

*Original Research*

# Genotypic Divergences of Important Mungbean Varieties in Response to Salt Stress at Germination and Early Seedling Stage

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## Abstract

Salinity drastically hampers the germination and growth of legumes including mungbean which jeopardizes the food and nutritional security of the rising human population. An experiment entailing varying salinity levels (0, 50, and 150 Mm NaCl) was conducted to investigate the response of salinity on germination and seedling growth of four mungbean genotypes (BARI Mung-7, BARI Mung-8, BU Mug-2, and BU Mug-4). The germination indices such as percentage and rate of germination along with the coefficient of velocity (GP) of all mungbean genotypes were significantly reduced by the salt stress, especially of Binamoog-5 at 150 mM NaCl. Contrarily, BARI Mung-8 remained superior by recording better germination indices under all salinity levels. The same cultivar outperformed the rest of the cultivars based on the greatest weights (fresh and dry) and length of roots and shoots, while BU Mug-2 could not perform at par under a saline environment. Thus, it might be inferred that mungbean genotypes differ in their potential for salt endurance due to the germination vigor and seedling growth robustness and screening of salt-tolerant cultivars could mitigate the detrimental effects of saline environment.

**Keywords:** germination rate, mungbean, salinity, seed germination, seedling growth

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## Introduction

The global population is projected to increase by 8.6 billion in 2030, 9.8 billion in 2050, and 11.2 billion in 2100 [1], and food security is under-challenged due to an ever-increasing human population, limited cropland, and the risk of climate change [2]. Abiotic stresses caused by climate change progressively affect the cropping systems, which poses serious threats for global food production. Salinity is an abiotic environmental stress that seriously limits seed germination and hampers the seedlings and plant growth of different crops [3-7]. Salt stress is increasing day by day due to human action and climate change, which has a dramatic response to the morpho-physiology of plants. The coastal areas like the Ganges delta in Bangladesh are especially prone to salinity, which necessitates developing salt tolerant crop cultivars. The population in South Asian countries like Bangladesh is increasing rapidly from 75 million (1971) to 170 million (2022), whereas the production of pulse crops is decreasing rapidly because of salinity [8].

Mungbean (*Vigna radiata* L. Wilczek) belongs to the family of Fabaceae and is a major pulse crop for people in Asian countries like Bangladesh [9]. It is extensively cultivated in Bangladesh owing to its rapid stand establishment and early maturity. It is a vital constituent of diet owing to its superior nutritional value having 62.5% carbohydrates, 26% protein, 4.2% fibers, and 1.4% fat along with numerous minerals and vitamins [10]. It is the cheapest source of dietary protein for humans and livestock, extensively used in various culinary preparations, and recommended for diabetes [6]. The population of Bangladesh is increasing rapidly while cultivable land is decreasing day by day [11], and hence, it is indispensable to produce more food from our restricted land. Farmers use their fresh and fertile soils to grow more cereal crops like rice, wheat, and maize to meet the basic demand for food. For this reason, farmers do not use their fresh-fertile land in pulse cultivation [11]. With an increasing demand for grain food, farmers truly have no scope to use good soils for pulses, and this situation is projected to incur a serious shortfall of pulses soon [12]. Therefore, the crop should be shifted to the problem soils like saline soils. To overcome the protein deficiency, as well as malnutrition, problem pulses like the mungbean crop should be cultivated in the newly reclaimed lands, especially under saline conditions of such soil.

The productivity of mungbean is very low due to soil salinity that hampers plant growth and slices yield through specific ion toxicity [13], altered water relations [14], and the nutritional imbalance that causes huge aggregation of sodium ion and decreased potassium, calcium, and micronutrients [15-17]. The introduction of salt-tolerant mungbean genotypes after thorough screening in existing cropping patterns might enhance the utilization efficiency of salt-affected areas [18]. Therefore, it is now very important to screen out existing salt-tolerant cultivars and develop new varieties

having novel ameliorative mechanisms to cope with the deleterious effects of a saline environment.

