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Responses of Maize Varieties to Salt Stress in Relation to Germination and Seedling Growth

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Abstract. A pot experiment was carried out at the Laboratory of Department of Agronomy, Hajee Mohamad Danesh Science and Technology University (HSTU), Bangladesh during 2016 to evaluate the response of maize varieties at germination and seedling growth stages under salt stress. The seeds of the BARI (Bangladesh Agricultural Research Institute) developed four maize varieties *viz.* Barnali, Khoi Vutta, Mohor and BARI Maize 5 were placed in plastic pots (each of 25 cm length and 12 cm width) on sand bed irrigated with tap water (control), 100 and 200 mM NaCl salt solutions. It was replicated in thrice with completely randomized design (CRD). Salinity stress significantly affected the germination characters and seedling growth parameters of maize varieties. The germination percentages (GP) and germination rate (GR) reduced significantly with increasing salinity, and the variety Khoi Vutta showed the highest GP and GR followed by Barnali and Mohor showed the lowest GP and GR followed by BARI maize 5. Under high salinity level, seedling growths characteristics like shoot and root lengths, fresh and dry weight of shoot and roots reduced remarkably in the variety Mohor indicating salt susceptible while the minimum reduction of the aforementioned traits was observed in the variety Khoi Vutta demonstrating high salt tolerant variety. The studied varieties can be ranked on the basis of salt tolerance as Khoi Vutta > Barnali > BARI Maize 5 > Mohor from the experiment.

Introduction

Maize (*Zea mays* L.) occupies one of the important cereal crops all over the world. It serves as food and oil for human, feed for livestock and as raw material for industry [1], [2]. It is widely grown in various soil and climatic conditions due to its contribution among cereals in the world. It can play a glorious role in economy of the country by feeding malnourished people as well as solving food problems. Therefore, maize should get priority considering the protein malnourishment of the people, because it encompasses more digestible protein than the other cereals [3]. Furthermore, due to the rising poultry industry in Bangladesh, the need for maize is increasing very sharply as maize is an important component of poultry feed. In Bangladesh, total land area and production of maize are 395500 ha and 279500 m tons respectively [4].

The world agriculture faced lots of problems due to soil salinity as its damage the various cellular function of plant. The land is becoming non-productive due to accumulation of salt in fresh soil through tidal flow close proximity to sea level in each year. About 300 million ha of irrigated farmland is estimated to be affected by salinity. Four countries viz. China, India, Pakistan and United States provided more than half of all salt-affected irrigated farmlands in the world [5]. The most severe difficulties for crop production in the dry regions are high concentration of toxic ions especially NaCl either in soil or in irrigation water [6]. Plant growth and productivity drastically restricted by salinity that is of the major environmental factors [7]. The salt stress could be lead to a

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decrease in the growth and productivity of various crops in the world [8-16]. The disruption of intracellular ionic concentration and osmotic gradients inhibiting a number of vital physiological functions reduced by salinity resulting malfunctioning of plant morpho-physiological characters i.e photosynthesis [17], reduction of protein synthesis and activities of enzyme [18], poor nutritional balance (lowering N, P, K^+, Ca^{2+} unbalanced carbon metabolism) [19], and stunted stem length, stem width, stempith diameter, leaf blade thickness, leaf vascular bundle length and leaf xylem vessels [20], [21].

Reduction of nutrient uptake capacity often accompanied by mineral toxicity leading to nutritional imbalance [22]. Soil reclamation and/or improved irrigation techniques (generally expensive) could be a systematic tactics for the management of problematic soils/salt affected soil in the arid and semi-arid tropics of this universe. The most inexpensive and more sustainable solution for using these problematic soils is the crop improvement through genetically or agronomical management. So, improvement of new methods to introduce salt stress resistance and tolerance varieties is so important. By cultivating the tolerant genotype that may sustain a reasonable yield on salt affected soil [23]. The germination and tolerance mechanism greatly varied in crop to crop at growth and seedling stage [24]. The selection criterion for screening salt tolerant individual and increasing salt tolerance in many species is the vigorous growth at the seedling stage [25]. Among all of the life cycle of plant, the germination and seedling stage is the sensitive to salinity than the adult stage [26]. The greater reduction of early seedling and growth stage was observed in wheat and sorghum with increasing salinity [27]. Therefore, the present experiment was carried to evaluate salt tolerance of four maize varieties at germination and seedling growth under saline stress environment.

Materials and Method

Location and duration

A pot trial was took place in the laboratory of Department of Agronomy, Hajee Mohamad Danesh Science and Technology University (HSTU), Bangladesh during the period of 01 November to 15 November, 2016.

