

Screening of Maize (*Zea mays* L.) cultivars for salinity tolerance at germination and early seedling stages

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Abstract

An experiment was conducted to evaluate the effects of salinity stress on seed germination and early seedling growth of five cultivars of maize (*Zea mays* L.). Salinity stress markedly reduced seed germination and early seedling growth in all cultivars exposed to 0-300 mM NaCl under controlled laboratory conditions for 14 days. However, cultivar responses differed significantly. Cultivar BHM-9 showed the highest tolerance, maintaining comparatively higher germination (80% at 300 mM NaCl) and better biomass retention, with lower reductions in shoot and root dry weight (78.95 and 63.64%, respectively). In contrast, BHM-13 and BHM-16 were highly sensitive, exhibiting sharp declines in germination (16.67 and 20.00% germination rate, respectively). The declining rate of biomass accumulation was also relatively higher in BHM-13 (90.48 and 66.67% reduction) and BHM-16 (93.75 and 83.34% drop in shoot and root dry weight) at 300 mM NaCl concentration. Overall, BHM-9 demonstrated superior performance under salt stress and is identified as a promising cultivar for saline-prone environments at the germination and early seedling stages.

Keywords: Salinity, maize, germination, seedling growth, dry weight, salt tolerance.

INTRODUCTION

Salinity is one of the most serious environmental constraints limiting agricultural productivity worldwide. Salinity stress involves changes in various physiological and metabolic processes, depending on severity and duration of the stress, and ultimately inhibits crop production (Khanam *et al.*, 2025; Akhtar *et al.*, 2013). These adverse effects lead to reduced cell division and elongation, decreased photosynthetic efficiency, and metabolic disturbances that ultimately limit crop growth and yield (Afrin *et al.*, 2021a; Ahanger & Agarwal, 2017). In most of the plants, salinity changes in gene expression which leads to an increased synthesis of osmo-protectors and osmo-regulators (Afrin *et al.*, 2021b). Salinity stress induces the excessive generation of reactive oxygen species (ROS), which might cause cell death through causing damage to proteins, lipids and DNA, thereby disrupting membrane integrity and cellular homeostasis. (Ahmad *et al.*, 2010; Gill & Tuteja 2010).

Seed germination and seedling establishment are among the most salt-sensitive stages in the plant life cycle. High salinity conditions reduce the osmotic potential of the surrounding medium, thereby limiting water uptake by seeds and delaying germination.

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In Bangladesh, soil salinity is a major constraint to sustainable agriculture, particularly in coastal regions. About one fifth of the total area of Bangladesh is laid low with various degrees of salinity (Khanam *et al.*, 2018). According to Haque (2006), 1.06 million hectares, representing almost 30% of the total arable land in the coastal regions of Bangladesh are subjected to different degrees of salinity. The salinity-affected area has gradually expanded over the past decades due to sea-level rise, tidal flooding, reduced upstream freshwater flow, and climate-change-induced saltwater intrusion. These conditions significantly limit crop productivity and restrict the cultivation of many economically important crops in coastal agro-ecosystems.

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide and has gained increasing importance in Bangladesh because of its high yield potential and diverse uses in food, feed, and agricultural sectors. In recent decades, maize cultivation has expanded rapidly due to the increasing demand for poultry and livestock feed. However, the expansion of maize cultivation into marginal and coastal areas exposes the crop to salinity stress, which can significantly reduce plant growth, physiological activity, and yield. Hence, it is necessary to take an effort to determine the effects of salinity on the germination of maize. Considering the increasing extent of salinity-affected soils in Bangladesh and the growing importance of maize cultivation, identifying maize cultivars capable of tolerating saline conditions is essential for sustainable crop production. Screening maize genotypes at the germination and seedling stages provides valuable insights into their tolerance mechanisms and adaptability to saline environments. Despite clear evidence that germination is highly sensitive to salinity, there remains a lack of comparative screening of locally available maize cultivars in our country at the early growth stages. Therefore, the present study was conducted to evaluate the effects of salinity on germination and early seedling growth of five cultivars of maize.

