindering seed germination (Dash and Panda 2001). Seed germination is usually the most critical stage in seedling establishment, determining successful crop production (Almansourie et al. 2001; Bhattacharjee 2008). Salinity stress creates potential problems during the seed germination and survival of seedlings. The crop performance largely determines by germination of seeds which is more susceptible to soil salinity than established plants (Kumar et al. 2008). The chain of various steps that proceeds to protrusion of the radicle is termed as germination. The balance of imbibition forces of seeds and osmotic forces of soil solution are the determining fact for water uptaking in germination. The lowering water uptake and inhibiting activities of hydrolytic enzymes are the main reason for retarding the seed germination during salt stress (Dubey and Rani 1990; Kumar et al. 1996). Mandal and Singh (2000) reported that salinity stress greatly varied the germination and seedling growth in different crop cultivars. It is generally accepted that the germination and early seedling stages of plant's life cycle is more sensitive to salinity than the adult stage. For the successful field establishment, good crop stands as well as for higher yield, seeds should have the ability to germinate and seedlings growth properly under salt stress. The superior performance regarding germination and seedling growth traits under salt stress has been used as a selection criterion for recognizing salt tolerant individuals. Therefore, the present research work was undertaken to know the effect of salt stress on the germination and early seedling growth of mungbean and to find out the most salt tolerant variety.

## MATERIALS AND METHODS

This research work was carried out to investigate the effect of salt stress on the germination of mungbean varieties at the Agronomy Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Bangladesh during March, 2014. The daily weather data (average) on temperature and humidity during experimental period were recorded regularly by the HOBO U12 Family of Data Loggers (MicroDAQ.com) at the Meteorological Station, HSTU, Dinajpur. The temperature ranged from 17.2 to 30.8$^{o}$C and the average temperature was around 23.6$^{o}$C during seed germination and seedling growth test. The minimum humidity of those days was 57% and maximum was 78%. The data on temperature (maximum, minimum and average) and humidity are presented in figure 1.

The experiment was carried out in thrice with completely randomized design (CRD) with three replications. Three salinity levels (0, 75 and 150 mM NaCl) were imposed within five mungbean varieties (BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5 and BARI Mung-6). The characteristics of those varieties are presented in Table 1.

Seeds of five mungbean varieties were surface sterilized by dipping the seeds in 1% mercuric chloride solution for 2 minutes and rinsed thoroughly with sterilized water. Saline solutions (75 and 150 mM) were prepared dissolving calculated amount of NaCl in tap water. Tap water was used as control. The plastic glassware (7.5 cm diameter and 11.3 cm height) contains twenty seeds of each genotype on sand bed irrigated with control

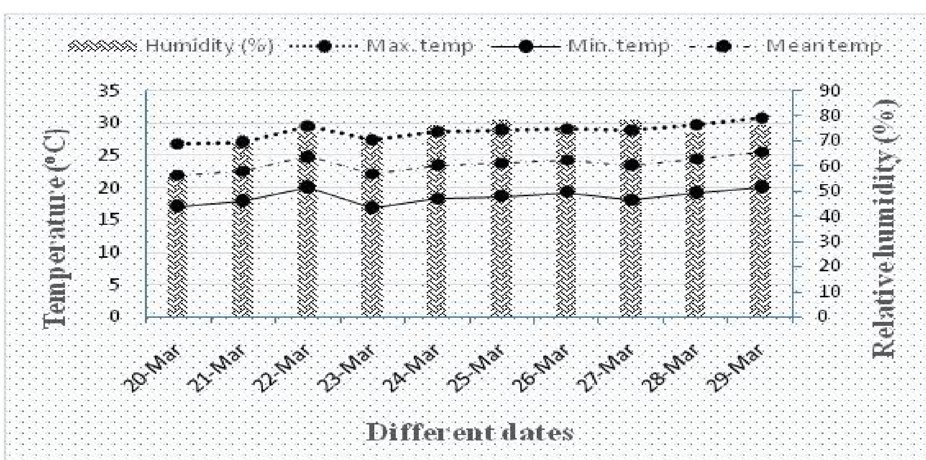


Figure 1. The average monthly temperature (maximum, minimum and average) and humidity during the experimentation