The sort out of salt-tolerant genotypes or lines has been done by many researchers on different species but no evidence exists regarding the response of existing mungbean genotypes to varying levels of salt stress. Thus, our research hypothesis was that mungbean genotypes might differ in their potential for salt tolerance and these could respond differently to varying levels of salinity. Therefore, the present research was conducted to identify the potential salt tolerance ability of existing mungbean cultivars under subtropical environments.

## Experimental

### Experimental Area and Weather Conditions

The experiment was carried out at the laboratory of the Agronomy Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh. It was located at 25°37'N latitude, and 88°39'E longitude, and the elevation was 37.5 m. The maximum, minimum, and average temperature, and relative humidity at room conditions in the lab, were documented regularly at the time of conduction of the experiment. Temperature recorded from 17 to 30°C during germination and seedling growth test. The average temperature, minimum, and maximum humidity were 25°C, 57%, and 76%, respectively. Data are shown in Fig. 1.

### Design of Experiments and Treatments

Two factors completely randomized design (CRD) was implemented in the experiment, and the treatment factors were three saline conditions (0, 75, and 150 mM NaCl), and four mungbean genotypes (BARI Mung-7, BARI Mung-8, BU Mug-2, and BU Mug-4). Each treatment was replicated eight times.

### Collection of Seeds and Their Characteristics

The seeds of BARI Mung-7 and BARI Mung-8 were assembled from the Pulse Research Centre, Bangladesh Agricultural Research Institute (BARI), and the seeds of the other two (BU Mug-2 and BU Mug-4) were collected from Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The characteristic features of those varieties are shown in Table 1.

### Placement of Seeds for Germination

Before placing, the seeds were sterilized using mercuric chloride (0.5% w/v) solution for two minutes and washed properly with distilled water after sterilization. Required amounts of NaCl were dissolved in tap water to prepare 75 and 150 mM NaCl

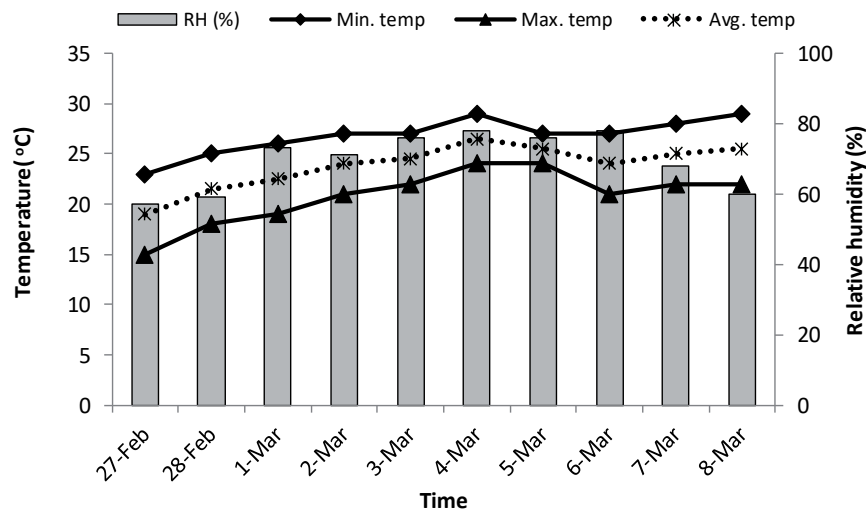


Fig. 1. Daily maximum, minimum, and average temperature and relative humidity during the experimental period.

Table 1. Characteristic features of the mungbean genotypes.

Variety	Source	Release year	TGW (g)	Life span (days)	Major diseases and pests
BARI Mung-7	Pulse Research Centre, BARI, Gazipur	2015	49-51	60-62	Powdery mildew, Cercospora leaf spot and yellow mosaic virus tolerant
BARI Mung-8	Pulse Research Centre, BARI, Gazipur	2015	30-32	60-62	Powdery mildew, Cercospora leaf spot and yellow mosaic virus tolerant
BU Mug-2	BSMRAU, Gazipur	2001	50-55	60-62	Have the ability to resist leaf spot and yellow mosaic virus disease
BU Mug-4	BSMRAU, Gazipur	2006	50-55	40-50	Have the ability to resist leaf spot and yellow mosaic virus disease

salt solutions. Fifty seeds were kept in each plastic pot (25 cm length, 20 cm width, and 15 cm deep) containing sand as a growing medium, and a total of 400 (50 x 8) seeds were used for the study. Tap water was irrigated in control treatment pots and prepared solutions of salt were irrigated as per treatment. Pots were retained at room temperature.

