Water Relations and Dry Matter Accumulation of Black Gram and Mungbean as Affected by Salinity

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ABSTRACT

To evaluate the water relations and dry matter accumulations of black gram and mungbean, the present research work was performed in front of the Agronomy Department under shade house at Hajee Mohammad Danesh Science and Technology University (HSTU), Bangladesh during 2014. In this study, one mungbean (BARI Mung-5) and one black gram (BARI Mash-1) genotypes were tested under five salinity levels (0, 30, 60, 90 and 120 mM NaCl) in small plastic pot. Salinity greatly reduced the relative water content (RWC), water saturation deficit (WSD), water retention capacity (WRC), and water uptake capacity (WUC) in both black gram and mungbean. The water relations in black gram was affected less than that in mungbean in all salinity levels. Black gram always exudated higher water than mungbean under stress conditions. Under 120 mM salt stress, the rate of exudation in black gram was 28.20 mg/hr, while the value was only 14.89 mg/hr in mungbean. Considering all the parameters, it can be concluded that the black gram (BARI Mash-1) may be treated as the more salt tolerant than mungbean (BARI Mung-5) genotype.

Keywords: Salinity, black gram, mungbean, dry matter accumulation, water relations

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INTRODUCTION

Black gram (*Vigna mungo* L. Hepper) is a grain legume and has relatively short life span. It is extensively used in various culinary preparations and recommended for diabetes. The green pods are used as a vegetable which is highly nutritious. The hulls or the outer covering of grain and straw are used as feed. Another important pulse crop of Bangladesh is mungbean (*Vigna radiata* L. Wilczek). It contains higher protein and ranks fifth both in acreage and total production in Bangladesh (BBS, 2011). It has many effective uses such as green pods in cooking as peas; sprouts are rich in vitamins and amino acids. It is widely cultivated in the worldwide for its' high content of protein in seeds (Islam *et al*., 2018).

Salt stress harmfully influences all growth stages of leguminous crops (EL Sabagh *et al*., 2015; Mansouri and Kheloufi, 2017; EL Sabagh *et al*., 2019). It is hampers the agricultural output by lowering the yield of various crops in salt affected areas/regions of the world (Kapoor and Srivastava, 2010). The total land area under pulses crops are 627,000 acres of land and the total production of pulses is 231,000 metric tons in Bangladesh. But the total requirement of pulses in our country is higher as compared it production (BBS, 2011). Bangladesh is importing pulses from foreign countries to fulfill our requirements for the consumption. For this reason, Bangladesh is losing huge amount of currency. It is needed to stop the import and possible to produce pulses 50% more for the development of our countries economy. The total salt affected area in Bangladesh is about 3.1 million ha over the last three decades (Haque, 2006). Day by day this area is increasing due to tidal flow over the soil in close proximity to the sea. So, the people of Bangladesh should use the normal and abnormal/problematic soils like saline soils for increasing total production. The mechanisms responsible for reduction in plant growth under salt stress are: i) salinity exerts osmotic pressure and reduce soil water potential making water unavailable to plants (Munns *et al*., 2006), ii) excessive amount of certain ions (Na^+ and Cl^{-1}) at supra-optimal level under salt stress (Li *et al*., 2010), and iii) nutritional imbalance-N accumulation is reduced that ultimately reduces growth and yield of the crops (James *et al*., 2006); low solubility of Ca-P minerals (Qadir and Schubert, 2002); interference in the acquisition of K^+ by the roots, the low concentration of Ca^{2+} (Cakmak, 2005) and Mg^{2+} (Hu and Schmidhalter, 1997).

Farmers of Bangladesh are interested to allocate good soils for cereals due to increasing demand for cereals instead of legumes. Consequently, legume cultivation is pushing to the problem soils including saline soils. Farmers are growing summer legumes like mungbean and black gram in those areas and salinity levels in summer become low due to monsoon rain. By cultivating salt tolerant mungbean and black gram crops in these saline soils may be an alternative way for increasing production. Black gram is reported to be a relatively salt tolerant crop than mungbean (Raptan, 2000; Islam, 2001). The water relation as well as other physiological responses of these crops to saline environment are insufficiently addressed. For that reason, it is necessary to have clear understanding on the physiological mechanisms. Therefore, the present investigation was carried out to analyze water relations of black gram and mungbean to elucidate their physiological mechanisms of salt tolerance.