MATERIALS AND METHODS

Seeds of five cultivars of maize- viz. BARI Hybrid Maize-7 (BHM-7), BHM-9, BHM-13, BHM-14, and BHM-16 were collected from the Bangladesh Agricultural Research Institute (BARI) and used as plant materials in this experiment. The germination experiment was carried out in Plant Physiology and Biochemistry laboratory, Jahangirnagar University to determine salinity tolerance among the maize cultivars. The seeds were thoroughly rinsed with distilled water after being surface sterilized for three minutes with 0.1% sodium hypochlorite. As maize seeds are relatively large, ten seeds were placed in each 9 cm Petri dish on moist blotting paper to avoid overcrowding and maintain uniform germination conditions. The experiment consisted of seven treatments (0, 50, 100, 150, 200, 250 and 300 mM NaCl), each with three replications. These treatments were prepared by dissolving sodium chloride (NaCl) directly in distilled water to the respective molar concentrations. The 0 mM treatment (control) consisted of distilled water alone. The experiment was conducted at $25 \pm 2^{\circ}\text{C}$ under a 16 h light/8 h dark photoperiod. The number of seeds that were germinated was recorded at 24 hours intervals for 14 days. After 14 days, germination percentage, germination index and

germination speed were calculated following standard formula of Kandil *et al.* (2012); Karim *et al.* (1992); Mohammad *et al.* (1989), respectively.

Measurements of shoot and root length and fresh weight were taken on the 14th day. During the harvest, the seedlings were placed in an oven and subjected to a drying process at a temperature of 65-70°C until they attained a stable weight to measure the dry weight of the cultivars. Data on germination behavior and seedlings characteristics for each NaCl treatment were compared with those in the control treatment.

Statistical analysis: All data were examined utilizing the statistical software IBM SPSS Statistics version 25. A one-way analysis of variance (ANOVA) was carried out on the mean $\pm$ standard deviation (SD) values. The least significance difference test (LSD Test) is employed to compare the results at a 5% probability level.

RESULTS AND DISCUSSION

Germination percentage (GP) and Germination index (GI): The results show a continuous decline in germination rates as salinity levels increase across different maize cultivars (Table 1). At 300 mM NaCl, BHM-9 had the highest germination percentage (80.00%), while BHM-13 had the lowest (16.67%), relative to the control. Cultivars BHM-7, BHM-14, and BHM-16 demonstrated similar patterns, with low germination percentages of 26.67, 26.67 and 20.00%, respectively. Under higher salt concentrations, BHM-9 outperformed the other four cultivars. At salinity treatments of 0, 50, 100, 150, 200, 250, and 300 mM, this cultivar was reported to germinate at 100%, 100%, 96.67%, 96.67%, 93.33%, 86.67%, and 80.00%, respectively. In summary, BHM-9 exhibited the highest germination throughout the experiment and remained statistically similar at 0, 50, 100, and 150 mM NaCl, with significant reductions observed from 200 mM onwards. In contrast, BHM-7, BHM-13, BHM-14, and BHM-16 showed significant decreases in germination with each increase in salinity level, as indicated by the different letter groupings across treatments. Similar results have been observed regarding the germination index across the seven cultivars (Table 2). Seed germination is the primary physiological process affected by abiotic stress like salinity. Presumably the osmotic effect due to salinity on inhibition of seeds was the main cause for the reduction of germination as indicated by Akbar & Ponnamperna (1982). Numerous scientists observed comparable results of decreasing GP in many crops, including wheat and maize (Goudarzi and Pakniyat, 2008), mustard (Lallu and Dixit, 2005), rice (Bera *et al.*, 2006) and soybean (Hosseini *et al.*, (2002). Karim *et al.*, (1992) also observed that a negative correlation coefficient was obtained between the NaCl concentration and GI.