Recorded Data

Germination Percentage (GP)

The data regarding germination was counted at 24-hour intervals and continued up to the 10<sup>th</sup>. The GP was calculated by following the formula according to ISTA [19].

$$\text{Germination percentage} = \frac{\text{No. of seeds emerged on the final day}}{\text{No. of seeds kept for the emergence}} \times 100$$

Rate of Germination (RG)

The formula of Maghsoudi and Arvin [20] was used to measure RG.

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

Coefficient of Velocity of Germination (CVG)

The CVG was calculated based on the formula of Maguire [21]:

$$\text{CVG} = \frac{(G_1 + G_2 + G_3 + \dots + G_n)}{(1 \times G_1 + 2 \times G_2 + 3 \times G_3 + \dots + n \times G_n)}$$

Where G stands for germinated seeds number, and n for the last day of emergence.

Mean Germination Time (MGT)

The mean germination time (MGT) was assessed according to the formula of Ellis and Roberts [22] to get a better idea about the rate of germination:

$$\text{MGT} = \frac{\sum (D_n)}{\sum n}$$

Where n stands for the number of seeds that emerged on each day and D stands for the day of counting.

### Shoot and Root Length (cm)

Seedlings are taken from each pot 10 days after placement for germination and washed thoroughly with tap water. Shoot and root lengths of each seedling were measured using a scale and finally mean lengths were calculated according to the treatment.

### Shoot and Root Fresh Weight (g)

The fresh weights of shoot and root were measured for each treatment combination from the seedlings of each pot and were gathered as a sampling.

### Shoot and Root Dry Weight (g)

Seedlings collected as sampling were kept at 7°C for 72 hours in an oven and then dry weights of shoot and root were measured for individual treatment combinations.

### Seedling Vigor Index (SVI)

The seedling vigor index was evaluated using the formula of Baki and Anderson [23] as follows:

$$\text{SVI} = [\text{length of seedling (cm)} \times \text{germination percentage}] / 100$$

### Tolerance Indices

Salt tolerance index (STI): The formula of Goudarzi and Pakniyat [24] was used to evaluate the STI.

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

### Statistical Analysis

MSTAT-C program was used to analyze the data and the Analysis of Variance (ANOVA) and mean variations

among the treatment combinations were evaluated at a 5% level of probability with Duncan's Multiple Range Test [25].

## Results

### Germination Percentage (GP)

Germination and seedling emergence are greatly hampered due to salt stress. The germination percentage of various genotypes significantly decreased with increasing salt stress, and those genotypes expressed different responses to the rising levels of salt stress (Table 2). Nonetheless, the highest GP (88.54 and 20.0%) was recorded in BARI Mung-8 and the lowest (77.48 and 6.23%) was in BU Mug-2 at 75 and 150 mM NaCl stress, respectively. The extreme level of salinity (150 mM NaCl) severely lessened the GP of all genotypes ranging from 77.41 to 91.45%. The minimum decrease was found in BARI Mung-8 (23.20 and 77.41%) and the Maximum reduction was attained in BU Mug-2 (59.33 and 91.45%) at 75 and 150 mM NaCl, respectively.

### Rate of Germination (RG)

A high mortality rate is an important step in seed germination. The GR declined significantly due to the salinity of all cultivars (Table 2). However, the maximum GR was observed in BARI Mung-8, and the minimum was in BU Mug-2 under 75 mM salt stress. Similar trends were also found at 150 mM salt stress.

### Coefficient of Velocity of Germination (CVG)

CVG declined significantly in all genotypes under increasing saline treatment (Table 3). At 75 mM NaCl and 150 mM NaCl, the highest reduction was noticed in BU Mug-2 (10.13% and 25.67, respectively), whereas the

Table 2. Germination percentage and germination rate of mungbean genotypes performed under salt stress.