Table 1. Characteristics of existing mungbean varieties used in the present research

| Varieties | Year of release | Life span (days) | Plant height (cm) | 1000-grain weight (g) | Major diseases and pest |
|---|---|---|---|---|---|
| BARI Mung-2 | 1987 | 60-65 | 40-45 | 30-40 | Highly tolerant to *yellow mosaic virus and Cercospora leaf spot* |
| BARI Mung-3 | 1996 | 60-65 | 50-55 | 28-29 | Highly tolerant to *yellow mosaic virus and Cercospora leaf spot* |
| BARI Mung-4 | 1996 | 50-55 | 50-55 | 28-32 | Highly tolerant to *yellow mosaic virus and Cercospora leaf spot* |
| BARI Mung-5 | 1997 | 60-65 | 40-42 | 40-42 | Highly tolerant to *yellow mosaic virus and Cercospora leaf spot* |
| BARI Mung-6 | 2003 | 55-60 | 40-45 | 51-52 | Highly tolerant to *yellow mosaic virus and leaf spot* |

and saline solution as per treatment and incubated at room temperature. Plastic glasses were used instead of petri-dishes to avoid coiling of roots. They were properly irrigated for the better seedling growth and development.

Germination was counted at daily interval and continued up to 10th day (240 h). About 2 mm long radicle was considered as germinated seed. Finally germination percentage was calculated by using the following formulae.

$$\text{Germination percentage} = \frac{\text{No. of seeds germinated at final count}}{\text{No. of seeds placed for germination}} \times 100$$

Maghsoudi and Arvin (2010) reported the formulae for determining rate of germination.

$$\text{Rate of germination (\%)} = \frac{\text{No. of seeds germinated at 72 h}}{\text{No. of seeds germinated at 240 h}} \times 100$$

Coefficient of velocity of germination (CVG) was evaluated according to Maguire (1962):

$$\text{CVG} = \frac{(G1 + G2 + G3 + \cdots \ldots \ldots + Gn)}{(1 \times G1 + 2 \times G2 + 3 \times G3 + \cdots \ldots \ldots + n \times Gn)}$$

Where, *G* is the number of germinated seeds and *n* is the last day of germination.

The mean germination time (MGT) was calculated by the following equation proposed by Ellis and Roberts (1981):

$$MGT = \frac{\sum (D \times n)}{\sum n}$$

Where, *n* is the number of seeds germinated on each day and *D* is the day of counting. Cotyledons were not included in fresh and dry weight comparisons.

The seedlings from each plastic glass were collected as a sampling after 10 days of the placement for germination.

Length of shoot and root of individual seedling were recorded manually with scale. The mean lengths (cm) were calculated as per treatment combination. Shoot and root were weighed separately in fresh condition. The mean shoot and root fresh weight were calculated by total weight divided by total no. of plants. The mean and dry weights (mg) were calculated for each treatment combination.

Vigor index (VI) was calculated by using the formula of Baki and Anderson (1973) as shown below: Vigor index (VI) = Germination (%) X (Mean shoot length + mean root length).

Salt tolerance index was calculated as (Goudarzi and Pakniyat 2008) by the following formula:

$$\text{Salt tolerance index} = \frac{\text{Variable measured under stress condition}}{\text{Variable measured under normal condition}}$$

The data were analyzed with the help of computer using 'R' command program.

## RESULTS AND DISCUSSIONS

### Germination percentage

Salinity caused considerable delay and reduction in seed germination (Table 2). The germination percentage (GP) of different varieties drastically reduced and they showed dissimilar results with increasing salt stress.

