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SALINITY TOLERANCE OF BLACK GRAM CULTIVARS DURING GERMINATION AND EARLY SEEDLING GROWTH

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ABSTRACT. A laboratory experiment regarding germination and seedling growth test was conducted with three black gram genotypes tested under three salinity levels (0, 75 and 150 mM), for 10 days, in sand culture within small plastic pot, to investigate the germination and seedling growth characteristics. Different germination traits of all black gram genotypes, like germination percentage (GP), germination rate (GR), coefficient of velocity of germination (CVG) greatly reduced, as well as mean germination time (MGT) increased with increasing salt stress. At high salt stress, BARI Mash-3 provided the highest GP reduction (28.58%), while the lowest was recorded (15.79% to control) in BARI Mash-1. Salinity have the negative impact on shoot and root lengths, fresh and dry weights. The highest (50.32% to con-trol) and lowest reduction (36.39%) of shoot length were recorded in BARI Mash-2 and BARI Mash-1, respectively, under 150 mM NaCl saline conditions. There were significant reduction of root lengths, root fresh and dry weight, shoot length, shoot fresh and dry weight in all genotypes under saline condition. The genotypes were arranged as BARI Mash-1 > BARI Mash-3 > BARI Mash-2, with respect to salinity tolerance.

Keywords: *Vigna mungo*; NaCl; vigour index.

INTRODUCTION

Black gram (*Vigna mungo* L.) is one of the most important grain legume among pulses in Bangladesh. It is widely cultivated in the worldwide for high protein in its seeds. It is highly nutritious and the green pods are eaten as vegetable. Being a legume, it enriches soil health through biological N fixation with rhizobia and it can also break disease cycles and encourage mycorrhizae (Hedley, 2001). As the price of nitrogen fertilizer increases, it is

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considered increasingly profitable crops, because of the lower input requirements. It is the cheapest source of dietary protein for human and livestock. It is extensively used in various culinary preparations and recommended for diabetes. In Bangladesh, about 378251 MT pulses are produced from 918261 acres of land, which is very low as compared the total requirement (BBS, 2017). To meet up the demand for consumption of pulses, we are losing huge amount of currency during the importation of pulses. Therefore, increment of black gram production is crucial importance. It is unfortunate that, as legumes, black gram tends to grow in more marginal environments, under various biotic and abiotic stresses, especially saline and drought conditions, and as such their yield is often much below their potential (Turner *et al*., 2003). Soil salinity is a major, and the most persistent, threat to irrigated agriculture in Bangladesh. The effect of salinity on the growth of black gram plants has been reported sporadically (Islam, 2001; Faruquei, 2002). In Bangladesh, more than 30% of the net cultivable land is in the coastal area. The salt affected area in the coastal zone of the country was about 0.83 Mha in 1975-76, which expanded to 3.1 Mha over the last three decades (Haque, 2006).

Salt stress hampers the agricultural productivity by lowering the yield of various crops in arid and semi-arid regions of the world (Kapoor and Srivastava, 2010; Abd El-Wahed *et al.,* 2015; El Sabagh *et al.,* 2015c; Hasan *et al.,* 2017; Rahman *et al.,* 2017). Seed germination is one of the most critical periods in the life cycle of plants. It is a biological process that demands as pre-requirement the seed viability, which needs physiologic pathway ready to active the metabolism, salt stress can change the metabolic activity during the imbibitions process of the seed. Salt stress greatly influenced the germination of black gram seed. The germination rate determines the crop productivity by optimizing germination factors. A fruitful crop production largely depends on the adequate seed germination, as well as the proper seedling establishment (Almansouri *et al*., 2001; Bhattacharjee, 2008). The highest germination percentage was observed in the control among all of the treatment combinations, as reported by Naher and Alam (2010). The plant growth and seed germination, as well as final germination percentage, were exponentially reduced by salt stress (Rahman *et al*., 2000). However, with increasing (0 to 180 mM of NaCl), salinity decreases germination by 50% in species of the genus *Phaseolus*, reported by Bayuelos-Jimenez *et al.* (2002). The germination of seed, plant growth and development were adversely affected by salinity (Dash & Panda, 2001). Moreover, salinity stress significantly reduced the seed germination by producing an osmotic potential that avoids water uptake or due to toxic effects of Na^+ and Cl^- ions (Khajeh-Hosseini *et al*., 2003).