Genotypes	Germination percentage (GP)					Rate of germination (RG)				
	Control	75 mM	% Reduction	150 mM	% Reduction	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mung-7	86.59b	57.00f	34.17	13.22j	84.73	69.23c	50.00e	27.78	40.00g	42.22
BARI Mung-8	88.54a	68.00e	23.20	20.00i	77.41	71.43b	60.00d	16.00	50.00e	30.00
BU Mug-2	77.48d	31.51h	59.33	6.62l	91.45	50.00e	30.00i	40.00	20.00j	60.00
BU Mug-4	80.29c	40.26g	49.85	10.00k	87.54	77.77a	48.33f	37.86	35.57h	54.26
LS	**					**				
LSD	1.54					1.87				
CV (%)	3.57					3.26				

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

minimum CVG reduction was in BARI Mung-8 (5.26% and 13.17%, respectively).

### Mean Germination Time (MGT)

The response of all genotypes was significant in MGT (day) under salt stress. The MGT increased with rising salinity levels (Table 3). In 75 mM and 150 mM NaCl, the variety BARI Mung-8 showed the lowest MGT (5.79 and 15.5, respectively). The susceptible one (BU Mug-2) took the highest MGT of 11.45 and 34.67 in 75 mM and 150 mM NaCl, respectively.

### Shoot Length (cm)

A decreasing pattern in shoot length of mungbean genotypes was noticed with increasing salinity levels (Table 4). However, shoot lengths were significantly lower than control, at 75 mM NaCl concentration, and a greater reduction of shoot length was observed at 150 mM NaCl concentration over control. The shoot

length of BU Mug-2 and BARI Mung-7 reduced by more than 45% at 75 mM NaCl salinity level, whereas BARI Mung-8 and BU Mug-4 reduced the shoot length by less than 45%. On the other hand, BU Mug-2 showed 92.87% shoot reduction at 150 mM NaCl concentration but BARI Mung-7 and BARI Mung-8 showed less than 90% reduction in the shoot length, and the rest of the genotypes showed above 90% reduction. In this study, the lowest reduction of shoot length (33.68 and 77.69%) was observed in BARI Mung-8, and the highest (48.18 and 92.87%) was in BU Mug-2 at 75 and 150 mM NaCl concentrations, respectively.

### Root Length (cm)

Increasing salinity levels significantly reduced root length as compared to the control treatment (Table 4). At moderate stress (75 mM NaCl) BARI Mung-7 and BU Mug-2 showed more than 30% reduction of root length, whereas BARI Mung-8 and BU Mug-4 reduced less than 30%. At high stress (150 mM NaCl), the genotypes

Table 3. Effect of salt stress on the coefficient of velocity of germination and mean germination time.

Genotypes	Coefficient of velocity of germination					Mean germination time (days)				
	Control	75 mM	% Reduction	150 mM	% Reduction	Control	75 mM	% Increase	150 mM	% Increase
BARI Mung-7	0.150ab	0.140b-f	6.67	0.128g-j	14.67	4.81hi	8.33g	73.18	24.12c	189.56
BARI Mung-8	0.152a	0.144a-e	5.26	0.132 f-i	13.17	3.57i	5.79h	62.18	15.5d	167.70
BU Mug-2	0.148a-d	0.133fgh	10.13	0.111i	25.67	4.33i	11.45e	164.43	34.67a	202.79
BU Mug-4	0.149abc	0.138d-g	7.38	0.125h-k	16.11	4.62hi	10.66ef	130.74	26.35b	147.19
LS	**					**				
LSD	0.01					1.32				
CV (%)	3.83					4.78				

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

Table 4. Effect of different salinity levels on the shoot and root lengths of mungbean genotypes.