MATERIALS AND METHODS

Location and Duration

The present research work was carried out in earthen pot inside net house and natural light at the research field of Agronomy Department, HSTU on 17th April 2014 to 5th July 2014.

Plant Material

The seeds of one black gram (BARI Mash-1) and one mungbean (BARI Mung-5) were collected from Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. The properties of those varieties are presented in Table 1.

Table 1 Characteristics of existing black gram and mungbean 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 Mung-5	1997	60–65	40–42	40–42	Highly tolerant to yellow mosaic virus and Cercospora leaf spot

Temperature (Maximum, Minimum and Average) and Humidity

Various climatic conditions like temperature, relative humidity and rainfall were collected from weather station of wheat research center, Bangladesh Agriculture Research Institute (BARI), Nashipur, Dinajpur, Bangladesh. Data were presented in figure 1.

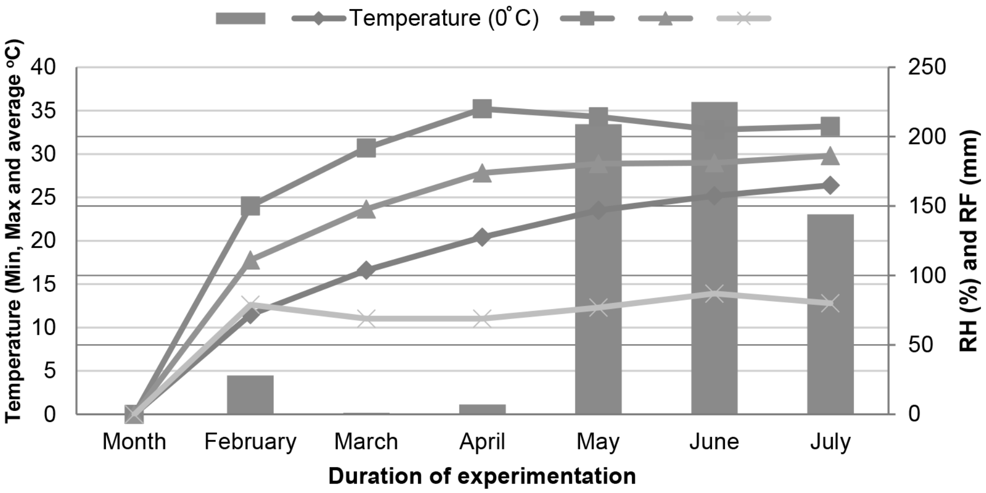

Figure 1 Weathering data for growing season of black gram and mungbean during 2014

Experimental Treatments and Design

In this study, one mungbean and one black gram genotypes were tested under five salinity levels viz., 0, 30, 60, 90 and 120 mM NaCl. For making 30, 60, 90 and 120 mM NaCl solution, salt (NaCl) available in market was artificially dissolved with fresh water. The experiment was designed in completely randomized design (CRD) with five replications. Fresh water collected from tap was used as control.

Pot Preparation

The plastic pot (17 cm × 19.5 cm) was mixed up with air dried soil, cow-dung and inorganic fertilizers in a shade house. Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were applied at 50, 90 and 40 kg/ha, respectively. Full doses of TSP, MP and urea were incorporated thoroughly into the soil as basal dose.

Sowing of Seeds

Twelve seeds of mungbean and black gram were sown in each pot separately. The pots were irrigated for proper germination. Adequate and uniform irrigation was properly supplied for the excellent germination.

Application of Treatments/Salt Solutions

Each pots were irrigated up to the emergence of seedling. About 7.5 mM NaCl solution was applied in salt-treated pots up to four days and 15 mM for next four days, 30 mM for next four days in all pots and in control treatment tap water was used, for hardening of seedlings before applying actual treatments. The required amount of salt solutions were applied in pots at flowering stage. The salt solutions were applied till maturity.

Dry Matter Accumulation and Partitioning

Three plants from each crop per treatment were harvested for the determination of the dry matter of various plant parts. From sampled plants, data on plant height were recorded leaf area of each sample plant was also measured with an automatic leaf area meter. The plants were partitioned into leaf, stem, petiole and reproductive organs, and oven dried at 48̊C for 72 hours. Weight of individual components was recorded.