Sufficient seed germination under saline condition is the key factor for the successful establishment of any crop. It has been well established that many crops can germinate at a higher level of salinity than they would tolerate at later stages of growth and that the seedling stage is the most sensitive to salinity (Shalhevet, 1994).

Vigorous plant growth at the seedling stage under saline condition has been used as a criterion for selecting salt-tolerant individuals and increasing salt tolerance in alfalfa (McKimmie and Dobrenz, 1987) and wheatgrass (Dewey, 1962). The intra-species genetic variability offers a valuable tool for studying mechanism of salt tolerance.

Considering the above facts, the study was undertaken to screen out the salt tolerance of very popular and high yielding black gram varieties in Bangladesh, by observing on the germination and early seedling growth traits under salt stress conditions.

MATERIALS AND METHODS

Location and duration

To investigate the germinations traits of black gram under salt stress, a pot experiment was carried out at the Agronomy Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during March, 2014.

Plant materials

Three high yielding black gram varieties, *viz.* BARI Mash-1, BARI Mash-2 and BARI Mash-3, were used in this experiment. The seeds of those varieties were collected from Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. The properties of black gram varieties are presented in *Table 1*.

Table 1 - Characteristics of existing black gram varieties used in the present research (BARI, 2011)

Varieties	Year of release	Life span (days)	Plant height (cm)	1000-grain weight (g)	Major diseases and pest
BARI Mash-1	1990	65-70	32-36	38-43	Highly tolerant to *yellow mosaic virus*
BARI Mash-2	1996	65-70	33-35	32-36	Highly tolerant to *yellow mosaic virus*
BARI Mash-3	1996	60-65	35-38	40-45	Highly tolerant to *yellow mosaic virus*

Temperature (maximum, minimum and average) and humidity

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 fluctuated from 17.2 to 30.8°C and the average temperature was around 23.6°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 *Fig. 1*.

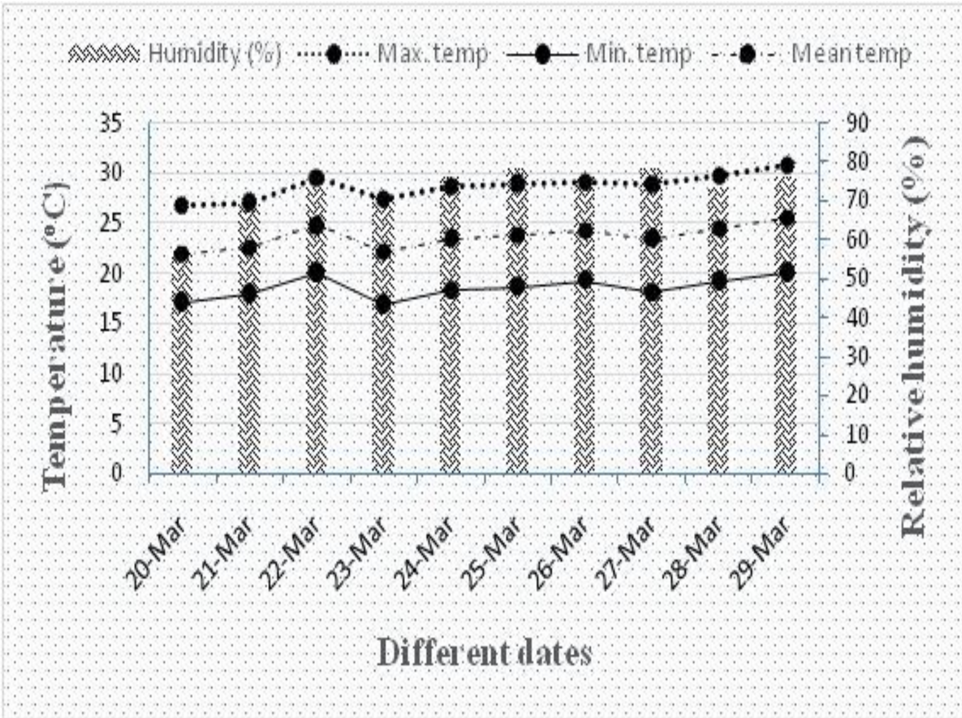

Figure 1 - The average monthly temperature (maximum, minimum and average) and humidity during the experimentation

Experimental treatments and design

Three levels of salinity, *viz*. 0, 75 and 150 mM NaCl, was used for creating salt stress. The experiment was carried out in thrice with completely randomized design (CRD).