Genotypes	Shoot length (cm)					Root length (cm)				
	Control	75 mM	% Reduction	150 mM	% Reduction	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mung-7	23.96a	12.00e	49.91	2.750g	88.52	15.79a	11.05d	30.02	2.93h	81.45
BARI Mung-8	21.45c	14.22d	33.68	4.783f	77.69	13.68b	11.19d	18.19	4.99g	63.55
BU Mug-2	21.71bc	11.26e	48.18	1.547g	92.87	15.54a	10.26e	34.00	2.67h	82.84
BU Mug-4	22.73b	13.36d	41.24	1.56 g	91.13	12.86c	9.150f	28.86	3.09 h	75.97
LS	**					**				
LSD	1.22					0.51				
CV (%)	10.84					6.06				

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

BARI Mung-8 and BU Mug-4 showed less than 80% reduction, while BARI Mung-7 and BU Mug-2 showed more than 80% reduction. In both salt stresses, BARI Mung-8 showed the lowest reduction (18.19-63.55%) and BU Mug-2 showed the highest reduction (34.00-82.84%) under 75 and 150 Mm NaCl, respectively.

#### Shoot Fresh Weight (g)

Genotypic variations for the shoot fresh weight of all the rice genotypes were found when grown under normal and saline conditions. The shoot fresh weight decreased significantly for all the genotypes due to an increase in salinity (Table 5). Under 75 mM saline condition, the maximum reduction was recorded at BU Mug-2 (46.82%) followed by BU Mug-4 (39.67%) showing more susceptible genotypes. Similarly, the reduction reached the minimum level at BARI Mung-8 (26.29%) followed by BARI Mung-7 (39.57%) indicating tolerant varieties. At high stress, BARI Mung-8 performed the best among all the genotypes (Table 7).

#### Root Fresh Weight (g)

The root fresh weight of mungbean genotypes (10 days old seedlings) was significantly inhibited by the salinity, but the trend of inhibition for all genotypes was not similar at 75 and 150 mM saline treatments (Table 5). However, BU Mug-4 and BARI Mung-7 showed more than 20% reduction at 75 Mm saline treatment, while the rest of the varieties showed less than 20% reduction in root fresh weight as compared to control. At 150 Mm NaCl, BU Mug-2 reduced by more than 80% root fresh weight, but only BARI Mung-8 reduced by less than 50%. BARI Mung-8 showed the lowest reduction (46.87%) and BU Mug-2 showed the highest reduction (85.18%) under 150 mM NaCl salinity levels.

#### Shoot Dry Weight (g)

Increasing salinity levels significantly reduced the shoot dry weight in comparison to the treatment having

Table 5. Effect of different salinity levels on the shoot and root fresh weights of mungbean genotypes.

Genotypes	Shoot fresh weight (g plant <sup>-1</sup> )					Root fresh weight (g plant <sup>-1</sup> )				
	Control	75 mM	% Reduction	150 mM	% Reduction	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mung-7	0.235ab	0.142 efg	39.57	0.057j	75.74	0.107ab	0.082c-f	23.36	0.027j	74.76
BARI Mung-8	0.213b-d	0.157e	26.29	0.107g-i	49.76	0.096a-d	0.084c-e	12.50	0.051i	46.87
BU Mug-2	0.252a	0.134e-h	46.82	0.031j	87.69	0.081cd	0.067d-h	17.28	0.012k	85.18
BU Mug-4	0.247ab	0.149ef	39.67	0.038j	84.61	0.105a-c	0.074d-g	29.52	0.033ij	68.57
LS	**					**				
LSD	0.04					0.02				
CV (%)	8.06					4.12				

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

Table 6. Influence of salt toxicity on the shoot and root dry weights of mungbean cultivars.

Genotypes	Shoot dry weight (g plant <sup>-1</sup> )					Root dry weight (g plant <sup>-1</sup> )				
	Control	75 mM	% Reduction	150 mM	% Reduction	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mung-7	0.015bc	0.010de	33.33	0.003f	80.00	0.011a	0.005de	54.54	0.002f	81.81
BARI Mung-8	0.017abc	0.012cf	29.41	0.006ef	64.70	0.008bc	0.006cd	25.00	0.002f	75.00
BU Mug-2	0.021a	0.012cf	42.85	0.004f	80.95	0.006c	0.003ef	50.00	0.001f	83.33
BU Mug-4	0.016bc	0.011d	31.25	0.004f	75.00	0.009ab	0.005de	44.44	0.002f	77.77
LS	**					**				
LSD	0.004					0.002				
CV (%)	6.40					1.87				

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

Table 7. Influence of salt stress on Seed Vigor Index of mungbean genotypes.