Plant materials

The seeds of the four maize varieties *viz.* Barnali, Khoi Vutta, Mohor and BARI Maize 5 were used in this experiment. The seeds of those varieties were collected from Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. The properties of maize varieties are presented in Table 1 [28].

Temperature (maximum, minimum and average) and relative humidity

The daily weather data (average) on temperature and humidity during experimental period were recorded from the Meteorological Station, HSTU, Dinajpur, Bangladesh. The temperature fluctuated from 12 to 24oC and the average temperature was around 18oC during seed germination and seedling growth test. The minimum humidity of those days was 47% and maximum was 57%. The data on temperature (maximum, minimum and average) and humidity are presented in Fig. 1

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

Varieties	Year of release	Life span (days)	1000-grain weight (g)	Major grain properties, diseases and pest
Barnali	1986	140-145	245-320	Golden yellow, semi-flint, large cob size, pointed at the tip, almost resistant to diseases and pests.
Khoi Vutta	1986	125-130	140-150	Bright yellow, flint, suited for its high popping per cent (>95%) and popping quality, almost resistant to diseases and pests.
Mohor	1991	135-145	180-300	Bright yellow, flint, large cob girth, open pollinated, suitable for fodder purpose.
BARI Maize 5	1998	145-155	290-310	Bright yellow, flint, open pollinated, resistance to diseases, pests and lodging.

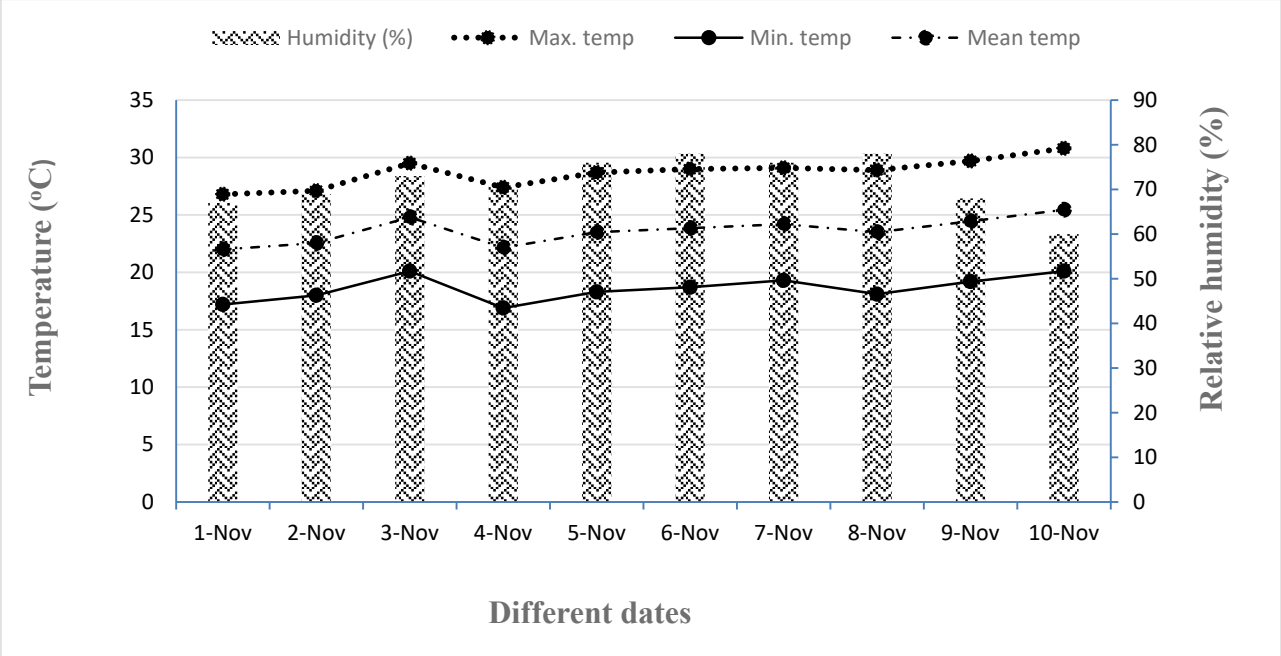


Figure 1. Weather data on temperature (maximum, minimum and average) and relative humidity during experimentation.