For the sterilization of black gram seeds, 1% mercuric chloride solution were used for 2 min. and rinsed thoroughly with sterilized water.The dissolved calculated amount of NaCl in tap water was used to make saline solutions of 75 and 150 mM. Tap water was used as control.

Experimentation

Transparent plastic trays (10 cm diameter and 15 cm height) were used for the placement of 25 seeds for each variety on sand bed irrigated with control and saline solution as per treatment and incubated at room temperature. In this study, to avoid coiling of root, plastic trays were used instead of Petri dishes.

The required amount of salt solution was irrigated as per necessary. Three batches of plastic trays were used for each salinity levels.

Data collection

Germination was counted at 24 hrs interval and continued up to 10th day (240 hrs).

When the plumule and radicle came out about >2 mm long from seed then it was considered as germinated seedling.

Germination percentage

The following formulae were used to calculate the germination percentage:

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

Rate of germination

The rate of germination was calculated by using the following formulae (Maghsoudi and Arvin, 2010).

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

Coefficient of velocity of germination (CVG)

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

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

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

Mean germination time (MGT)

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

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

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.

Shoot and root lengths

Seedlings from each plastic glass were collected as a sampling after placement for germination at 10 days. The shoot and root length (cm) of individual seedling were recorded manually with scale.

Fresh and dry weight of shoot and root

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.

An electric oven (Model- E28# 03-54639, Binder, Germany) was used for drying the shoot and root separately at

70^0C for 72 hrs and weights were recorded with an electrical balance (Model-AND EK-300).

Vigor index (VI)

Vigor index (VI) was calculated by using the formula of Abdul-Baki and Anderson (1973), as shown below:

Vigor index (VI) = germination (%) × mean shoot length + mean root length.

Salt tolerance index

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

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

Statistical analysis

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

RESULTS AND DISCUSSION

Salinity induced comparative changes in germination characteristics of black gram genotypes.

Germination percentage

Salinity caused the seed retarded germination. Black gram drastically reduced the germination percentage (GP) with increasing salt stress (*Table 2*). The GP of BARI Mash-1, BARI Mash-2 and BARI Mash-3 were recorded 15.79, 24.08 and 28.58% at 150 mM NaCl and, as compared to control, the rate of reduction was only 15.79, 24.08 and 28.58%, respectively.

A progressive reduction of GP was observed in all the genotypes at 150 mM NaCl. The genotypes can be arranged on the basis of GP in the following order: BARI Mash-1 >BARI Mash-3>BARI Mash-2.

The seedling emergence and germination percentage in black gram decreased by salinity was reported by Sangeetha and Subramani (2014).

These results are, generally, agreement with the findings of Mensah and Ihenyen (2009) in black gram, Naher and Alam (2010), Sehrawat *et al.* (2013) in mungbean and El Sabagh *et al.* (2015a,b,c) in soybean.

The reduction of the percentages of germination with increasing salinity was due to the specific ion effect (Hassen, 1999), or toxicity of salts (Al-Moaikal, 2006), or due to the effect of added Cl-ions (Gill *et al*., 2002), to the limited water supply due to low osmotic potential (Bal and Dutt, 1986; Khan and Gulzar, 2001; Chauhan *et al.,* 2016).

