



## Maize under Stress: Identifying Robust Cultivars for Saline Industrial Landscapes

<sup>1</sup>Siddhartha Kumar Roy, <sup>2</sup>Progna Shil, <sup>3</sup>Tusar Kanti Roy\*, <sup>4</sup>Israt Jahan Irin\*, <sup>5</sup>Md. Shafiqul Islam Sikdar, <sup>6</sup>Md. Yasin Ali, <sup>7</sup>Bikash Chandra Sarker, <sup>5</sup>Md. Sohrab Hossain, <sup>5</sup>Tamanna Tasnim, <sup>1</sup>Md. Asgar Hossain

<sup>1</sup>Khulna Public College, Boyra, Khulna, Bangladesh

<sup>2</sup>Khulna Government Model School and College, Boyra, Khulna, Bangladesh

<sup>3</sup>Department of Agricultural Chemistry, Khulna Agricultural University, Khulna, Bangladesh

<sup>4</sup>Department of Agronomy, Khulna Agricultural University, Khulna, Bangladesh

<sup>5</sup>Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

<sup>6</sup>Agrotechnology Discipline, Khulna University, Khulna, Bangladesh

<sup>7</sup>Department of Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

### Article information

#### Article history:

Received: December, 23, 2025

Accepted: April, 30, 2026

Available online: June, 14, 2026

#### Keywords:

Maize hybrid,  
Stress Tolerance Index,  
Salinity stress,  
Germination rate,  
Salinity

#### \*Corresponding Author:

Israt Jahan Irin  
[isratjahankau20@gmail.com](mailto:isratjahankau20@gmail.com);  
Tusar Kanti Roy  
[tusar@kau.ac.bd](mailto:tusar@kau.ac.bd)

#### DOI:

<https://doi.org/10.53523/ijoirVol13I1ID637>

This article is licensed under:

[Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

### Abstract

Salinity significantly reduce maize growth at seedling and germination stage which impact negatively its agro-industrial growth. This study evaluates the salinity response of eight maize cultivars across four salinity gradients (0.5.10.15 Dsm-1 of NaCl) to identify robust genotypes for saline-prone agricultural zones. Statistical analysis reveals that critical productivity indicators including germination percentage (GP), germination rate (GR), vigor index (VI), and shoot/root biomass vary significantly based on four salinity levels. In high-input hybrid systems, BHM 9 demonstrated superior performance with the highest GP (92.78%) and RG (92.40%), followed by BHM 7 and BHM 6. Conversely, within inbred lines, Khoibhutta maintained the highest vigor and coefficient of germination (CG) under control and low-stress conditions, while Mohor and BHM 5 exhibited the highest susceptibility to saline stress. These findings provide a data-driven foundation for cultivar selection in salt-affected regions. For industrial-scale farming, the deployment of BHM 9 (hybrid) and Khoibhutta (inbred) is recommended to ensure high germination rates and seedling uniformity, thereby mitigating the financial risks associated with crop failure in saline soils. Identifying these tolerant genotypes allows for more precise land-use planning and targeted breeding programs, ensuring stable yields in increasingly marginalized agricultural environments.

## 1. Introduction

Salinity is a major abiotic stress that inhibits seed germination, reduces germination percentage, and delays germination time in many crop species [1]. Nearly 90% of the global plant-based food supply depends on approximately 30 major crop species, most of which are salt-sensitive glycophytes [2]. In agro-industrial production systems, poor stand establishment results in uneven crop growth, reduced resource-use efficiency, and substantial economic losses. Excessive salinity decreases the osmotic potential of the soil solution, thereby limiting water imbibition and reducing the ability of dry seeds to absorb water. Moreover, excessive accumulation of sodium ( $\text{Na}^+$ ) and chloride ( $\text{Cl}^-$ ) ions induces ionic toxicity and oxidative stress, disrupting essential physiological and biochemical processes such as respiration, protein synthesis, nucleic acid metabolism, and energy production [3, 4].