Germination speed: Table 3 indicated that, salinity dramatically reduced the germination speed (GS) in every treatment. The speed of germination of BHM-9 decreased from 8.23 at the control to 6.46 at 300 mM NaCl, indicating a reduction of approximately 78.49% in speed relative to the control. At the highest level of NaCl exposure, BHM-14 and BHM-16 showed a decrease in germination speed, reaching 87.11 and 86.05%, respectively, compared to the control.

In contrast, it was shown that BHM-7 and BHM-13 reduced germination speed by nearly half when compared to the control (67.38 and 55.23%, respectively). Overall, BHM-9 and BHM-14 consistently maintained higher GI values than the other cultivars across the salinity treatments, whereas BHM-7 and BHM-13 exhibited the greatest reductions, particularly under 250–300 mM NaCl. The speed of germination may have been decreased due to inactivation of hydrolase enzymes at the germination stage of seeds at high concentrations of NaCl salinity (Blum, 1988). The decreasing tendency of the speed of germination due to salinity was in conformity with the reports of others (Das *et al.*, 2017 and Akhtar *et al.*, 2021).

Table 1. Effects of different concentrations of NaCl salinity on germination percentage of five cultivars of maize

Treatments (NaCl)	Maize cultivars				
	BHM-7	BHM-9	BHM-13	BHM-14	BHM-16
0 mM	83.33 ± 5.77 a	100.00 ± 0.00 a	86.67 ± 15.27 a	63.33 ± 11.55 a	63.33 ± 11.55 a
50 mM	63.33 ± 11.55 b	100.00 ± 0.00 a	76.67 ± 15.27 b	53.33 ± 5.77 b	56.67 ± 15.27 b
100 mM	60.00 ± 20.00 c	96.67 ± 5.77 b	63.33 ± 32.14 c	50.00 ± 10.00 c	43.33 ± 23.09 c
150 mM	50.00 ± 26.46 d	96.67 ± 5.77 b	53.33 ± 11.54 d	36.67 ± 28.87 d	26.67 ± 15.28 d
200 mM	36.67 ± 5.77 e	93.33 ± 11.55 c	23.33 ± 5.77 e	33.33 ± 5.77 e	23.33 ± 11.55 e
250 mM	33.33 ± 5.77 f	86.67 ± 15.28 d	20.00 ± 10.00 f	30.00 ± 20.00 f	20.00 ± 17.32 f
300 mM	26.67 ± 5.77 g	80.00 ± 17.32 e	16.67 ± 5.77 g	26.67 ± 15.27 g	20.00 ± 10.00 f
Cultivar mean	50.48	93.33	48.57	41.9	36.19
CV%	44.05%	11.90%	62.53%	44.39%	59.57%
LSD (0.05)	12.23	8.96	14.04	14.04	13.51

*In a column followed by same letters do not differ significantly at 5% level of significance.

* Average value of 3 plants in each treatment.

Table 2. Effects of different concentrations of NaCl salinity on germination index of five cultivars of maize

Treatments (NaCl)	Maize cultivars				
	BHM-7	BHM-9	BHM-13	BHM-14	BHM-16
0 mM	100.00 ± 6.93 a	100.00 ± 0.00 a	100.00 ± 19.92 a	100.00 ± 18.23 a	100.00 ± 18.23 a
50 mM	76.00 ± 13.86 b	100.00 ± 0.00 a	88.46 ± 19.64 b	84.21 ± 9.11 b	89.47 ± 24.12 b
100 mM	72.00 ± 24.00 c	96.67 ± 5.77 b	73.07 ± 17.93 c	78.95 ± 15.79 c	68.42 ± 36.46 c
150 mM	60.00 ± 31.75 d	96.67 ± 5.77 b	61.53 ± 15.06 d	57.89 ± 45.58 d	42.10 ± 24.12 d
200 mM	44.00 ± 6.92 e	93.33 ± 11.55 c	26.92 ± 13.04 e	52.63 ± 9.11 e	36.84 ± 18.23 e
250 mM	40.00 ± 6.92 f	86.67 ± 15.28 d	23.08 ± 7.59 f	47.37 ± 31.58 f	31.58 ± 27.35 f
300 mM	32.00 ± 6.92 g	80.00 ± 17.32 e	19.23 ± 7.53 g	42.10 ± 24.12 g	31.58 ± 15.79 f
Cultivar mean	60.57	93.33	56.04	66.17	57.14
CV%	44.06%	11.90%	25.67%	44.40%	59.57%
LSD (0.05)	14.68	8.96	18.32	21.96	21.33