Table 2 - Germination percentage of black gram genotypes as influenced by salt stress

Genotypes	Germination percentage				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	95.00 a	90.00 ghi	5.26	80 cdef	15.79
BARI Mash-2	90.00 ab	83.33 ab	7.41	68.33 ij	24.08
BARI Mash-3	81.67 cde	70.00 cd	14.29	58.33 k	28.58
LSD			5.34		
CV (%)			4.32		

Rate of germination

Salinity stress significantly decreased the germination rate (GR) of all the black gram genotypes (*Table 3*). The highest GR was obtained in BARI Mash-1 and the lowest was in BARI Mash-3, under 75 mM saline stress, and the reduction was 5.26 and 14.27%, respectively (*Table 3*).

Similar trends were also observed in BARI Mash-1 and the BARI Mash-3 under at high salt (150 mM) stress. Salinity reduced the seed germination rate by creating an external osmotic potential. Salinity reduced the germination in black gram and mung bean also reported by Dash and Panda (2001) and Soltani *et al*. (2006). These results are in agreement with those concluded by Ahmed and Rasul (2005) and Misra and Gupta (2006) in green gram, Babbar *et al*. (2007) in mung bean.

In our experiment, the reduction of germination rate under salinity stress are in agreement with the reports reviewed by Kandil *et al*. (2012), who observed that salinity stress enhances dormancy in crop seeds and this may be a strategy for plants to survive in soils of high salinity.

Table 3 - Germination rate of black gram genotypes as influenced by salt stress

Genotypes	Rate of germination				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	19.00 a	18.00 abc	5.26	16.00 de	15.78
BARI Mash-2	18.00 abc	16.67 cd	7.39	13.67 hij	24.05
BARI Mash-3	16.33 abc	14.00 ghij	14.27	11.67 kl	28.53
LSD			1.11		
CV (%)			4.03		

Coefficient of velocity of germination

Salt stress reduced the coefficient of velocity of germination (CVG) in black gram genotypes (*Table 4*).

At moderate salt stress (75 mM NaCl), the highest reduction of (6.22%) was recorded in BARI Mash-2, while BARI Mash-1 showed the lowest reduction (3.71%) of CVG.

On the other hand, under high salt stress (150 mM NaCl) similar trends were observed of those cited varieties, that means BARI Mash-2 recorded the highest reduction of CVG (24.88%), whereas BARI Mash-1 recorded the lowest reduction (21.30%).

We can arrange the salt tolerance rank as follows: BARI Mash-1>BARI Mash-3>BARI Mash-2.

This is confirmatory with the findings of Sunita *et al*. (2013), who reported that the NaCl concentration negatively increased the CVG of *Tephrosia purpurea* seed.

Similar results were reported by Katembe *et al*. (1998) in *Atriplex* species and Lobato *et al*. (2009) in cow pea.

Table 4 - Coefficient of velocity of germination of black gram genotypes as influenced by salt stress

Genotypes	Coefficient of velocity of germination (CVG)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	0.216a	0.208c	3.71	0.170e	21.30
BARI Mash-2	0.209bc	0.196d	6.22	0.157g	24.88
BARI Mash-3	0.214ab	0.206c	3.74	0.164f	23.37
LSD			0.0058		
CV (%)			0.8965		

Mean germination time

The variation of mean germination time (MGT) in black gram was different due to various salinity levels (*Table 5*). BARI Mash-2 took the maximum time (5.09 days) for germination than among all of the black gram genotypes at moderate stress. The MGT increased with the increasing salt stress and at high salt stress (150 mM NaCl); the variety BARI Mash-2 took the utmost time (33.05% more over control) for germination, while BARI Mash-1 took the minimum time MGT (26.98% more over control). Salt stress delayed the seed germination time may be due to disturbing the pre-requisite of germination conditions, especially unavailability of water to seed. Our results are in agreement with the observation of Debez *et al*. (2004), who noted that low water uptake due to low water potential is a determining factor inhibiting seed germination under saline stress. The decreasing mean germination time, due to increasing salinity, can be correlated to the nature of salinity to reduce imbibition of water due to lowered osmotic potentials of the medium (Yupsanis *et al*., 1994). Nasri *et al*. (2015) reported that, with imposing the salt stress, the mean germination time (MGT) was greatly reduced in lettuce. Similar results were proposed by Sardoei *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).