There is a considerable reduction of GP in the

Table 2. Germination percentage of mungbean genotypes as influenced by salt stress

| Genotypes | Germination percentage | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 76.67 efg | 66.67 ij | 13.04 | 50.00 l | 34.78 |
| BARI Mung-3 | 80.00 cdef | 70.00 hi | 12.5 | 55.00 k | 31.25 |
| BARI Mung-4 | 85.00 bc | 78.33 def | 7.85 | 63.33 j | 25.49 |
| BARI Mung-5 | 91.67 a | 85.00 bc | 7.28 | 75.00 fgh | 18.18 |
| BARI Mung-6 | 85.00 bc | 71.67 bc | 15.68 | 58.33 k | 31.38 |
| LSD | | | 4.43 | | |
| CV (%) | | | 4.57 | | |

Table 3. Germination rate of mungbean genotypes as influenced by salt stress

| Genotypes | Rate of germination | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 15.33 defg | 13.33 ij | 13.05 | 10.00 m | 34.77 |
| BARI Mung-3 | 16.00 de | 14.00 ghij | 12.50 | 11.00 lm | 31.25 |
| BARI Mung-4 | 17.00 bcd | 15.67 def | 7.82 | 12.67 jk | 25.47 |
| BARI Mung-5 | 18.33 ab | 17.00 bcd | 7.25 | 15.00 efgh | 18.17 |
| BARI Mung-6 | 17.00 bcd | 14.33 fghi | 15.70 | 11.67 kl | 31.35 |
| LSD | | | 1.49 | | |
| CV (%) | | | 6.13 | | |

salinity level of 75 mM for almost all the varieties except BARI Mung-5 and BARI Mung-4 which appeared to be less reduction of GP over control condition. The GP of BARI Mung-5 and BARI Mung-4 were recorded 75 and 65.33% at 150 mM NaCl and as compared to control the rate of reduction was only 18.18 and 25.49 percent, respectively. A progressive reduction of GP was observed in all the varieties at 150 mM NaCl. Based on GP, the varieties can be arranged in the following order: BARI Mung-5>BARI Mung-4>BARI Mung-6>BARI Mung-3>BARI Mung-2 at 150 mM. This is due to the inadequate supply of water resulting the low osmotic potential. Germination percentages greatly varied between the control treatment and the salt treatments (100, 150 and 200 mM NaCl) as reported by (Al-Seedi and Gatteh 2010). These results are in general agreement with the findings of Sehrawat et al. (2013) and Kandil et al. (2012) in mungbean. Low water potential due to solute potential arisen from salinity is a determining factor inhibiting the seed germination (Debez et al. 2004).

**Rate of germination**

Germination rates (GR) were recorded daily up to 10 days for all the varieties under different treatments during germination (Table 3). At 75 mM saline stress the highest GR was obtained in BARI Mung-5 and the lowest was in BARI Mung-2 and the reduction was 7.25 and 7.82%, respectively (Table 3). Similar results were also observed in BARI Mung-5 and the BARI Mung-2 under at high salt (150 mM) stress. Germination process can be considered in terms of three sequential steps: imbibition (corresponding to the time necessary for the apparition of the first germination), metabolism (leading to initiation of radicle growth representing a fast increase in the rate of germination), and radicle growth (leading to radicle emergence corresponding a final rate of germination). Seed germination reduced by salinity through creating an external osmotic potential. Inhibition in germination had also been reported by (Kumar et al. 2008). Salinity creates the toxic and osmotic effects of salt ions especially sodium and chloride have the negative effect on germination (Tester and Davenport 2003). Salinity reduced the germination in mungbean also reported by Kandil et al. (2012). The present results agree with those reported by Pujol et al. (2000) in halophytes, Babbar et al. (2007) in mungbean, Cokkizgin (2012) in common bean, who observed that an increase in salinity induces both a reduction in the percentage of germinating seeds.