*In a column followed by same letters do not differ significantly at 5% level of significance.

* Average value of 3 plants in each treatment.

Table 3. Effects of different concentrations of NaCl salinity on germination speed of five cultivars of maize

Treatments (NaCl)	Maize cultivars				
	BHM-7	BHM-9	BHM-13	BHM-14	BHM-16
0 mM	7.88 ± 0.25 a	8.23 ± 0.06 a	7.93 ± 0.23 a	8.07 ± 0.18 a	7.17 ± 0.43 a
50 mM	7.79 ± 0.07 b (98.85%)	8.09 ± 0.21 b (98.29%)	7.43 ± 0.62 b (93.69%)	8.00 ± 0.00 b (99.13%)	6.94 ± 1.29 b (96.79%)
100 mM	7.47 ± 0.21 c (94.79%)	7.90 ± 0.10 c (95.99%)	7.33 ± 0.30 c (92.43%)	7.38 ± 0.40 c (91.44%)	6.88 ± 1.17 b (95.96%)
150 mM	7.32 ± 0.31 d (92.89%)	7.69 ± 0.19 d (93.43%)	7.27 ± 0.25 c (91.67%)	7.37 ± 0.32 c (91.32%)	6.88 ± 0.10 b (95.96%)
200 mM	6.94 ± 0.42 e (88.07%)	7.40 ± 0.10 e (89.91%)	7.16 ± 0.83 d (90.29%)	7.36 ± 0.31 c (91.20%)	6.77 ± 0.39 c (94.42%)
250 mM	6.33 ± 0.58 f (80.32%)	7.21 ± 0.21 f (87.60%)	5.33 ± 2.92 e (67.21%)	7.25 ± 0.79 d (89.83%)	6.55 ± 0.14 d (91.35%)
300 mM	5.31 ± 1.25 g (67.38%)	6.46 ± 0.39 g (78.49%)	4.38 ± 2.33 f (55.23%)	7.03 ± 0.29 e (87.11%)	6.17 ± 2.75 e (86.05%)
Cultivar mean	7.01	7.57	6.69	7.49	6.77
CV%	14.14%	7.93%	26.16%	6.54%	16.10%
LSD (0.05)	0.5	0.18	1.29	0.35	1.09

*In a column followed by same letters do not differ significantly at 5% level of significance.

* Average value of 3 plants in each treatment.

*Values within parenthesis indicate percentage relative to the control.