Table 5 - Mean germination time of black gram genotypes as influenced by salt stress

Genotypes	Mean germination time (days)				
	Control	75 mM	% Increase	150 mM	% Increase
BARI Mash-1	4.630d	4.817cd	4.04	5.879b	26.98
BARI Mash-2	4.786cd	5.095c	6.48	6.368a	33.05
BARI Mash-3	4.664d	4.924c	5.58	6.081d	30.39
LSD			0.3614		
CV (%)			1.01		

Salinity induced comparative changes in seedling growth characteristics of black gram genotypes

Shoot length

Shoot length was significantly reduced by salt stress in all the genotypes of black gram (*Table 6*). Among black gram genotypes, the lowest shoot length reduction, due to salinity, was recorded at BARI Mash-1 and the highest reduction was recorded at BARI Mash-3 in all salinity levels. On the other hand, BARI Mash-1 produced the highest shoot length and BARI Mash-2 produced the lowest under 75 and 150 NaCl stress. The lowest rate of reduction (36.39%) was recorded in BARI Mash-1 and the highest reduction were recorded (50.32% to control) at BARI Mash-2 at high levels of salinity. The findings of the study reconfirm the report of Saroj and Soumana (2014), that the seedling length of black gram gradually decreased with increasing salinity levels. In general, stunning of plant growth is the most common effect of salinity. Shoot and root length of black gram gradually reduced due to the application of saline water (Reddy *et al*., 2013). Salinity may lead to disturbances in plant metabolism that leads to reduction of plant height, as reported by Chauhan *et al*. (2016).

Table 6 - Shoot length of black gram genotypes as influenced by salt stress

Genotypes	Shoot length (cm)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	22.23 bc	18.88 fg	15.06	14.14 ij	36.39
BARI Mash-2	20.03 ef	13.61 j	32.05	9.95 lm	50.32
BARI Mash-3	21.23 cde	16.12 h	24.06	12.19 k	42.58
LSD			1.57		
CV (%)			5.51		

Root length

Root length was significantly affected by salinity in black gram, as compared to the control (*Table 7*). The longest root length were found (10.02 cm) at control condition, in BARI Mash-1, and smallest root length were found (5.26 cm) at high salt stress, in BARI Mash-2. At moderate stress (75 mM NaCl), BARI

Mash-2 and BARI Mash-3 reduced more than 10% root lengths, whereas BARI Mash-1 reduced 9.48%. Under high salt stress (150 mM NaCl) condition, BARI Mash-2 and BARI Mash-3 reduced more than 29% root lengths. BARI Mash-1 showed the lowest reduction (20.33% to control) among all genotypes at high salinity levels. The more sensitive root growth was observed with increasing the salt stress in both mung bean and cowpea, reported by Balasubramanian and Sinha (2006). The root length of black gram gradually decreased with increasing the concentration of salt stress, compared to control (Kandil *et al*., 2012; Velmani *et al*., 2015), decreased root lengths and number of lateral roots in mung bean (Haleem and Mohammed, 2007; Mohammed, 2007). Al-Mutawa (2003) reported that increased salinity leads to decreased radicle lengths of chickpea.

Table 7 - Root length of black gram genotypes as influenced by salt stress

Genotypes	Root length (cm)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	10.02 a	9.07 b	9.48	7.98 cd	20.35
BARI Mash-2	8.73 b	7.24 e	17.07	5.26 h	39.75
BARI Mash-3	9.08 b	8.09 cd	10.90	6.42 g	29.29
LSD			0.35		
CV (%)			2.58		

Shoot fresh weight

The shoot fresh weight of black gram genotypes was decreased remarkably under saline stress (*Table 8*). At moderate saline condition (75 mM), maximum reduction was found in BARI Mash-3 (45.04%), followed by BARI Mash-1 (38.74%). However, salinity at 150 mM NaCl concentrations significantly reduced shoot fresh weight in all genotypes of black gram. The highest reduction was found (70.66%) in BARI Mash-2 and the lowest was found (61.87%) in BARI Mash-1. Akbari *et al.* (2008) reported that salinity greatly reduced the weight of green parts. These above result reconfirm the results of Mohamed and Kramany (2005) in mung bean. The reduction of seedling fresh weight may be due to a decrease in water uptake by seedling for arising osmotic potential under saline conditions (Hussain and Ilahi, 1992; Haleem and Mohammed, 2007; Aloui *et al*., 2014).