**Coefficient of velocity of germination**

Coefficient of velocity of germination in mungbean showed significant variation due to salt stress (Table 4). BARI Mung-5 produced the maximum (0.2141) CVG value in among all the mungbean genotypes in control condition as well as the minimum reduction (2.55%) was observed at 75 mM NaCl salt stress while the maximum reduction (10.93%) was observed in BARI Mung-2 at the same treatment. At higher salt stress (150 mM), BARI Mung-5 produced the minimum reduction (14.47%) of CVG while the maximum (16.74%) was observed in BARI Mung-2 (Table 3). On the basis of CVG, we can arrange the salt tolerance rank as follows: BARI Mung-5> BARI Mung-6> BARI Mung-4> BARI Mung-3> BARI Mung-2. This result might be due to that osmotic potentiality greatly hampered by NaCl salt stress. These results are also in agreement with those reported by Katembe et al. (1998) in *Atriplex* species. Sunita et al. (2013) reported that the increased NaCl concentration negatively affected the CVG of *Tephrosia purpurea* (L.) seed.

Table 4. Coefficient of velocity of germination (CVG) of mungbean genotypes as influenced by salt stress

| Genotypes | Coefficient of Velocity of Germination (CVG) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 0.2049ab | 0.1825bcd | 10.93 | 0.1706d | 16.74 |
| BARI Mung-3 | 0.2089ab | 0.1969abc | 5.74 | 0.1743cd | 16.56 |
| BARI Mung-4 | 0.2104a | 0.1990abc | 5.41 | 0.1780cd | 15.40 |
| BARI Mung-5 | 0.2141a | 0.2087ab | 2.55 | 0.1831bcd | 14.47 |
| BARI Mung-6 | 0.2116a | 0.2054ab | 2.95 | 0.1795cd | 15.17 |
| LSD | | | 0.022 | | |
| CV (%) | | | 0.76 | | |

Table 5. Mean germination time of mungbean genotypes as influenced by salt stress

| Genotypes | Mean Germination Time (Days) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Increase | 150 mM | % Increase |
| BARI Mung-2 | 4.881f | 5.481d | 12.29 | 5.861a | 20.08 |
| BARI Mung-3 | 4.787g | 5.078e | 6.08 | 5.737b | 19.84 |
| BARI Mung-4 | 4.754g | 5.025e | 6.26 | 5.617c | 18.15 |
| BARI Mung-5 | 4.671h | 4.791g | 2.57 | 5.461d | 16.91 |
| BARI Mung-6 | 4.727gh | 4.861f | 2.84 | 5.550cd | 17.41 |
| LSD | | | 0.078 | | |
| CV (%) | | | 0.71 | | |

### Mean germination time

Mean germination time (MGT) was greatly varied among the mungbean genotypes due to salinity stress. Among all of the treatment combinations and genotypes the mean germination time was decreasing with increasing the salinity levels (Table 5). The minimum MGT increasing (2.57%) rate was recorded in BARI Mung-5 whereas BARI Mung-2 takes the maximum time (5.48 days) to germinate as well as the increasing MGT (12.29%) is the maximum at 75 mM NaCl salt stress. BARI Mung-5 and BARI Mung-6 provided the less than 17.5% increasing rate of MGT while BARI Mung-2, BARI Mung-3 and BARI Mung-4 provided the more than 18.1% increasing rate of MGT under the highest salt stress (150 mM NaCl stress.) Nasri et al. (2015) reported that the mean germination time (MGT) was greatly reduced in lettuce with imposing the salt stress. It seems that, NaCl concentration (salinity stress) affects on seed germination via limitation of water absorption by seeds (Dodd and Donovan 1999). Similar results were proposed by Salehi et al. (2013) in tomato. It was observed during the study that there is significant difference in MGT after NaCl treatment (Sunita et al. 2013).

The initiation of the germination process and as well as the percentage of germinating seeds greatly hampered by salt stress as reported by Pujol et al. (2000). Salt stress beyond the tolerance limits of the species can also cause a complete inhibition of the germination process. Similar trends in various crops were also reported by Welbaum et al. (1990) in muskmelon, Rahman et al. (2000) in rice, Murillo-Amador et al. (2002) in cowpea, Mensah and Ihenyen (2009) in mungbean.