Effects on shoot and root length: The shoot and root lengths of all cultivars diminished markedly with elevated NaCl concentrations (Table 4). At the highest level of NaCl exposure, the shoot lengths of BHM-9 and BHM-14 reduced sharply (93.16 and 93.92%, respectively), corresponding over the control. BHM-7 and BHM-16 exhibited a similar pattern of declining shoot length rate at 300 mM NaCl (90.21 and 90.21%, respectively). BHM-13, on the other hand, had a comparatively less decline, showing 88.92% of the length of the shoot compared to the control. Table 4 also demonstrated that, the root length decreased significantly with the increase in salinity levels. BHM-9 showed the significant decrease at 300 mM NaCl, with a 90.72% drop in root length compared to the control. The length of the root corresponding to the control decreased by more than 80% in BHM-7, BHM-13, and BHM-14, showing 85.44, 84.95 and 86.51% drop at the highest salinity level, respectively. Whereas, BHM-16 showed relatively lower reduction in root length, which fell from 15.13 cm to 2.63 cm, having a declining rate of 82.62% at 300 mM NaCl. Karim *et al.* (1992) pointed out that shoot growth was more sensitive to salinity than germination and root growth. Moud & Maghsoudi (2008) and Datta *et al.* (2009) have reported similar results of reduced shoot and root length. The results indicated that BHM-9 and BHM-14 showed comparatively better seedling growth under salinity, while BHM-7, BHM-13, and BHM-16 experienced greater reductions, with significant differences observed among most treatments. The relatively high CV values reflect the wide variation in shoot and root growth across the broad salinity gradient (0–300 mM NaCl), particularly under higher salt stress where seedling growth was markedly inhibited.

Effects on shoot and root fresh weight: Results obtained from this experiment showed that salinity levels had a substantial impact on the fresh weight of the maize seedlings (Fig. 1). Regarding shoot fresh weight, BHM-9 and BHM-16 had relatively lower reduction rates (91.05 and 90.20%, respectively) at 300 mM NaCl, over the control. BHM-7 and BHM-13 exhibited a similar rate of shoot fresh weight decline by 87.76 and 88.53%, respectively at the maximum salt stress. In contrast, the fresh weight of the BHM-14 shoot declined by 93.34% at 300 mM NaCl, showing the most significant reduction. The root fresh weight also exhibited comparable patterns, with BHM-14 demonstrating the most significant reductions (85.71%) at the highest NaCl treatment. BHM-7, BHM-9 and BHM-16 exhibited almost similar results of root fresh weight decline. Compared to the control, BHM-13, on the other hand, showed relatively less reduction rate of 76.32% at the same treatment. The results are in confirmation with the findings of Weisany *et al.* (2012), Idris and Ali (2015) and Afrin *et al.* (2023).

Table 4. Effects of different concentrations of NaCl salinity on shoot and root length (cm) of five cultivars of maize