Salt tolerance during germination is particularly important because soluble salts accumulate predominantly in the upper soil layers due to evaporation and capillary rise, where seeds are generally sown. Elevated salinity adversely affects both seed germination and early seedling establishment [5]. Increasing salinity levels significantly reduce germination percentage, germination uniformity, and seedling vigor in maize, with the severity of reduction depending on the salt concentration [6]. In large-scale mechanized agriculture, non-uniform crop establishment causes staggered maturity, harvesting inefficiency, and increased postharvest losses.

Soil salinity is considered one of the major environmental constraints limiting crop productivity and sustainability, particularly in arid and semi-arid regions. Poor establishment during the early growth stage often causes direct economic losses through reduced plant population and costly reseeding. Excess  $\text{Na}^+$  and  $\text{Cl}^-$  ions disrupt ionic balance and nutrient uptake due to antagonistic interactions with essential mineral nutrients. The extent of salinity-induced damage depends on the type, concentration, and duration of salt exposure [1]. In maize, increasing salinity severely reduces plant growth, yield, and grain quality. Sodium chloride ( $\text{NaCl}$ ) stress generally causes greater injury than  $\text{Na}_2\text{SO}_4$  or mixed-salt stress because of the higher toxicity and dominance of  $\text{Na}^+$  and  $\text{Cl}^-$  ions. The detrimental effects become particularly severe at electrical conductivity (EC) levels around  $16 \text{ dS m}^{-1}$  [7]. Increasing salinity lowers soil osmotic potential and restricts water uptake by roots; under severe stress conditions, roots may even lose water to the surrounding soil solution [1, 8]. Sensitive maize genotypes accumulate toxic ions more rapidly, leading to chlorosis, necrosis, premature leaf senescence, and overall growth reduction, which ultimately decreases grain quality and market value.

Salinity stress also suppresses shoot growth by inhibiting leaf initiation, leaf expansion, and internode elongation while accelerating leaf senescence and abscission [9, 10]. Prolonged salt stress further reduces photosynthetic efficiency, chlorophyll content, and enzymatic activities associated with carbon assimilation. Recent studies have also demonstrated that salinity disrupts plant hormonal balance by decreasing auxin and cytokinin levels while increasing abscisic acid concentration, thereby negatively affecting plant growth and reproductive performance.

Abiotic stress tolerance is largely controlled by genetic factors, and genotypic variation becomes more evident under stressful environments. Such variation originates from allelic diversity, gene duplication, and neo-functionalization processes [11]. Therefore, screening maize genotypes for salinity tolerance at the germination and seedling stages is an effective strategy for identifying tolerant cultivars and minimizing production risks in saline-prone agricultural systems. Evaluation of germination behavior and seedling performance under salt stress enables researchers and agro-industrial producers to select suitable maize cultivars according to the salinity conditions of their production environments.

Therefore, the present study was conducted to evaluate varietal differences in salinity tolerance in maize during germination and early seedling growth. The findings of this study may contribute to screening programs aimed at identifying salt-tolerant cultivars and developing effective management strategies for saline soils.

## 2. Experimental Procedure

### 2.1. Experimental Site and Plant Materials

Detailed agronomic characteristics and pedigree information of the studied cultivars are summarized in Table (1). Eight maize cultivars were selected to provide a comprehensive representation of germplasm available in Bangladesh, ranging from early composite releases (e.g., Barnali, Shuvra) to modern high-yielding hybrids (e.g., BHM 9). The selection specifically included a diversity of end-uses, such as Khoibhutta for popcorn and Mohor

for fodder, as well as varying grain types (flint, semi-flint, and dent) and stress resistance profiles (e.g., lodging and TLB resistance). The experiment was conducted at Khulna University in a plastic shed during December 2016–January 2017. A two-factor CRD design was used with three replications. Factor A included four salinity levels (0, 5, 10, and 15 dSm<sup>-1</sup> NaCl), and Factor B included eight maize cultivars. Seeds were surface sterilized and placed in plastic pots filled with sand, irrigated daily with saline solutions. Germination and seedling traits were measured after 15 days. Salt Tolerance Index (STI) was computed, and statistical analysis was conducted using DMRT via Statistix 10 software.