Determination of Water Relations

The shoot systems of black gram and mungbean plants were separated at 45 DAE. Fresh weight of fully expanded third trifoliate leaves from three top, petiole of the leaf and part of stems were taken. Distilled water for 24 h at room temperature in the dark were used for immersing the various plant parts. The turgid weights of those plant parts afterwards all the materials were oven-dried at 80̊C to take dry weight. Various plant segments (fresh, turgid and dry weights) were used to determine the following parameters:

$$\text{Relative Water Content (RWC)} = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

$$\text{Water Saturation Deficit (WSD)} = 100 - \text{RWC}$$

$$\text{Water Retention Capacity (WRC)} = \frac{\text{Turgid weight}}{\text{Dry weight}}$$

$$\text{Water Uptake Capacity (WUC)} = \frac{\text{Turgid weight - Fresh weight}}{\text{Dry weight}}$$

Exudation Rate

About 5 cm from the stem base, exudation rate was measured. After taking dry cotton weight, a slanting cut on stem was made with the help of sharp knife. At normal temperature, exudation rate was collected from the cotton that placed on the cut surface of stem. Finally, cotton with sap weight was taken. The following equations was used to determine the exudation rate per hour basis:

$$\text{Exudation rate} = \frac{\text{(Weight of cotton sap + sap) - (Weight of cotton)}}{\text{Time (h)}}$$

Data Analysis

The data were analyzed statistically using the ‘R’ command program.

RESULTS AND DISCUSSION

Dry Matter Accumulation

Production of economic yield is determined by the proportion of assimilates partitioned to reproductive organ. Thus, it is important to understand the dry matter accumulation pattern for the improvement of yield level in saline soils. The effect of salinity on the pattern of dry matter accumulation and the partitioning in leaves, stem, reproductive organ and roots are described hereunder.

Leaf dry matter

Leaf dry matter plant^{-1} was highly significant at different growth stages of mungbean and black gram. Black gram and mungbean genotypes markedly influenced by salinity in leaf dry weight at all growth stages. Salinity significantly decreased the leaf dry matter per plant (Table 2). Leaf dry matter per plant between the species was statistically highly significant due to salt stress. At 48 DAE and till maturity Black gram produced higher leaf mass than mungbean in all salinity levels. The maximum leaf dry matter reduction was found (89.86%) in mungbean whereas the reduction was found only 62.44% to control in black gram at 48 DAE under high salt stress. At 78 DAE, the maximum leaf dry matter reduction was found (89.29% to control) in mungbean under 90 Mm NaCl but the reduction was found (81.84% to control) at the same stress in black gram. The decrease in leaf dry weight at later part of growth may be due to leaf senescence and remobilization of stored materials to the reproductive organs (Khan and Ungar, 2001; Islam *et al*., 2011). It was found leaves dry matter gradually reduced with increasing salinity levels (Islam, 2004; Yassin *et al*., 2019). Salinity stress significantly reduced the shoot weight due to clear stunting of plant growth as accompanied by Parida and Das (2005); Hajier *et al*. (2006); Rahman *et al.* (2017); Hassan *et al*. (2018); Out *et al*. (2018).

Table 2 Effect of NaCl on dry matter accumulation in the leaf of black gram (BG) and mungbean (MB) measured at DAE

NaCl (mM)	Leaf dry matter (mg)			
	48 DAE		78 DAE	
	BG	MB	BG	MB
Control	0.836[a]	0.710[b]	1.052[a]	0.850[b]
30	0.736[b] (11.96)	0.590[c] (16.90)	0.744[c] (29.28)	0.488[d] (42.59)
60	0.626[c] (25.12)	0.450[d] (36.62)	0.394[e] (62.55)	0.186[f] (78.12)
90	0.496[d] (40.67)	0.270[e] (61.97)	0.226[g] (78.52)	0.168[h] (80.23)
120	0.314[e] (62.44)	0.072[f] (89.86)	0.191[h] (81.84)	0.091[i] (89.29)
LSD	0.08084		0.04042	
CV (%)	12.15		5.37	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Stem dry matter

Both black gram and mungbean genotypes drastically reduced the stem dry matter production per plant at different stages by salinity. Stem dry weight progressively decreased with increasing salinity (Table 3). Mungbean provided lower stem dry weight than black gram in irrespective of salinity levels. At all salinity levels, the pattern of stem dry matter production was almost similar to that of leaf dry matter. The maximum stem dry matter reduction was found (78.70% to control) under high salt stress in mungbean, on the other hand the reduction was only 54.78% (over control) at the same stress in black gram at 48 DAE.