Treatments (NaCl)	Shoot length (cm)					Root length (cm)				
	BHM-7	BHM-9	BHM-13	BHM-14	BHM-16	BHM-7	BHM-9	BHM-13	BHM-14	BHM-16
0 mM	18.38 ± 2.08 a	23.23 ± 2.52 a	24.44 ± 4.51 a	21.87 ± 4.48 a	15.62 ± 5.87 a	14.63 ± 3.62 a	26.81 ± 6.48 a	25.44 ± 6.33 a	19.19 ± 9.38 a	15.13 ± 9.41 a
50 mM	11.69 ± 3.89 b (63.60%)	16.27 ± 2.66 b (70.03%)	16.40 ± 3.90 b (67.10%)	12.27 ± 5.11 b (56.10%)	6.97 ± 2.26 b (44.62%)	9.47 ± 3.91 b (64.73%)	13.41 ± 3.01 b (50.01%)	11.57 ± 6.46 b (45.48%)	13.16 ± 4.97 b (68.57%)	9.21 ± 2.19 b (60.87%)
100 mM	6.92 ± 1.65 c (37.64%)	10.57 ± 1.56 c (45.50%)	8.28 ± 1.92 c (33.87%)	5.24 ± 2.43 c (23.96%)	5.66 ± 2.20 b (36.23%)	6.65 ± 2.60 c (45.45%)	10.99 ± 2.19 b (40.99%)	8.49 ± 1.75 bc (33.37%)	7.02 ± 3.73 c (36.58%)	7.91 ± 3.58 bc (52.28%)
150 mM	2.67 ± 0.92 d (14.52%)	5.53 ± 1.16 d (23.80%)	5.57 ± 1.88 d (22.79%)	2.46 ± 1.88 d (11.24%)	2.53 ± 0.82 c (16.19%)	3.50 ± 0.47 d (23.97%)	5.24 ± 1.19 c (19.54%)	5.80 ± 1.97 cd (22.79%)	5.01 ± 1.52 c (26.10%)	5.87 ± 2.09 bcd (38.79%)
200 mM	2.43 ± 0.19 d (13.22%)	2.18 ± 0.53 e (9.38%)	3.76 ± 0.94 de (15.38%)	2.04 ± 0.67 d (9.32%)	2.10 ± 1.38 c (13.44%)	3.40 ± 1.24 d (23.23%)	3.29 ± 0.68 c (12.27%)	4.56 ± 1.26 d (17.92%)	4.42 ± 1.09 c (23.03%)	4.40 ± 2.75 cd (29.08%)
250 mM	1.89 ± 0.68 d (10.28%)	1.97 ± 0.65 e (8.48%)	3.67 ± 0.84 de (15.01%)	1.68 ± 0.57 d (7.68%)	1.87 ± 0.90 c (11.97%)	2.85 ± 1.20 d (19.48%)	2.87 ± 0.47 c (10.70%)	4.16 ± 0.88 d (16.35%)	3.80 ± 1.63 c (19.80%)	2.97 ± 1.45 d (19.62%)
300 mM	1.80 ± 0.47 d (9.79%)	1.59 ± 0.46 e (6.84%)	2.71 ± 0.84 e (11.08%)	1.33 ± 0.52 d (6.08%)	1.53 ± 0.59 c (9.79%)	2.13 ± 0.71 d (14.56%)	2.49 ± 0.88 c (9.28%)	3.83 ± 1.29 d (15.05%)	2.59 ± 0.63 c (13.49%)	2.63 ± 1.10 d (17.38%)
Cultivar mean	6.53	8.76	9.26	6.69	5.18	6.09	9.3	9.12	7.88	6.87
CV%	94.65%	90.87%	86.37%	114.78%	102.93%	78.96%	93.33%	87.59%	89.05%	82.79%
LSD (0.05)	19.06	25.09	24.49	23.11	15.14	13.67	26.43	23.13	18.19	13.13

*In a column followed by same letters do not differ significantly at 5% level of significance.

* Average value of 3 plants in each treatment.

*Values within parenthesis indicate percentage relative to the control.