Experimental treatments and design

Three levels of salinity viz. 0, 100 and 200 mM NaCl was used for salt treatments completely randomized design (CRD) with five replications. Before sowing, the seeds were sterilized and thoroughly rinsed with 1% mercuric chloride solution with distilled water, respectively for 2 minutes. The dissolved calculated amount of NaCl in tap water was used to make saline solutions of 100 and 200 mM. Fresh water collected from tap was used as control.

Experimental procedure

The seeds of maize varieties were germinated in plastic pots (25 cm x 12 cm) on sand bed culture. One hundred seeds were sown in equal distances between seeds and between lines in each tray. The treatments were imposed with tap water for control and calculated amount NaCl salt solutions for creating 100 and 200 mM NaCl salt stress as necessary for obtaining desire moisture condition. Appropriate care and pest-diseases control were confirmed in each pot during the experimental period.

Data collection

Interval at 24-hour and continued up to 10^{th} day (240 h), germination was counted. The seed considered as germinated seedling, when the plumule and radicle came out about >2 mm long from seed.

Germination percentage

The following formulae were used to calculate the germination percentage.

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

Rate of germination

By using the following formulae [29], the germination rate was calculated.

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

Shoot and root lengths

Seedlings from each plastic pot were collected as a sampling after placement for germination at 10 days. Scale was used to measure the shoot and root length (cm) of individual seedling.

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 number of plants. For measuring the shoot and root dry weight, an electric oven was used at 80^0C for 72 h and weights were recorded through an electrical balance.

Statistical analysis

The collected data were analysed statistically and means were adjudged by DMRT at 1 and 5% level of probability. The data were analysed with the help of computer using 'R'Command program.

Results and Discussion

Germination percentage

Salinity caused a considerable delay and reduction in seed germination. The germination percentage (GP) of different maize varieties drastically reduced and the varieties showed dissimilar results with increasing salt stress (Table 2). At 100 mM NaCl salinity level, the maximum reduction in GP (34.87%) was found in Mohor followed by the variety BARI Maize 5 (33.96%) and the minimum reduction (13.59%) was found in Khoi Vutta which is followed by the varieties of Barnali (16.81%) when compared to control. Again at high salinity level (200 mM NaCl), the GP reduced severely in all maize varieties. The maximum reduction (57.74%) was noted in Mohor whereas the minimum reduction (23.73%) was noted in Khoi Vutta when compared to control condition. It is indicated that the GP decreased significantly with the increasing salinity levels. The osmotic potential which retards the uptake of water necessary for mobilization of nutrients disturb by salt stress resulting reduction of germination. The result of confirms the results of [30], [31], in maize. The osmotic effect of salts present in the growth medium gradually decreased the germination percentage as reported by [32].

Germination rate

Salinization resulted in a general reduction of germination rate (GR) for all the varieties and showed varied responses among the varieties to the increased levels of salinity (Table 3). The maximum GR (138.51%) was documented in the variety of Khoi Vutta while the lowest (108.39%) was documented in the variety of Mohor which was statistically similar with the variety of BARI Maize 5 (109.42%) under control condition. Moreover, at 100 mM NaCl salinity level, the maximum reduction of GR (32.63%) was recorded in BARI Maize 5, in contrast the minimum reduction (15.30%) was observed from Khoi Vutta. On the other hand, at high salinity level (200 mM NaCl) harshly reduced the germination rates of all maize varieties. The maximum reduction (59.40%) was noted in Mohor followed by BARI Maize 5 (57.26%) though the minimum reduction (41.46%) was recorded in Khoi Vutta over control condition. The main reason of reducing germination rate are the toxic effects of certain ions and higher concentration of salt disturbs the water potential in the medium which hinders water absorption by germinating seeds [33], [34].

Table 2. Germination percentage of maize varieties as influenced by salt stress.

Genotypes	Germination percentage (%)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	94.00 b	79.20 e	16.81	61.06 g	35.04
Khoi Vutta	98.33 a	84.96 d	13.59	75.00 f	23.73
Mohor	87.43 c	56.94 h	34.87	36.95 j	57.74
BARI Maize 5	85.39 d	56.39 h	33.96	47.22 i	44.70
LS		**		**	
CV (%)			1.11		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of significance

Table 3. Germination rate of maize varieties as influenced by salt stress.