Mungbean showed higher reduction (91.16%) at 120 mM than black gram (90.71%) at 78 DAE under 120 mM. Black gram was comparatively more tolerant than mungbean in terms of both absolute and relative stem biomass production. The result is in agreement with Murillo-Amador and Tryo-Diequez (2000) who reported the stem dry weight decreased gradually with increasing salinity level. Salt stress enhanced the stunting of plant growth resulting a measurable decrease in fresh and dry weights of stems (Parida and Das, 2005; Hajier *et al*., 2006).

Table 3 Effect of NaCl on dry matter accumulation in the stem of black gram (BG) and mungbean (MB) measured at different days after emergence

NaCl (mM)	Stem dry matter (mg)			
	48 DAE		78 DAE	
	BG	MB	BG	MB
Control	0.942[a]	0.836[ab]	1.122[a]	0.948[b]
30	0.836[ab] (11.25)	0.716[bcd] (14.35)	0.880[c] (21.57)	0.652[d] (31.22)
60	0.758[bc] (19.53)	0.616[d] (26.32)	0.580[e] (48.30)	0.318[f] (66.45)
90	0.638[cd] (32.27)	0.460[e] (44.98)	0.324[f] (71.12)	0.208[f] (78.05)
120	0.426[e] (54.78)	0.178[f] (78.70)	0.104[h] (90.71)	0.084[g] (91.16)
LSD	0.1278		0.0572	
CV (%)	15.71		7.48	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Petiole dry matter

Petiole dry matter plant^{-1} showed a significant response to salinity in both black gram and mungbean (Table 4). Salt stress greatly damaged the petiole of mungbean than the black gram. The petiole dry matter at high salt stess (120 mM NaCl) black gram produced 0.074 g while in mungbean it was only 0.03g at the stage of 48 DAE) and the reduction were 66.67% (to the control) in black gram and mungbean showed 81.01% at the same treatments. At 90 mM salt stress condition mungbean showed 76.16% reduction (to control) on petiole dry whereas black gram showed 72.01% reduction (to control) on petiole dry matter at 78 DAE. Salinity induced damage in petiole mass was also reported earlier by Raptan (2000) and Islam (2001) in black gram and mungbean.

Table 4 Effect of NaCl on dry matter accumulation in petiole of black gram (BG) and mungbean (MB) measured at different days after emergence

NaCl (mM)	Petiole dry matter (mg)			
	48 DAE		78 DAE	
	BG	MB	BG	MB
0	0.222[a]	0.158[b]	0.318[a]	0.172[b]
30	0.162[b] (27.02)	0.09[cd] (43.03)	0.262[c] (17.61)	0.112[d] (34.88)
60	0.126[bc] (43.24)	0.084[cd] (46.86)	0.164[e] (48.43)	0.075[f] (56.39)
90	0.124[bc] (44.14)	0.06[de] (62.02)	0.089[g] (72.01)	0.041[h] (76.16)
120	0.074[b] (66.67)	0.03[e] (81.01)	0.068[h] (78.61)	0.029[h] (83.13)
LSD	0.0404		0.0404	
CV (%)	14.89		13.87	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Water Relations

Relative water content

At 58 days after emergence (DAE) maturity the relative water content (RWC) of leaf, petiole and stem was measured in black gram and mungbean. The RWC of leaf, petiole and stem in both the crops significantly decreased by salinity (Table 5). Mungbean showed higher relative water content in the leaf, stem and petiole than black gram. But, all the plant parts of black gram showed conspicuously lower reduction in RWC than mungbean. Particularly, stem of mungbean showed remarkable reduction in RWC at high salt stress compared to those organs of black gram. In case of stem, Showed 10.86% reduction of RWC over control, while mugbean showed 13.63% reduction over control at 60 mM NaCl salt stress. At high salt stress (120mM) the reduction of RWC was recorded (25.78%) by mungbean while black gram showed (16.79%) reduction of RWC was found in petiole.