### Seedling growth properties under salt stress

### Shoot length

Salt stress reduced the length of shoot in all the varieties of mungbean (Table 6). The lowest shoot length reduction due to salinity was recorded at BARI mung-5 and the highest reduction was recorded at BARI Mung-2 among all of the varieties in all salinity levels. BARI Mung-5 produced the highest shoot length (24.28 cm) and BARI Mung-2 produced the lowest (20.01cm) under control condition. At high levels of salinity the highest reduction were recorded (53.97% to control) at BARI Mung-2 and the lowest rate of reduction (40.81%) was recorded in BARI Mung-5. The most common salinity effect is a general stunning of plant growth. Mayer et al. (1973) reported that the different vital activities of plants, such as a depression on the enzymes activities, metabolism, cells division and photosynthesis as well as the reduction of plant growth under salt stress. These results are in line with Pujol et al. (2000) and Al-Seedi (2004), who observed that an increase in salinity induces to delay the initiation of the germination process. Salinity deteriorated seed-germination features at high NaCl osmotic potentials during germination.

### Root length

Salinity stress significantly affected the root length in mungbean varieties as compared to the control (Table 7). BARI Mung-2, BARI Mung-3, BARI Mung-4 and BARI Mung-6 reduced root length more than 17% whereas, BARI Mung-5 reduced less than 11.06% under moderate stress (75 mM NaCl). At high salt stress (150 mM NaCl), BARI Mung-2, BARI Mung-3, BARI Mung-4 and BARI Mung-6 reduced root length more than 40%.

Table 6. Shoot length of mungbean genotypes as influenced by salt stress

| Genotypes | Shoot length (cm) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI mung 2 | 20.01 bc | 16.08 h | 19.64 | 9.21 m | 53.97 |
| BARI Mung-3 | 20.37 def | 15.36 hi | 24.59 | 10.34 lm | 49.23 |
| BARI Mung-4 | 21.55 cd | 14.69 hij | 31.83 | 11.24 kl | 47.84 |
| BARI Mung-5 | 24.28 a | 19.95 ef | 17.83 | 14.37 ij | 40.81 |
| BARI Mung-6 | 23.19 ab | 18.05 g | 22.16 | 11.11 kl | 52.09 |
| LSD | | | 1.33 | | |
| CV (%) | | | 4.77 | | |

Table 7. Root length of mungbean genotypes as influenced by salt stress

| Genotypes | Root length (cm) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 7.04 ef | 5.05 hi | 28.26 | 2.82 k | 59.94 |
| BARI Mung-3 | 7.58 de | 6.04 g | 20.32 | 3.53 j | 53.39 |
| BARI Mung-4 | 8.07 bc | 6.53 fg | 19.08 | 4.53 i | 43.87 |
| BARI Mung-5 | 9.04 a | 8.04 cd | 11.06 | 6.55 fg | 27.54 |
| BARI Mung-6 | 8.60 ab | 7.10 ef | 17.44 | 5.10 hi | 40.70 |
| LSD | | | 0.65 | | |
| CV (%) | | | 6.11 | | |

Table 8. Shoot fresh weight of mungbean genotypes as influenced by salt stress

| Genotypes | Shoot fresh weight (mg) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 2.7 e | 1.77 g | 34.44 | 0.55 i | 79.63 |
| BARI Mung-3 | 3.4 d | 2.3 f | 32.35 | 0.78 hi | 77.06 |
| BARI Mung-4 | 3.5 d | 2.4 ef | 31.43 | 0.97 h | 72.29 |
| BARI Mung-5 | 5.4 a | 4.2 c | 22.22 | 2.4 ef | 55.56 |
| BARI Mung-6 | 4.81b | 3.55 d | 26.25 | 1.94 g | 59.70 |
| LSD | | | 0.35 | | |
| CV (%) | | | 7.71 | | |

BARI Mung-5 showed the lowest reduction (27.54% to control) among all the varieties at high salinity levels. Both mungbean and cowpea showed greater reduction of root growth as compared with control due to salt stress as reported by Balasubramanian and Sinha (2006). Salinity stress significantly reduced radical length by disturbing the absorption of water and nutrients from soil in roots (Mehmet Demir 2003; Muhammad and Majid 2013).