Table 8 - Shoot fresh weight of black gram genotypes as influenced by salt stress

Genotypes	Shoot fresh weight (mg)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	4.93 b	3.02 e	38.74	1.88 fg	61.87
BARI Mash-2	3.92 c	2.71 e	30.87	1.15 hi	70.66
BARI Mash-3	4.04 c	2.22 f	45.04	1.32 h	67.33
LSD			0.11		
CV (%)			2.37		

Shoot dry weight

Blackgram genotypes significantly reduced the shoot dry weight with increasing salinity levels (*Table 9*). Among the genotypes BARI Mash-2 and BARI Mash-3 showed 26-27% reduction, whereas BARI Mash-1 showed less than 23% reduction in shoot dry weight and showed highly salt tolerant at moderate saline condition. At high salt stress (150 mM), BARI Mash-2 and BARI Mash-2 showed more than 55% reduction, while BARI Mash-1 was 40.84%, which indicates highly salt tolerant among all black gram genotypes. The lowest shoot dry weight reduction was recorded (40.84%) in BARI Mash-1 and the highest was recorded (65.11%) in BARI Mash-2, under 150 mM. The negative response of dry biomass with increasing salinity stress may be attributed to decreased rate of photosynthesis. The stem dry weight showed decreased with increasing salinity, compared to control observed by Islam *et al.* (2011), El Sabagh *et al.* (2015b), Velmani *et al.* (2015) and Ahmad *et al*. (2005). The reduced in dry matter production at the highest salinity levels might be due to the inhibition in hydrolysis of reserved foods and their translocation to the growing shoots (Xu *et al.,* 2008).

Table 9 - Shoot dry weight of black gram genotypes as influenced by salt stress

Genotypes	Shoot dry weight (mg)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	0.71 a	0.55 b	22.53	0.42 cd	40.84
BARI Mash-2	0.43 c	0.31 fg	27.91	0.15 klm	65.11
BARI Mash-3	0.56 b	0.41 cd	26.78	0.25 hi	55.35
LSD			0.02		
CV (%)			3.84		

Root fresh weight

Root fresh weight of black gram genotypes (10 days old seedlings) was significantly inhibited by the salt stress (*Table 10*).

The effect of salinity was not similar for all the genotypes at 75 and 150 mM saline treatments. BARI Mash-2 and BARI Mash-3 showed more than 10% reduction at 75 mM saline treatment, while BARI Mash-1 showed not more than 10% reduction in root fresh weight.

At 150 mM NaCl, BARI Mash-2 and BARI Mash-3 reduced more than 20% root fresh weight. On the contrary, BARI Mash-1 reduced less than 16%. Present results also exhibited that when the seeds exposed to high salt stress, severe reduction in root length and root fresh weight appeared in all the black gram genotypes.

Under saline condition, water uptake by seedling is hampered resulting reduced the root fresh weight. Kandil *et al.* (2012) reported that the root fresh weight showed greater variation due to differing salt concentrations in mung bean genotypes.

The reduced rate of germination formed weak seedlings, which ultimately produced poorer root fresh weight of *Phaseolus* spp. (Bayuelo-Jimenez *et al*., 2002).

Table 10 - Root fresh weight of black gram genotypes as influenced by salt stress

Genotypes	Root fresh weight (mg)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	2.10 a	1.91 b	9.04	1.78 c	15.24
BARI Mash-2	1.49 e	1.33 gh	10.73	1.11 i	25.50
BARI Mash-3	1.77 c	1.59 d	10.17	1.41 f	20.34
LSD			0.08		
CV (%)			2.93		