Genotypes	Seedling vigor index		
	Control	75 mM	150 mM
BARI Mung-7	34.41 a	12.46 e	0.75 i
BARI Mung-8	31.10 b	17.27 d	1.94 h
BU Mug-2	28.86 c	6.78 g	0.27 i
BU Mug-4	28.57 c	9.06 f	0.46 i
LS	**		
LSD	0.70		
CV (%)	5.51		

In a column, values having similar letter(s) do not differ significantly at a 5% level of probability, \*\* = 1% level of significance, LS = Level of significance

no salt for all cultivars (Table 6). In both treatments, BARI Mung-8 showed the lowest reduction (29.41-64.70%), on the other hand, BU Mug-2 showed the highest reduction (42.85-80.95%) from 75 to 150 mM NaCl, respectively.

#### Root Dry Weight (g)

With increasing saline toxicity, the root dry weight reduced significantly for all the genotypes (Table 6). Anyhow, BARI Mung-7 and BU Mug-2 revealed a more than 50% decrease at 75 mM NaCl, while BARI Mung-8 and BU Mug-4 revealed a less than 45% decrease in root dry weight at the same saline condition. On the other hand, BARI Mung-7 and BU Mug-2 decreased by more than 80% root dry weight, whereas BARI Mung-8 and BU Mug-4 reduced by less than 80% at 150 mM NaCl. In both treatments (75 and 150 Mm NaCl), BARI Mung-8 showed the lowest reduction (25.00 and 75.00%) and BU Mug-2 showed the highest reduction (5.00 and 83.33%), respectively.

#### Seedling Vigor Index

NaCl significantly decreased the seed vigor index (SVI) of mungbean genotypes (Table 7). The SVI increased with the decreasing levels of salinity. BARI Mung-8 showed the highest SVI (17.27 and 1.94) in 75 mM and 150 mM NaCl, respectively. The susceptible one (BU Mug-2) had the lowest SVI (6.78 and 0.27) in 75 mM and 150 mM NaCl, respectively. In 150 mM NaCl, the SVI of BU Mug-2 was dissimilar with BARI Mung-7 and BU Mug-4.

#### Salt Tolerance Index (STI)

In all genotypes, the variation was found in the case of STI based on the dry weight of the shoot under salt stress (Fig. 2). At 75 mM NaCl (moderate salt), BARI Mung-8 showed the highest STI value of 0.72, while

BU mug-2 showed the lowest STI value of 0.57 among all genotypes. At elevated saline conditions (150 mM NaCl), BARI Mung-8 provided the highest STI value of 0.35, while BU mug-2 showed the lowest STI value of 0.19 (Fig. 2). STI with a high value means BARI Mung-8 was most salt stress tolerant among all genotypes.

#### Discussion

Seed germination is a crucial indicator that determines plant population and ultimately economic yield of pulses. In this study, the GP of various mungbean varieties was significantly affected by salinity levels. The GP was lessened gradually with rising salinity from 0-150 mM NaCl in all mungbean cultivars (Table 2). The cultivar BARI Mung-8 showed the minimum reduction of GP (23.20 to 77.41%), while the highest reduction (59.33 to 91.45%) was in BU Mug-2 at 75 and 150 mM NaCl concentration, respectively. These findings are in good agreement with the observations

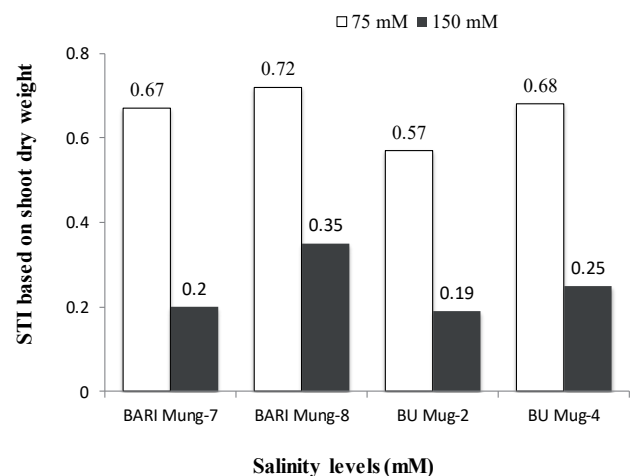


Fig. 2. Salt tolerance index (STI) based on dry weight of shoot of mungbean under saline environment.