Table 5 Effect of NaCl on relative water content in different plant parts of BARI Mash-1 (BG) and BARI Mung-5 (MB)

Salt Stress (mM)	Relative water content (RWC)					
	Stem		Petiole		Leaf	
	BG	MB	BG	MB	BG	MB
0	84.21^bc^	91.65^a^	87.93^bc^	93.41^a^	88.53^b^	94.41^a^
30	81.46^bc^ (3.26)	86.47^b^ (5.65)	85.30^cd^ (2.99)	88.42^b^ (5.34)	86.10^bc^ (2.74)	89.42^b^ (5.28)
60	75.06^de^ (10.86)	79.25^cd^ (13.53)	82.23^ef^ (6.48)	84.27^de^ (9.49)	83.23^cde^ (5.99)	85.27^bcd^ (9.68)
90	68.03^f^ (19.21)	70.27^ef^ (23.32)	78.16^g^ (11.11)	80.20^fg^ (14.14)	79.16^ef^ (10.58)	81.40^de^ (13.78)
120	60.40^g^ (28.27)	58.32^g^ (36.37)	73.17^h^ (16.79)	69.32^i^ (25.78)	74.17^g^ (16.22)	75.46^fg^ (20.07)
LSD	4.91		2.78		4.27	
CV (%)	5.08		2.89		3.99	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Among all of the salinity levels black gram (BARI Mash-1) showed the lowest reduction of RWC than mungbean (BARI Mung-5) in various plant parts. In saline conditions plant suffers from osmotic shock due to lower water potential in the soil solution (Greenway and Munns, 1985; Orcutt ahd Nilsen, 2000). Synthesize of different metabolites are very much essential for maintaining turgor pressure across different plant parts. The RWC signifies the water content in plants. In the present study mungbean was found to suffer more from water stress than black gram reported by Win *et al*. (2011).

Water saturation deficit

Water saturation deficit (WSD) performed a reverse trend of RWC. The amount of water deficit in plants termed as WSD. WSD in all the parts studied, viz. leaf, petiole of black gram and mungbean substantially increased with increasing salt levels (Figure 2). Black gram showed a lower reduction of WSD (% of the control) than mungbean in different plant parts under salt stress. This present study reveals that mungbean plants surffered more from water deficit at high salinity level than black gram (Greenway and Munns, 1985; Orcutt and Nilsen, 2000). Radicle length provides significant clue to the response of plants due to salinity stress as the roots absorb water and nutrients from soil (Mehmet Demir, 2003; Moose and Mumms, 2008; Muhammad and Majid, 2013). The WSD increased under salt stress with the plant age black gram and mungbean and the reduction was more in mungbean than in black gram (Islam, 2001).