Root dry weight

Reduction of the root dry weight, due to salt stress, showed the same pattern as in fresh weight for almost all the genotypes in this study (*Table 11*). The maximum reduction was recorded (33.33% to control) in BARI Mash-2, and the lowest reduction was recorded (13.79% to control) in BARI Mash-1 among all genotypes under moderate salt stress (75 mM NaCl). The root dry weight of BARI Mash-2, also severely reduced (73.33%) at high salt stress (150 mM NaCl), but BARI Mash-3 exhibited moderate sensitivity (54.93% reduction). In this case, BARI Mash-1 showed better performance in terms of the root growth and proved to be tolerant to lower, as well as high level of salinity. Velmani *et al.* (2015), however, reported that the effect of NaCl on root dry weight decreased in black gram with increasing concentration, compared to control. This is confirmatory with the findings of Mohamed and El Kramany (2005), Saha *et al*. (2010), Shakeel and Mansoor (2012), El-Kafafi *et al*. (2015), who observed that salinity significantly reduced the root dry weight and root was more affected that shoot in mung bean.

Table 11 - Root dry weight of black gram genotypes as influenced by salt stress

Genotypes	Root dry weight (mg)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	0.87 a	0.75	13.79	0.61 d	29.88
BARI Mash-2	0.60c	0.40	33.33	0.16 ij	73.33
BARI Mash-3	0.71 b	0.54	23.94	0.32 gh	54.93
LSD			0.02		
CV (%)			2.31		

Vigor index

Salt stress drastically reduced the vigor index (VI) of black gram (*Table 12*). At 75 mM salinity level, BARI Mash-1 showed significantly lower VI (17.89%), while BARI Mash-2 and BARI Mash-3 provided higher reduction (32.86 and 31.56%). BARI Mash-1 provided the lowest (42.23%) reduction and the BARI Mash-2 showed the higher (59.86%) reduction at higher salt stress (150 mM) among the genotypes. Cokkizgin (2012) reported that the seedling vigor index increased when the NaCl concentration decreased, which shows that increased NaCl concentration caused a harmful effect in the seedling. Similar trends were reported by Khajeh-Hosseini *et al*. (2003) in soybean, Saroj and Soumana (2014) in *Vigna* spp.

Table 12 - Vigor index of black gram genotypes as influenced by salt stress

Genotypes	Vigor index (%)				
	Control	75 mM	% Reduction	150 mM	% Reduction
BARI Mash-1	612.81a	503.16abcd	17.89	354.02abcdefg	42.23
BARI Mash-2	517.52abc	347.49abcdefg	32.86	207.7defg	59.86
BARI Mash-3	495.06abcde	338.80abcdefg	31.56	214.43cdefg	56.68
LSD			19.50		
CV (%)			2.84		

Salt tolerant index based on shoot dry weight

The salt tolerance index (STI), based on shoot dry weight greatly, varied in all genotypes under salt stress (*Fig. 2*). At moderate saline condition (75 mM), BARI Mash-2 and BARI Mash-3 showed 0.72 and 0.75 STI value, contrary BARI Mash-1 provided 0.78 STI value. BARI Mash-1 provided 0.59 STI value, while BARI Mash-2 and BARI Mash-3 showed 0.35 and 0.47 STI value at high saline treatment (150 mM NaCl). The highest STI value (0.78), recorded from while the lowest (0.21), was found from BARI Mash-2 among all genotypes and salinity levels (*Fig. 2*). Higher, the value of STI indicates more salt tolerant of the variety BARI Mash-1. Increasing salt stress progressively reduced the STI values, as reported by Syeed and Fatma (2011) in *Vigna* spp., Goudarzi and Pakniyat (2008) and Alam (2014) in wheat, Kausar *et al*. (2012) in sorghum.

Figure 2 - Effect salinity on salt tolerant index (STI) based on shoot dry weight of black gram

CONCLUSION

Salt stress progressively decreased the germination and seedling growth parameters of black gram genotypes. The GP, GR, CVG reduced more in the variety BARI Mash-2; whereas, comparatively, very less reduction was observed in BARI Mash-1.

Seedling growth characteristics also inhibited more, due to salinity in BARI Mash-2, but less inhibition was recorded in BARI Mash-1. On the basis of germination and seedling growth traits, it can be concluded that BARI Mash-1 can be treated as the most salt tolerant, and BARI Mash-2 as highly salt susceptible genotypes.

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