**Shoot fresh weight**

Mungbean shoot fresh weight was decreased drastically under saline stress (Table 8). The maximum reduction was found in BARI Mung-2 (34.44%) followed by BARI Mung-3 (32.35%), BARImung-4 (31.43%) and BARI Mung-6 (26.25%) at moderate saline condition (75 mM). The minimum reduction was obtained in BARI Mung-5 (22.22%) exhibits highly tolerant among all varieties of mungbean. Moreover, the greatest shoot fresh weight of mungbean significantly reduced by salinity level of 150 mM NaCl concentrations in all varieties. The highest reduction was found (79.63%) in BARI Mung-2 and the lowest was found (55.56%) in BARI Mung-5. With increasing of the salt stress from 4 to 20 EC progressively decreased the biomass of the roots and shoots in mungbean (Sing et al. 2011). This above result reconfirms the result of Mohamed and Kramany (2005) in mungbean.

**Shoot dry weight**

Shoot dry weight of mungbean significantly increased with decreasing salinity stress (Table 9). At moderate saline condition among the varieties BARI Mung-2, BARI Mung-3 and BARI Mung-6 showed 27-42% reduction whereas, BARI Mung-5 showed less than 24% reduction in shoot dry weight and showed highly salt tolerant. BARI Mung-2, BARI Mung-3 and BARI Mung-6 showed 58-78% reduction while, BARI Mung-4 and BARI Mung-5 was 55 and 52.17% under high salt stress (150 mM), respectively which indicates highly salt tolerant among all varieties. At 150 mM the lowest shoot dry weight was recorded (52.17%) in BARI Mung-5 and the highest was recorded (78.57%) in BARI Mung-2. Salt stress reduced the dry biomass as well as the rate of photosynthesis. The most common salinity effect is a general stunning of plant growth. The gradual reduction of seed germination, plant height, shoot and root length, dry matter, biomass, root, stem and leaf were reduced in mungbean due to salinity stress as reported by Nafees et al. (2010). This result was corroborated with the findings of Singh et al.

Table 9. Shoot dry weight of mungbean genotypes as influenced by salt stress

| Genotypes | Shoot dry weight (mg) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 0.14 lmno | 0.08 op | 42.85 | 0.03 q | 78.57 |
| BARI Mung-3 | 0.17 jkl | 0.10 mnop | 41.17 | 0.07 pq | 58.82 |
| BARI Mung-4 | 0.20 ijk | 0.14 lmn | 30.00 | 0.09 nop | 55.00 |
| BARI Mung-5 | 0.46 c | 0.35 ef | 23.91 | 0.22 hij | 52.17 |
| BARI Mung-6 | 0.37 de | 0.27 gh | 27.02 | 0.14 lmno | 62.16 |
| LSD | | | 0.02 | | |
| CV (%) | | | 6.94 | | |

Table 10. Root fresh weight of mungbean genotypes as influenced by salt stress

| Genotypes | Root fresh weight (mg) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 0.30 p | 0.16 q | 46.67 | 0.09 r | 70.00 |
| BARI Mung-3 | 0.47 n | 0.36 o | 23.40 | 0.16 q | 65.96 |
| BARI Mung-4 | 1.00 j | 0.79 l | 21.00 | 0.56 m | 44.00 |
| BARI Mung-5 | 1.61 d | 1.46 e | 9.32 | 1.27 h | 21.12 |
| BARI Mung-6 | 1.34 g | 1.15 i | 14.18 | 0.94 k | 29.85 |
| LSD | | | 0.022 | | |
| CV (%) | | | 1.63 | | |