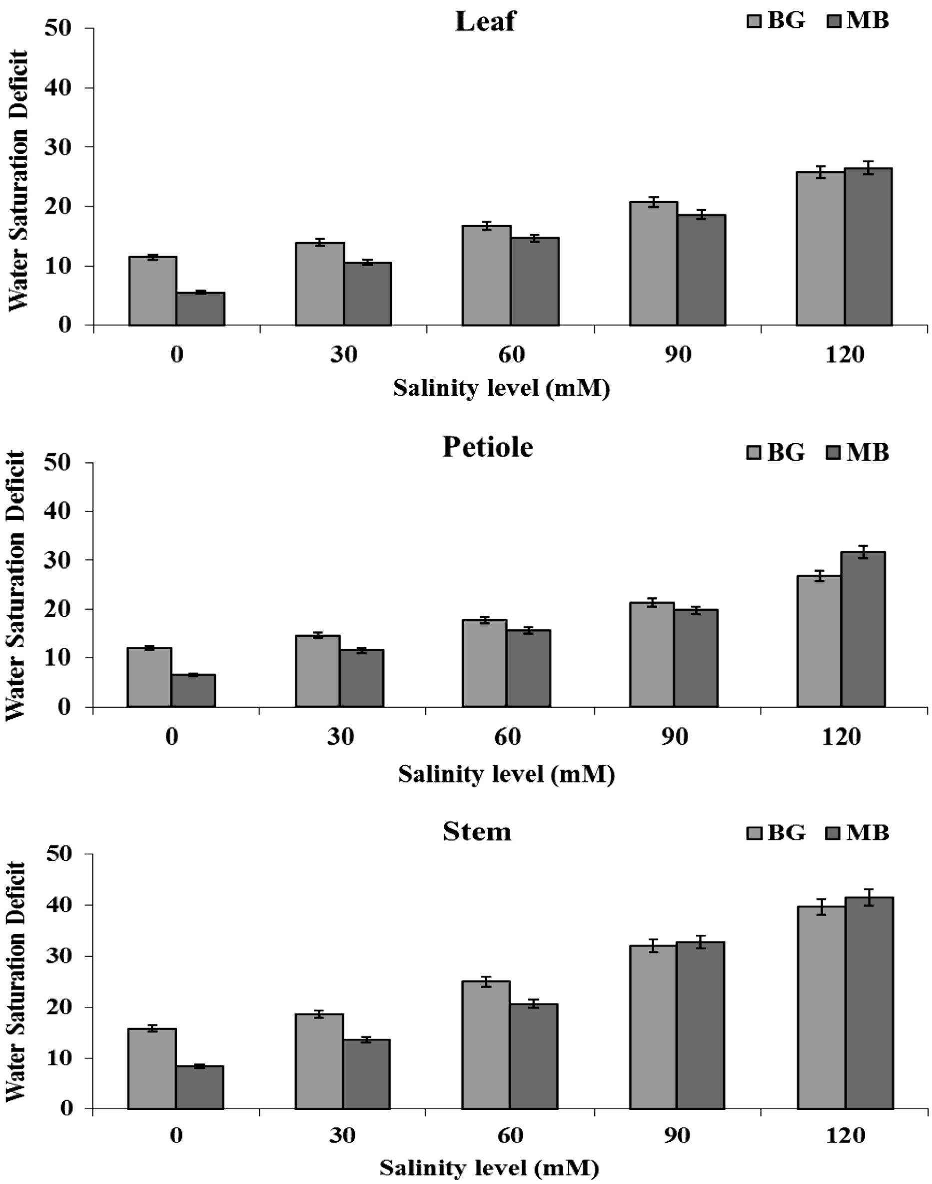

Figure 2 Effect of NaCl on water saturation deficit in different plant parts of black gram (BG = BARI Mash-1) and mungbean (MB = BARI Mung-5)

Water retention capacity

The ratio of turgid weight to dry weigh is termed as water retention capacity (WRC). The capacity of plant cell to retain water greatly influenced by WRC at a particular stage. WRC is determined by the structure of the cell. The WRC of black gram and mungbean significantly reduced by salt stress (Table 6). At the highest salinity stress (120 mM NaCl) the higher reduction of WRC (96.23% to control) was recorded in the stem of mungbean, while the reduction was only 92.89% over control in the stem of black gram.In case of leaf, the highest reduction of WRC was recorded (85.10%) from the 120 NaCl salinity among all treatments while black gram showed minimum reduction. In all studied plant parts, the WRC of black gram was much lower than that of mungbean. The higher reduction in WRC (% to the control) in mungbean than in black gram indicates a greater damage in cell structure due to salinity in the former crop than the later (Sangakkara *et al*., 1996; Islam, 2001; Kabir *et al*., 2004).

Table 6 Effect of NaCl on water retention capacity in different plant parts of BARI Mash-1 (BG) and BARI Mung-5 (MB)

Salt Stress (mM)	Water retention capacity (WRC)					
	Stem		Petiole		Leaf	
	BG	MB	BG	MB	BG	MB
0	9.14^{b}	11.42^{a}	6.98^{b}	9.27^{a}	8.18^{b}	10.27^{a}
30	7.55^{d} (17.40)	8.33^{c} (27.06)	5.13^{c} (26.50)	7.24^{b} (21.89)	6.13^{c} (25.06)	8.24^{b} (19.76)
60	5.29^{e} (42.12)	5.57^{e} (53.85)	3.53^{d} (49.42)	5.12^{c} (44.76)	4.53^{d} (44.62)	6.12^{c} (40.40)
90	2.03^{f} (44.98)	1.54^{f} (86.51)	2.17^{e} (68.91)	2.63^{e} (71.62)	3.17^{e} (61.25)	3.63^{e} (64.66)
120	0.65^{g} (92.89)	0.43^{g} (96.23)	1.51^{f} (78.37)	1.29^{g} (86.08)	1.51^{f} (81.54)	1.53^{f} (85.10)
LSD	0.72		0.51		0.76	
CV (%)	10.88		9.08		9.78	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Water uptake capacity

Water uptake capacity (WUC) decreased with increasing salinity in all the treatments. Different plant parts viz. leaf, stem and petiole of black gram and mungbean significantly reduced by salt stress (Table 7). The stem of black gram showed 40% reduction of WUC while mungbean provided 80.55% reduction at maximum salt stress (120 mM). Mungbean produced the maximum reduction (75.75% to control) of WUC in petiole while black gram showed 41.78% reduction of WUC. Under 120 mM salt stress black gram produced

38.20% reduction of WUC in leaf while mungbean showed 76.31% reduction of WUC. Black gram showed lower reduction of WUC than mungbean in all plant parts among all salinity levels. This trend was also found in other parameters such as RWC, WRC and WSD, and black gram had to uptake relatively more amount of water to reach turgidity than mungbean (Sangakkara *et al*., 1996; Islam, 2001; Kabir *et al*., 2004).