of Pattnaik et al. [26], who observed that increasing concentration of salinity progressively inhibited the germination of mungbean, and such findings have been reported previously by other researchers as well [27]. Similar results were also attained in several crops like pea [28], wheat [29] mountain rye (*Secale montanum*) [30], where significant reduction was obtained in germination and seedling growth characters. Several studies also recorded a significant variation in GP with rising salt stress [31-34]. Under salinity stress, seed germination is restricted due to low water potential [35]. The reduction of GP occurred owing to less absorption of water which altered the metabolic activity of plant cells [36] along with perturbing the hormonal balance of plants [37]. The reduction of GP owing to some metabolic disorders as well as specific ion toxic level concentrations is reported under salinity [38, 39], which lowered the water supply [40]. The decline of germination percentage under various salinity stresses can occur due to increasing dormancy in the seed [40]. The RG of mungbean varieties was also decreased imposing the NaCl-induced toxicity, and the magnitude of reduction varied among the varieties. The RG followed similar trends as the GP due to imposing salinity stress. Nevertheless, the minimum reduction of RG (16.00 and 3.00%) was opined in BARI Mung-8 at 75 and 150 mM NaCl stress, respectively, and reduction of RG can be ranked as BARI Mung-8 < BARI Mung-7 (27.78 and 42.22%) < BU Mug-4 (37.86 and 54.26%) < BU Mug-2 (40.00 and 60.00%), respectively (Table 2). The rate of germination decreased in saline conditions due to the high osmotic pressure of salt water at seed depth than lower soil profile [41]. The same result was found in black gram by Hasan et al. [6] who stated that the RG decreased due to the creation of external osmotic potential of the germination media. These observations are coined by Kandil et al. [40], Shahzad et al. [42], and Babbar et al. [43] in mungbean.

CVG was decreased significantly in mungbean genotypes owing to NaCl osmotic potential (Table 3). However, the reduction of CVG shadowed the similar tendency of GP and RG among the varieties used in our study. This observation was coined with the findings of Tsague et al. [44], who stated that NaCl osmotic potential negatively changed the CVG of cowpeas. Similar results were also attained in black gram [6], cowpea [45], and *Tephrosia purpurea* [46] seeds. The MGT was significantly enhanced by rising salinity levels (Table 3). Salinity delays the germination by damaging the seed. A similar result was also obtained in common bean by Cokkizgin [47], who found that salinity affects the germinating seeds negatively and at salt stress during germination, salinity damaged seed-germination features and finally increased MGT. A similar finding was also attained by Naveed et al. [48], who found a significant decrease in emerging seeds percentage as well as a delayed emergence process due to increasing salt stress. NaCl delays the seeds' emergence owing to the negative action of ion toxicity [49], and osmotic

stress due to NaCl inhibits the imbibition of water by seeds, resulting in the delay of radicle emergence [50], which might have increased the MGT.

Similar to germination, salt stress adversely affects the growth and development process of mungbean cultivars [6, 51-53]. In our study, significant reductions in lengths of shoot and root of mungbean genotypes were attained due to increasing salt toxicity. This might occur due to fewer physiological activities resulting from water and essential ion stress [54]. Less transfer of metabolites to the expanding tissues may also reduce lengths because metabolite synthesis is greatly hampered at high salinity conditions [39]. Our experimental findings are coined with the observations of the study conducted by Hassan et al. [5], Hajier et al. [34], Niamat et al. [55], Ungar [59], El-Kafafi et al. [56]. NaCl-induced toxicity enhanced abnormal seedling production as well as decreased the lengths of seedlings [48]. Al-Mutawa [57] observed reduced radicle lengths due to imposing salinity. Mohammed [58] found that salt stress decreased the growth traits of the mungbean cultivar by reducing root lengths and lateral root numbers. Rising saline conditions reduced the height of the root as stated by Qu et al. [33]. Similar results were investigated in root length reduction with increasing salinity levels by Hassan et al. [5], and Hasan et al. [6]. Mohammed [58] also reported a reduction in growth attributes like lengths of shoot and root of mungbean cultivars.