## 2.2. Data Recorded on Germination and Seedling Growth Characters

Germination was counted at 24-hour interval and continued up to 15<sup>th</sup> day (360 h). A seed was considered germinated as plumule and radicle came out and >2 mm long.

Germination percentage at final count was calculated using the following formula.

GP= Number of germinated seed/Total number of seeds tested x100

The rate of germination was calculated using the following formula by Maghsoudi and Arvin [12]:

$$GI = \sum (nt/t_1) = n_1/t_1 + n_2/t_2 + \dots + n_k/t_k \quad (1)$$

Where:  $n_t$  = Number of seeds germinated on day  $t$ ,  $t$  = Time (days) from the start of the experiment, and  $k$  = The final day of the germination test.

Co-efficient of germination and vigor index were calculated using the following formulae:

$$\text{Co-efficient Germination} = \frac{100(A_1 + A_2 + \dots + A_n)}{A_1 T_1 + A_2 T_2 + \dots + A_n T_n} \quad (2)$$

$$\text{Vigor Index} = \frac{A_1}{T_1} + \frac{A_2}{T_2} + \dots + \frac{A_n}{T_n} \quad (3)$$

Where: A = Number of seeds germinated, T = Time (days) corresponding to A, and n = No of days to final count.

At 15 days after placement for germination, five seedlings from each plastic pot were sampled to measure the length, fresh weight, dry weight of shoot and root. Shoot and root length of individual seedling were recorded manually with scale. Fresh shoot and root of five plants were weighed. Then the shoot and root were dried separately at 70°C for 72 h in an electric oven (Model- E28# 03-54639, Binder, Germany) and weight were recorded with an electrical balance (Model- AND EK- 300 i). The mean lengths (cm), fresh and dry weights (g) of shoot and root were calculated for each treatment combination.

Salt Tolerance Index (STI) was calculated following the method described by Goudarzi and Pakniyat [13]. To assess the salt tolerance of the maize cultivars, the Stress Tolerance Index (STI) was determined following the methodology proposed by Rustikawati *et al* [14]. A weighted STI was calculated to account for the physiological significance of specific biomass components. Specifically, shoot dry weight was assigned a weighting score of 2, while all other morphological and physiological variables were assigned a score of 1. Hybrids considered tolerant when the value of  $\bar{x} - \frac{1}{2}\sqrt{\delta^2}$ :

$$\text{Medium Tolerant if } \bar{x} - \frac{1}{2}\sqrt{\sigma^2} \leq STI \leq \bar{x} + \frac{1}{2}\sqrt{\sigma^2}, \text{ and sensitive if } STI < \bar{x} - \frac{1}{2}\sqrt{\sigma^2} \quad (4)$$

Based on STI at 10 dS m<sup>-1</sup> (mean STI = 0.79,  $\sqrt{\sigma^2} = 0.09$ ), cultivars were classified as:

Tolerant: STI > 0.84

Medium tolerant: 0.74 ≤ STI ≤ 0.84

Susceptible: STI < 0.74

### 3. Statistical Analysis

The data were analyzed by partitioning the total variance with the help of computer using Statistix 10 program. The treatment means were compared using Duncan's Multiple Range Test (DMRT).

### 4. Results and Discussion

#### 4.1. Effect of Salinity on Germination Percentage and Rate of Germination (%)

Both the germination rate and the germination percentage were significantly affected by salinity. Germination percentage (GP) and rate of germination (RG) were significantly decreased by increasing salinity levels (Table 2). S1 had the highest GP (90.22%), followed by S2 (80.79%) and S3 (69.31%), while S4 had the lowest value (58.59%). Likewise, S1 had the highest RG (92.77%), followed by S2 (84.58%) and S3 (75.23%), while S4 had the lowest RG (64.77%) Table (2). Germination characters of maize as influenced by different salinity levels

#### 4.2. Effect of Salinity on Co-efficient of Germination and Vigor Index

The Coefficient of Germination (CG) and Vigor Index (VI) showed a declining trend with increasing salinity levels (Table 2). The Coefficient of Germination (CG) and Vigor Index (VI) was found highest at S1 (control), which were 9.67 (CG) and 11.47 (VI); whereas lowest was recorded from S4 (15 dS m<sup>-1</sup>) followed by S2 (5 dS m<sup>-1</sup>) and S3 (10 dS m<sup>-1</sup>).