Varieties	**Germination rate (%)**				
	Control	**100 mM**	**% Reduction**	**200 mM**	**% Reduction**
Barnali	121.12 b	99.20 e	18.10	61.09 i	49.56
Khoi Vutta	138.51 a	117.31 c	15.30	81.08 f	41.46
Mohor	108.39 d	75.18 g	30.51	44.01 j	59.40
BARI Maize 5	109.42 d	73.72 h	32.63	46.76 j	57.26
LS		**		**	
CV (%)			1.03		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of significance

Root length

Maize varieties faced a significant reduction in root lengths due to salinity (Table 4). However, the root lengths were significantly lower at 100 mM NaCl concentration over control but greater than the subsequent higher salt stress for all the varieties. The highest root length (29.47 cm) was obtained in Khoi Vutta but the lowest (23.73 cm) was obtained from Barnali which was statistically similar with Mohor (24.24 cm) and BARI Maize 5 (24.45 cm) under control condition. At moderate salt stress (100 mM NaCl) Barnali showed the highest reduction (10.78%) in root length while Khoi vutta displayed the lowest reduction (7.50%) which was followed by the BARI Maize 5 (9.08%). On the other hand, at high salt stress (200 mM NaCl), Mohor showed the highest reduction (30.82%) in root length followed by Barnali whereas the lowest reduction (22.05%) was documented in Khoi Vutta. This reduction may be that the root growth is sensitive to the high salt

concentration available in the medium. The root length and biomass of all the wheat cultivars tested in their study dramatically reduced with greater amount of imposing NaCl stress as mentioned by [35],[36].

Table 4. Root length of maize varieties as influenced by salt stress.

Varieties	Root length (cm)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	23.73 cd	21.17 de	10.78	16.53 g	30.34
Khoi Vutta	29.47 a	27.26 b	7.50	22.97 d	22.05
Mohor	24.24 c	21.80 d	10.07	16.77 f	30.82
BARI Maize 5	24.45 c	22.23 d	9.08	17.96 f	26.54
LS	**			**	
CV (%)			2.59		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of significance

Shoot length

The highest shoot length (35.90 cm) was produced by Khoi Vutta but the lowest (31.60 cm) was observed from BARI Maize 5 under control condition. However, at moderate salt stress (100 mM NaCl) Barnali, Mohor and BARI Maize 5 presented more than 25% reduction of shoot length whereas Khoi Vutta presented less than 18%. Furthermore, Barnali, BARI Maize 5, and Mohor exhibited more than 40% reduction at high salt stress (200 mM NaCl) although Khoi Vutta exhibited only 20.14% reduction at the same stress (Table 5). The acceleration of leaf abscission and inter-nodal development as well as shoot growth drastically reduced by salinity stress as confirmed by [37], [38], [39]. This result is consistent with the result of [39].

Table 5. Shoot length of maize varieties as influenced by salt stress.

Varieties	Shoot length (cm)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	33.29 c	24.11 h	27.58	19.33 i	41.93
Khoi Vutta	35.90 a	29.65 e	17.41	28.67 f	20.14
Mohor	34.07 b	24.92 g	26.86	18.29 j	46.32
BARI Maize 5	31.60 d	23.68 h	25.06	17.89 j	43.39
LS	**			**	
CV (%)			1.62		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, Level of significance

Root fresh weight

Significant variation of root fresh weight among treatments of all the maize varieties was found when grown under normal and saline conditions. Due to increase in salinity, the shoot fresh weight decreased significantly for all the maize varieties (Table 6). However, at 100 mM saline condition, the maximum reduction (25.35%) was documented in Mohor whereas the minimum reduction (16.87%) was in Khoi Vutta. Furthermore, under 200 mM saline condition, the maximum reduction (46.48%) was recorded in Mohor showing more susceptible variety. Contrarily, the minimum reduction was observed in Khoi Vutta (33.73%) followed by Barnali (41.18%) when compared to the control. Moreover, the effect of salt stress at 200 mM NaCl concentration on root fresh weight was different among varieties. Similar results were reported by [40], for wheat and [41], for cotton.

Table 6. Root fresh weight of maize varieties as influenced by salt stress.

Varieties	Root fresh weight (g)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	0.51 cd	0.41 de	19.61	0.30 j	41.18
Khoi Vutta	0.83 a	0.69 b	16.87	0.55 c	33.73
Mohor	0.71 b	0.53 cd	25.35	0.38 d	46.48
BARI Maize 5	0.71 b	0.55 c	22.54	0.40 e	43.66
LS		**		**	
CV (%)			3.01		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of significance

Shoot fresh weight

Shoot fresh weight of maize varieties was significantly inhibited by the salinity but the trend of inhibition at 100 and 200 mM saline treatments was not similar for all varieties (Table 7). However, the maximum reduction in shoot fresh weight was exposed in BARI Maize 5 (18.28%) followed by the variety Mohor (17.44%) and the minimum reduction (7.29%) was received in Khoi Vutta at 100 mM NaCl but at the highest salinity level of 200 mM NaCl, the maximum reduction of shoot fresh weight (41.86%) was observed from the variety Mohor although the minimum reduction (25.00%) was documented in Khoi Vutta. The result showed that the increase in salinity level, fresh root weight reduced significantly. Salt stress showed a significant reduction in fresh and dry weights of shoot of two maize cultivars with the increase of stress treatments [33].