NaCl-induced toxicity significantly reduced the growth attributes (fresh and dry weights, and lengths of shoot and root) of mungbean cultivars [59]. However, shoot growth was affected severely compared to root growth. Salinity hampers plants' growth and development by decreasing emergence [60], and seedling growth [61]. In the present study, NaCl significantly affected the various growth attributes like the fresh weight of the shoot and root of mungbean varieties studied. From 0-150 mM NaCl, the shoot fresh weight was adversely damaged by salt toxicity, and the highest (87.69%) and the lowest (49.76%) reduction was examined in BARI Mung-8 and BU Mug-2, respectively (Table 5). The highest and lowest reduction of root fresh weight was attained at 150 mM salt stress in BARI Mung-8 and BU Mug-2, respectively (Table 5). Seedling fresh weight might be decreased due to low uptake of water by seedlings under induced saline toxic conditions [59, 62]. Anantharaju and Muthiah [63] also found similar results in their study. In the control condition, seedlings accumulate a huge amount of dry matter in the root and shoot compared to the seedlings in the salt stress condition [64]. An adverse effect of salinity on decreasing seedling length (shoot and root length) was also observed by Hasan et al. [6], Ullah et al. [27], Hosseini and Rezvani Moghaddam [65]. El-Kafafi et al. [56] observed salt stress drastically reduced the root fresh weight. Naher and Alam [66] also stated that the increasing salinity levels significantly reduced the growth of roots.



Salt stress significantly reduced the shoot and root dry weight. The reduction was severe in susceptible genotypes under NaCl-induced toxicity compared to the control treatment. Dry matter synthesis under salt stress might be due to the assembly of organic solutes and inorganic ions in an osmotic environment, while lower dry matter content at higher salinity levels might be due to the obstacle of reserved food hydrolysis and their distribution to the growing shoots [67]. The results are in agreement with the findings of Hasan et al. [6], and Saha et al. [68]. The reduction of shoot dry weight may happen due to the shoot osmotic adjustment ability under salinity [39]. This result also agreed with the observations of El-Kafafi et al. [56]. Fresh and dry weights of mungbean cultivars were decreased under salt stress [6, 56, 69, 70].

The seed vigor index was substantially lessened with increasing levels of salinity (Table 7). The SVI decreased with increasing levels of salinity, which indicates that higher salt stress caused a detrimental effect on the seed. Similar findings were attained by Khajeh-Hosseini et al. [71] in soybean, Segatoleslami [72] in the seeds of medicinal plants (*Satureja hortensis* L.), (*Cynara scolymus* L.) and Cokkizgin [47] in common bean seeds. On the other hand, the SVI expressed a substantial correlation with the GP, shoots, and root lengths of the fenugreek variety [73]; and with GP, CVG (Coefficient of velocity of germination) of common bean [46]. Reduction in seed vigor was also observed by Hokmalipour [74]. The findings of the study were also coined with the study of *Foeniculum vulgare* under salinity in which they observed that seed vigor was reduced under a saline environment [75].

To assess salt tolerance, one tolerance index was applied (STI) according to quantitative criteria based on their shoot dry weight in saline conditions. Higher STI means that the genotypes with high yielding capacity and high stress tolerance ability [6]. An increment of salt stress successively lessens the STI values [76].

## Conclusions

Our observations are aligned with the hypothesis related to genetic divergences of mungbean cultivars to varying salinity levels regarding germination indices and seedling growth characters. From the findings, it could be concluded that NaCl-induced toxicity significantly varied the germination and growth of seedlings of all mungbean genotypes, while BARI Mung-8 was observed as a moderately salt-tolerant genotype. Based on the emergence and seedling growth characteristics, BU Mug-2 could be tagged as a susceptible genotype. Thus, the general adoption of BARI Mung 8 might be recommended following results validations under varying agroecological conditions.

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## Conflict of Interest

The authors declare no conflict of interest.

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