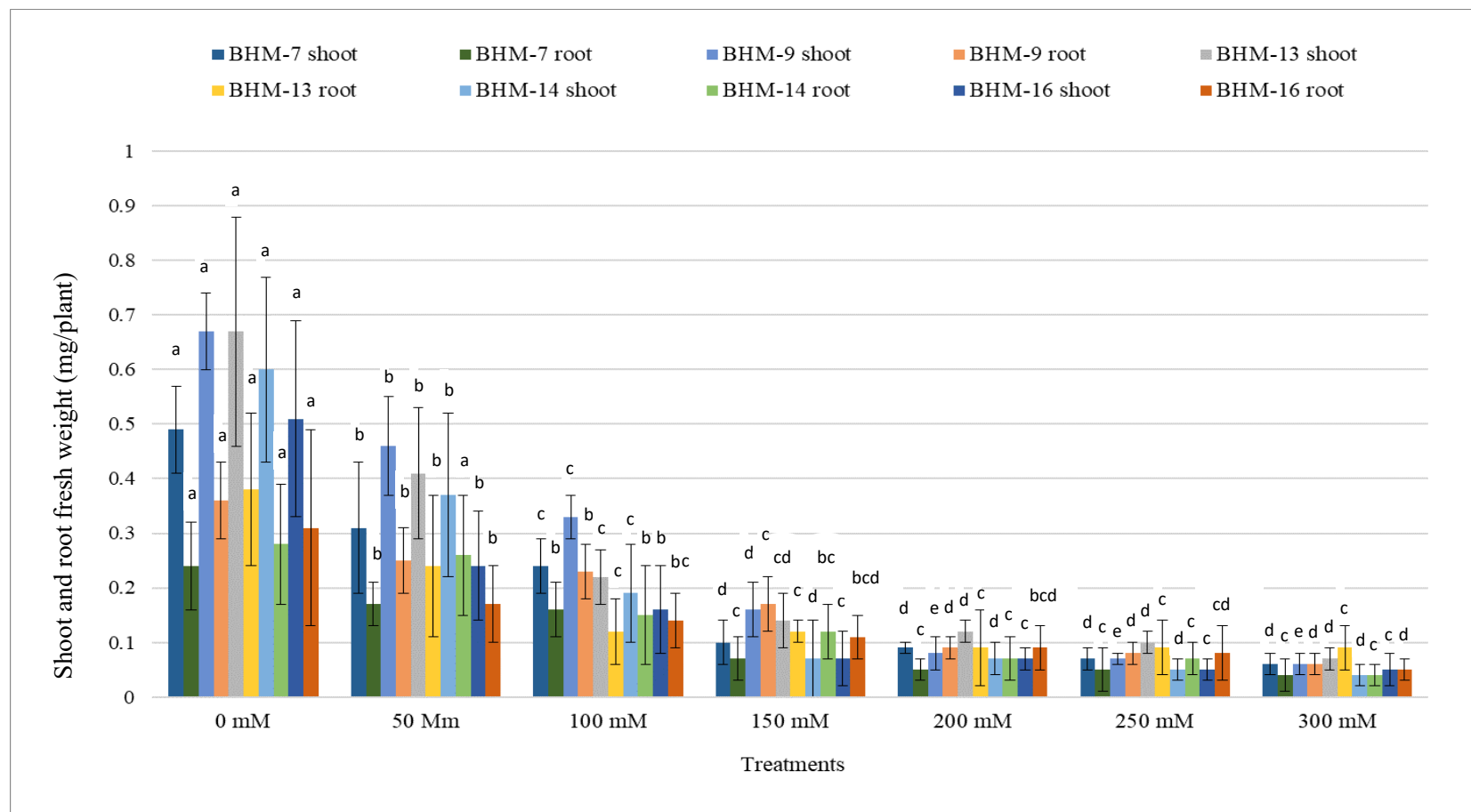


Fig. 1. Effects of different concentrations of NaCl salinity on shoot and root fresh weight (mg/plant) of five cultivars of maize