Table 7 Effect of NaCl on water uptake capacity in different plant parts of BARI Mash-1 (BG) and BARI Mung-5 (MB)

Salt Stress (mM)	Water uptake capacity (WUC)					
	Stem		Petiole		Leaf	
	BG	MB	BG	MB	BG	MB
0	0.85[a]	0.72[c]	0.79[a]	0.66[c]	0.89[a]	0.76[bc]
30	0.79[b] (6.74)	0.60[e] (16.67)	0.71[b] (10.12)	0.54[e] (18.18)	0.81[b] (8.99)	0.64[e] (15.79)
60	0.68[cd] (20.00)	0.47[f] (34.72)	0.63[cd] (20.25)	0.41[f] (37.88)	0.72[cd] (19.10)	0.51[f] (32.89)
90	0.65[d] (23.53)	0.34[g] (55.55)	0.60[d] (24.05)	0.26[g] (60.61)	0.69[de] (24.28)	0.38[g] (50.00)
120	0.51[f] (40.00)	0.14[h] (80.55)	0.46[f] (41.78)	0.16[h] (75.75)	0.55[f] (38.20)	0.18[h] (76.31)
LSD	0.04042		0.04042		0.05716	
CV (%)	6.29		3.28		7.18	

Note: Values in parenthesis indicate percent values to the control
BG = BARI Mash-1 = Black gram and MB = BARI Mung-5 = Mungbean

Exudation rate

Salinity significantly reduced the exudation rate of black gram and mungbean measured at 57 DAE (Figure 3). The exudation rate of black gram plants was much higher than mungbean at all levels of salinity. Black gram plants treated with 120 mM NaCl produced exudation rate of 28.2 mg/hr whereas mungbean was only 14.89 mg/hr at 57 DAE. At moderate salt stress (90mM), black gram produced 50.28 mg/hr and 20.08 mg/hr produced by mungbean plant. Among all of salt stress, the maximum exudation rate was recorded in black gram than mungbean. Higher exudation rates in black gram than mungbean disclosed that black gram plants maintained a better water relation than mungbean under saline condition (Sangakkara *et al*., 1996; Islam, 2001; Kabir *et al*., 2004).

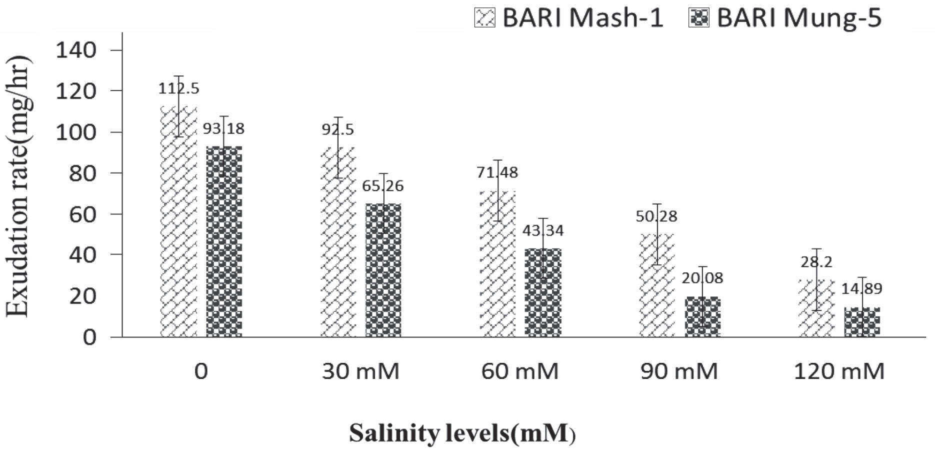

Figure 3 Effect of NaCl on exudation rate and yield of black gram (BG = BARI Mash-1) and mungbean (MB = BARI Mung-5)

CONCLUSION

From the overall results it may be concluded that black gram (BARI Mash-1) maintained lower reduction water relations and dry matter accumulation than in mungbean (BARI Mung-5) at different levels of salinity which indicated high salt tolerance of black gram than in mungbean. Therefore, black gram (BARI Mash-1) can be advised to grow in the salt affected regions i.e. southern part of Bangladesh.

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