#### 4.3. Effect of Maize Cultivars on GP, RG (%), CG and VI

Significant variation was observed among different maize cultivars regarding GP, Rate of RG, CG, and VI. Among the tested cultivars, BHM 9 exhibited the highest performance under saline conditions over BHM 7, showing the highest GP, RG, CG, and VI values and demonstrating good tolerance and stable germination behavior across salinity levels. In contrast, among the inbred lines, Khoibhutta showed relatively higher tolerance with better germination traits, while Mohor recorded the lowest performance, indicating higher sensitivity to salt stress. Based on the results it may suggest that BHM 9, carry better physiological mechanisms for germination and early seedling vigor under saline conditions compared to other inbred varieties.

#### 4.4. Interaction Effect of Maize Cultivar and Salinity Level on Germination Percentage and Rate of Germination (%)

Salinity had significantly reduced GP and RG among different maize cultivars, with various rang of salinity like 5, 10, and 15 dS m<sup>-1</sup> (Table 3). Results demonstrated that, , BHM 9 had the highest GP (92.78) and RG (92.40%), followed by BHM 7, BHM 6, and BHM 5 at 5 dS m<sup>-1</sup>. Whereas, among different inbreds, Khoibhutta had the highest GP (77.53) and RG (83.38%) at control salinity while Mohor had the lowest GP (70.30) and RG (76.56%). With the increasing salinity both GP and RG declined at present study. The present study was agreed by different researchers who stated that salinity reduces seed water uptake by creating osmotic stress, delaying germination start and lowering GP and RG [15, 16]. Ion toxicity, reduced water potential, hormonal imbalance (low GAs, high ABA), and oxidative stress also contribute to germination inhibition [17-19].

Seed germination and early seedling growth are more sensitive to salinity, with sodium toxicity being the major limiting factor in maize [23, 24]. These trends are consistent with earlier reports where salinity reduced GP, RG, and early seedling growth, with hybrids generally outperforming inbreds [20-22].

#### 4.5. Effect of Salt Tolerance Index (STI) Based On GP (%) And RG (%)

Salt tolerance index had varied significantly according to salinity level like 5, 10, and 15 dS m<sup>-1</sup> , (Table 3). For GP at 15 dS m<sup>-1</sup>, different cultivars, like BHM 9, BHM 7, and BHM 6 had shown STI >0.70, while all inbreds except Khoibhutta shown <0.60. For RG, BHM 9 and BHM 7 had exhibit STI >0.80, BHM 6 and BHM 5 between 0.70–0.80, and inbreds (except Mohor) 0.60–0.70; Mohor was lowest (0.54) at all salinity levels. BHM 9 consistently showed the highest STI and BHM 5 had lower STI among hybrids, while Khoibhutta was found highest among inbreds.

BHM 9 was the most salt-tolerant hybrid when taking into consideration Germination Percentage (GP) and Rate of Germination (RG). BHM 7 and BHM 6 were next in line. While Mohor (an inbred) and BHM 5 (a hybrid) were found to be vulnerable to salinity stress, Khoibhutta displayed a moderate tolerance. The cultivars were ranked in order of tolerance based on overall performance: BHM 9 > BHM 7 > BHM 6 > BHM 5 > Khoibhutta > Shuvra > Barnali > Mohor.

#### 4.6. Interaction Effect of Maize Cultivars and Salinity Level on Co-Efficient Of Germination and Vigor Index

Salinity had significantly reduced the coefficient of germination (CG) and vigor index (VI) of eight maize cultivars. (Table 4). The Coefficient of Germination (CG) and Vigor Index (VI) were significantly impacted by the interaction between salinity levels and maize cultivars. Although the amount of the decrease varied among cultivars, CG and VI values decreased with increasing salinity across all salinity treatments. CG ranged was found highest in control (9.05–10.60) and decreased to 6.01–9.18 at 15 dS m<sup>-1</sup> (mean 7.27). Among hybrids, BHM 9 showed highest CG followed by BHM 7 and BHM 6, where BHM 5 was shown lower. Among inbreds, Khoibhutta had highest CG, while Mohor showed the greatest reduction.