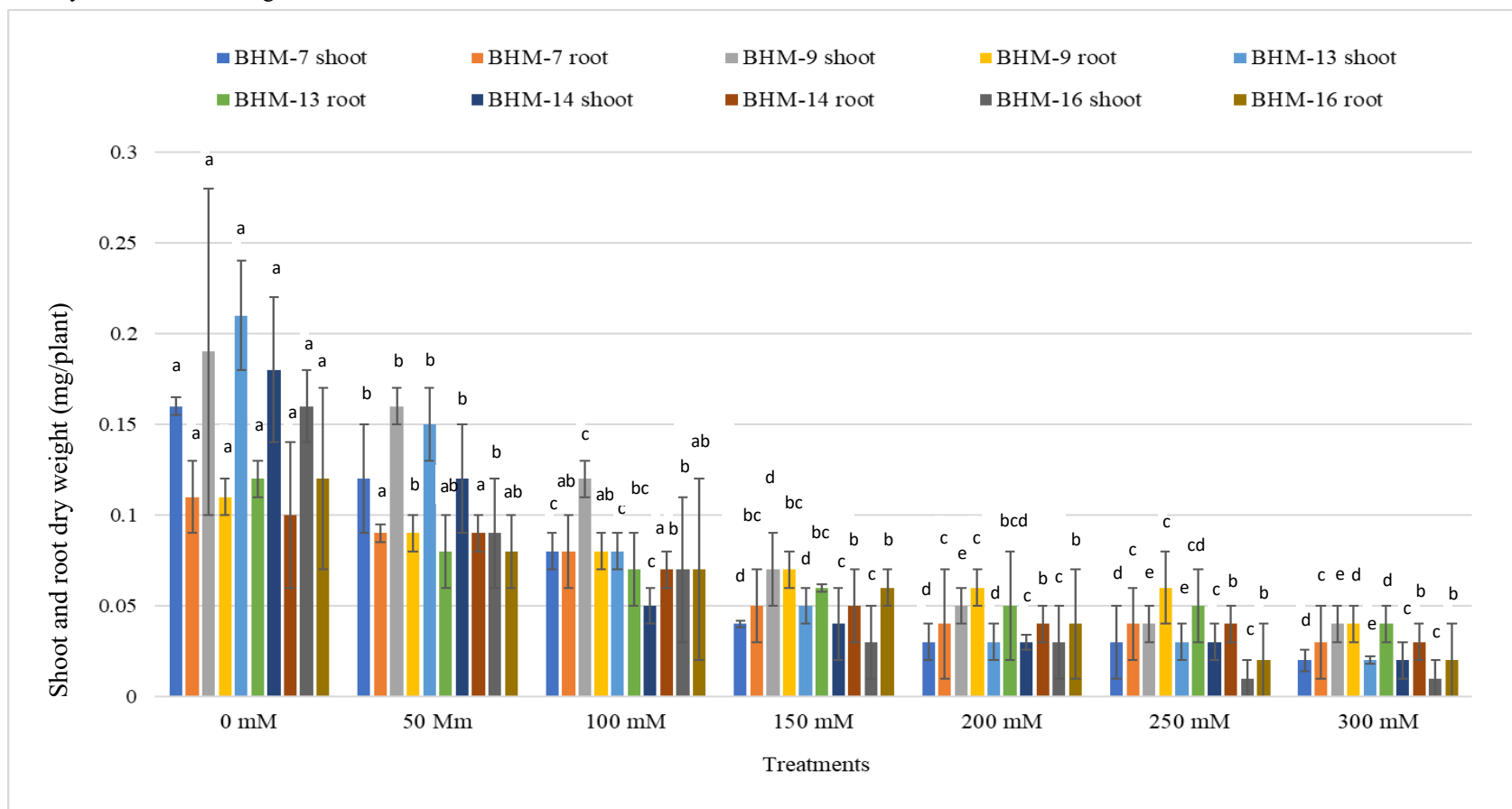


Fig. 2. Effects of different concentrations of NaCl salinity on shoot and root dry weight (mg/plant) of five cultivars of maize

Effects on shoot and root dry weight: A substantial drop in dry weight of the shoot and root was seen in figure 2. At the maximum salt stress, BHM-16 demonstrated the lower dry weight of the shoot and root, having the higher reduction rate of 93.75 and 83.34%, respectively, compared to the control. BHM-9 exhibited relatively higher dry mass of both shoot and root. The higher root dry weight in BHM-9, despite its lower root length and fresh weight, might suggest greater efficiency in transforming water and nutrients into biomass, potentially attributable to denser or more effective root tissue. Other cultivars showed moderate reductions in dry weight. Similar results of reduction in shoot and root dry weight under saline conditions have been reported in soybean (Hasan *et al.*, 2016) and maize (Idris & Ali, 2015).

Based on the present findings, it can be concluded that elevated salinity has a negative impact on maize seedling germination and early growth. In terms of germination performance and the dry mass of shoot and root, BHM-9 exhibited the lowest reduction rate to salinity among the five maize cultivars. Conversely, BHM-7, BHM-13 and BHM-16 were considered to be more susceptible. According to these results, BHM-9 may be an effective choice for field trials. Future studies should focus on understanding the molecular pathways underlying saline tolerance and investigating breeding techniques to provide resistance in maize cultivars of Bangladesh that are more vulnerable.

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