Table 11. Root dry weight of mungbean genotypes as influenced by salt stress

| Genotypes | Root dry weight (mg) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 0.08 jk | 0.05 jk | 37.5 | 0.02 k | 75.00 |
| BARI Mung-3 | 0.13 ijk | 0.08 jk | 38.46 | 0.04 jk | 69.23 |
| BARI Mung-4 | 0.43 fg | 0.23 hi | 46.51 | 0.07 jk | 83.72 |
| BARI Mung-5 | 0.75 b | 0.61 cd | 18.67 | 0.41 fg | 45.33 |
| BARI Mung-6 | 0.54 de | 0.33 fgh | 38.89 | 0.12 jk | 77.78 |
| LSD | | | 0.03 | | |
| CV (%) | | | 6.44 | | |

(2011) in mungbean.

## Root fresh weight

Salt stress significantly inhibited the root fresh weight of 10 days old mungbean seedlings (Table 10). At 75 and 150 mM saline treatments the effect of salinity was dissimilar for all the varieties. BARI Mung-2, BARI Mung-3 and BARI Mung-4 showed more than 20-46.67% reduction at 75 mM saline treatment, while BARI Mung-5 and BARI Mung-6 showed 9.32 and 14.18% reduction in root fresh weight. At 150 mM NaCl, BARI Mung-2, BARI Mung-3 and BARI Mung-4 reduced more than 43% root fresh weight. On the contrary, BARI Mung-5 reduced less than 22%. Present results exhibited that when the seeds exposed to high salt stress, severe reduction in root length and root fresh weight appeared in all the mungbean varieties. However, the varieties having genetic potential for salt tolerant showed different behavior as in case of BARI Mung-5 as tolerant among all varieties in the present study. The main reason of reducing the root fresh weight may be due to a decrease in water uptake by seedling under saline condition. The fresh weight showed greater variation in mungbean genotypes and salinity levels due to salt stress (NaCl) compared to control reported by Kandil et al. (2012). These results reconfirm the finding of Sehrawat et al. (2013) in mungbean.

## Root dry weight

In this study, the reduction of the root dry weight due to salt stress showed the different pattern among all the varieties (Table 11). Under moderate salt stress (75 mM NaCl), the maximum reduction was recorded (46.51% to control) in BARI Mung-4 and the lowest reduction was recorded (18.67% to control) in BARI Mung-5 among all varieties. The root dry weight of BARI Mung-4 severely reduced (83.72%) at high salt stress (150mM NaCl), but BARI Mung-2 exhibited moderate sensitivity (75% reduction). The lowest reduction of root dry weight (45.33%) due to high salt stress was observed in BARI Mung-5 among all the varieties of mungbean under high salt stress. In this case, BARI Mung-5 showed better performance in terms of the root growth and proved to be tolerant to lower as well as high level of salinity. Gradual decreases of root dry weight with increasing salt concentrations were noticed by Al-Seedi and Gatteh (2010) in mungbean. These results for root dry weights under different concentration of salts in this study, agree with the results presented by Mohamed and Kramany (2005) and Sehrawat et al. (2013) in their study of

Table 12. Vigor index of mungbean genotypes as influenced by salt stress

| Genotypes | Vigor index (%) | | | | |
|---|---|---|---|---|---|
| | Control | 75 mM | % Reduction | 150 mM | % Reduction |
| BARI Mung-2 | 443.19abcdef | 281.59bcdefg | 36.46 | 120.23g | 72.87 |
| BARI Mung-3 | 446.25abcdef | 299.64bcdefg | 32.85 | 152.57fg | 71.86 |
| BARI Mung-4 | 503.16abcd | 332.38abcdefg | 33.94 | 199.77defg | 60.29 |
| BARI Mung-5 | 612.36a | 476.27abcde | 22.22 | 313.81abcdefg | 48.75 |
| BARI Mung-6 | 540.37ab | 360.63abcdefg | 33.26 | 189.30efg | 64.97 |
| LSD | | | 42.83 | | |
| CV (%) | | | 7.28 | | |