Table 7. Shoot fresh weight of maize varieties as influenced by salt stress.

Varieties	Shoot fresh weight (g)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	0.93 ab	0.81 de	12.90	0.65 g	30.11
Khoi Vutta	0.96 a	0.89 bc	7.29	0.72 f	25.00
Mohor	0.86 cd	0.71 f	17.44	0.50 hi	41.86
BARI Maize 5	0.93 ab	0.76 ef	18.28	0.56h	39.78
Level of significance		**		**	
CV (%)			2.57		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation

Root dry weight

It was evident that there was significant variation of root dry weight among the treatments in all maize varieties (Table 8). The heaviest root dry weight (0.67 g) was obtained in Khoi Vutta although the slightest (0.34 g) was obtained in Barnali under control condition. At moderate stress (100 mM NaCl) Barnali, Mohor and BARI Maize 5 showed more than 20% reduction whereas Khoi Vutta showed less 12% reduction of root dry weight. At high stress (200 mM NaCl) Barnali, Mohor and BARI Maize 5 reduced more than 40% of root dry weight but Khoi Vutta reduced less than 33% of root dry weight over the control. Salt stress increased the metabolic energy cost and reduced carbon gain resulting decreased in root dry weight. The photosynthetic rates of leaf area greatly hampered by salt stress resulting reduction of dry weight [42]. This result is accordance with the result of [33], in maize cultivars

Table 8. Root dry weight of maize varieties as influenced by salt stress.

Varieties	Root dry weight (g)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	0.34 de	0.27 fg	20.59	0.20 h	41.17
Khoi Vutta	0.67 a	0.59 b	11.94	0.45 c	32.84
Mohor	0.54 b	0.41 c	24.07	0.30 ef	44.44
BARI Maize 5	0.40 cd	0.31 ef	22.50	0.23 gh	42.50
LS		**		**	
CV (%)			2.01		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of Significant

Shoot dry weight

Shoot dry weight of maize varieties was affected significantly by salinity (Table 9). At control condition there was non-significant variation among maize varieties. The results indicated that maximum reduction of shoot dry weight (22.08%) was detected in Mohor followed by BARI Maize 5 even though the minimum reduction (12.35%) was revealed in Khoi Vutta at 100 mM NaCl concentration compared to the control. On the other hand, Khoi Vutta successfully tolerated 200 mM NaCl salinity and exhibited only 20.99% reduction in shoot dry weight while Mohor evidenced to be sensitive and shoot dry weight severely reduced up to 43.75%. The combination of osmotic and specific ion effects of Cl^- and Na^+ result of salinity that are the reason of reducing the shoot dry weight [43], [44], [17]. The value of shoot dry weights of maize cultivars were negatively affected by increasing salt concentration [45].

Table 9. Shoot dry weight of maize varieties as influenced by salt stress.

Varieties	Shoot dry weight (g)				
	Control	100 mM	% Reduction	200 mM	% Reduction
Barnali	0.78 a	0.63 c	19.23	0.48 d	38.46
Khoi Vutta	0.81 a	0.71 b	12.35	0.64 c	20.99
Mohor	0.77 a	0.60 c	22.08	0.45 d	43.75
BARI Maize 5	0.79 a	0.62 c	21.52	0.51 d	35.44
LS		**		**	
CV (%)			4.97		

Values having same letter (s) do not differ significantly by DMRT at P<5% level
Values in parenthesis indicate reduction percent values to the control
** Highly significant (p≤ 1%)
CV= Coefficient variation, LS= Level of significance

Conclusion

From the above results it can be concluded, the screening of maize varieties under salt stress showed that germination and seedling growth parameters of maize varieties were affected by salinity but the effect was dissimilar among the varieties. The variety of Khoi Vutta showed less reduction of germination and seedling growth traits due to salt stress as compared to control condition indicating resistance to salt stress while Mohor exhibited the maximum reduction of those traits under salt condition which signifying susceptibility to salt stress. So Khoi Vutta may be recommended to grow in saline areas of the Southern part of Bangladesh.

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Conflict of interest

The authors declare no conflicts of interest.

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