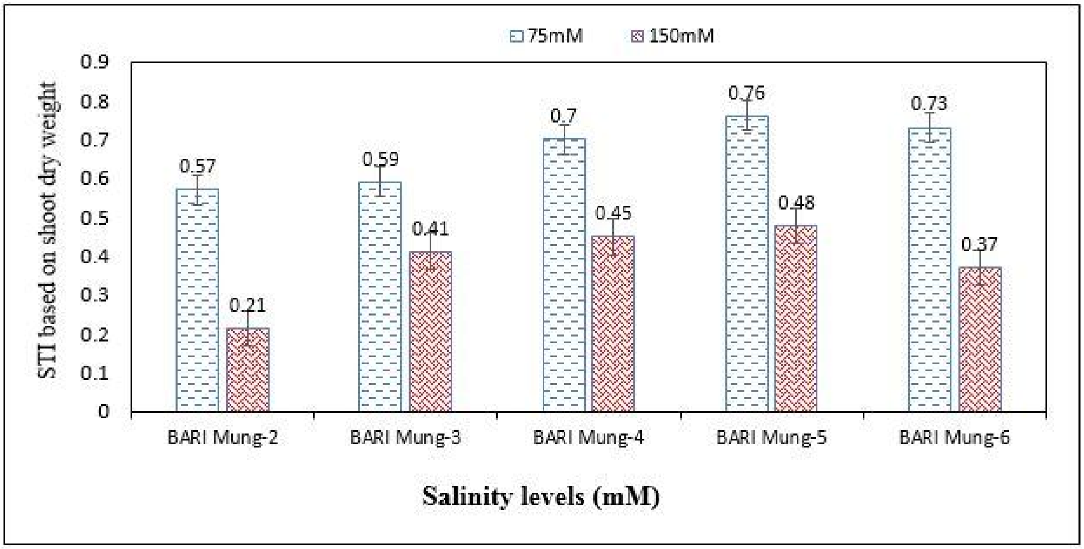


Figure 2. Salt tolerant index (STI) based on shoot dry weight as influenced by salt stress

mungbean genotypes.

**Seedling vigor index**

Seedling vigor of mungbean was drastically reduced by salt stress (Table 12). BARI Mung-5showed significantly lower VI (22.22%), while BARI Mung-2 and BARI Mung-3 provided higher reduction (36.46 and 32.85% respectively). At 75 mM salinity level among all the varieties. At higher salt stress (150 mM) BARI Mung-5 provided the lowest (48.75%) reduction and the BARI Mung-2 showed the higher (72.87%) reduction among the varieties. Kandil et al. (2012) reported that with increasing the NaCl stress decreased the seedling vigor of mungbean.

**Salt tolerance indexbased on shoot dry weight**

The all varieties varied greatly on salt tolerance index (STI) based on shoot dry weight with saline conditions (Figure 2). BARI Mung-4, BARI Mung-5 and BARI Mung-6 showed more than 0.69 STI value contrary BARI Mung-2, BARI Mung-3 provided less than 0.6 STI value at moderate saline condition (75 mM). At high saline treatment (150 mM NaCl), BARI Mung-5 showed 0.48 STI value, while BARI Mung-3, BARI Mung-4 and BARI Mung-6 provided more than 0.35 STI value. The highest STI value (0.76) recorded from BARI Mung-5 while the lowest (0.21) was found from BARI Mung-2 among all varieties and salinity levels. Syeed and Fatma (2011) reported that the salinity stress progressively reduced the salt tolerance index in mungbean. Negative correlation of STI with $Na^+$ showed that by increasing NaCl, there would be a decrease in STI as reported by Goudarzi and Pakniyat (2008) in wheat. These results reconfirm the findings of Kausar et al. (2012) in sorghum.

## CONCLUSION

From the results of germination percentage, rate of germination, mean germination time, coefficient of velocity of germination, shoot and root lengths, fresh and dry weights of shoot and root, seedling vigor index and salt tolerance index it can be concluded that BARI Mung-5 can be considered as salt tolerance genotype and BARI Mung-2 can be treated as salt susceptible among all varieties.

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