However, BHM 9 had the highest Vigor Index (VI) (12.66–10.17), followed by BHM 7 and BHM 6, while Mohor had the lowest (10.24–6.45). While Khoibhutta displayed the highest VI among the inbred lines, BHM 5 displayed a relatively lower VI among the hybrids. Strong tolerance was indicated by BHM 9's minimal VI reduction over the control, while high salt sensitivity was indicated by Mohor's maximal VI reduction. Overall, the most tolerant genotypes have been identified to be BHM 9 (hybrid) and Khoibhutta (inbred), while the most susceptible genotypes were determined to be BHM 5 (hybrid) and Mohor (inbred). These results align with previous research showing that salinity stress decreases maize germination percentage (GP), germination speed (GS), germination index (GI), seedling dry weight (SDW), seedling vigor index (SVI), and stress tolerance index (STI) significantly [25-27].

#### 4.7. Effect of Salinity Level and Maize Cultivars on Seedling Growth Characters

The seedling growth like shoot length (SL), Root Length (RL), Shoot Fresh Weight (SFW), Root Fresh Weight (RFW), Shoot Dry Weight (SDW) and Root Dry Weight (RDW) of maize cultivars was significantly influenced by the various salinity level (Table 5) and eight maize cultivars (Table 6). With the increasing of salinity level, the values of seedling growth characters were significantly decreased. At control (S1) level the highest SL (24.87 cm), RL (30.65 cm), SFW (1.14 gm), RFW (0.93 gm), SDW (0.097 gm) and RDW (0.078 gm) were recorded. The results at S2 level (5 dSm<sup>-1</sup>) were at par with S1 level (Figure 1) and S3 (10 dSm<sup>-1</sup>) and S4 (15 dSm<sup>-1</sup>) level significantly affected the seedling growth. The lowest SL (20.38), RL (25.76), SFW (0.76), RFW (0.57), SDW (0.041) and RDW (0.046) were recorded at highest salinity level (S4) followed by the S3 level (Table 5). The hybrid BHM 9 performed highest rate of SL (24.36), RL (30.53), SFW (1.17), RFW (0.93), SDW (0.101) and RDW (0.078) that was closer with the result of BHM 7 (Table 6). All inbreds had exhibited lower performances compared to hybrids. But among the different inbreds Khoibhutta performed better and the inbred Mohor showed the lowest value on SL (21.64), RL (25.54), SFW (0.68), RFW (0.57), SDW (0.044) and RDW (0.049) due to its highest susceptibility under salt stress.

The decrease in shoot length with increase in NaCl stress could be due to an inhibitory effect of NaCl salt in shoot growth. The higher level of salinity had a pronounced effect on shoot length. Reduction in shoot length as a result of salt stress has been reported by, Akram *et al.* [28], Akram *et al.* [9]. Salinity reduced shoot growth by suppressing leaf initiation and expansion, as well as internodes growth and by accelerating leaf abscission [29, 30]. This result was consistent with Bose *et al.* (2018) who observed that root and shoot length, number of leaves plant<sup>-1</sup>, fresh and dry mass production varied with NaCl stress which indicating that some cultivars of maize seedlings were highly susceptible to concentrated NaCl.

#### 4.8. Interaction Effect of Maize Cultivars and Salinity Level on Shoot Length (Cm) and Root Length (Cm)

Extreme (15 dS m<sup>-1</sup>; S4) salinity significantly reduce the shoot and root growth of all maize cultivars, (Table 7). Under control conditions, BHM 9 had the highest shoot (25.47 cm) and root lengths (31.72 cm), whereas inbred Mohor had the lowest (24.10 cm; 28.22 cm). At mild salinity (5 dS m<sup>-1</sup>), root length of BHM 7 and BHM 9 slightly increased, suggesting an initial tolerance response. At moderate (10 dS m<sup>-1</sup>) and high salinity (15 dS m<sup>-1</sup>), all inbreds and hybrid BHM 5 showed significant reductions. At S4, the highest shoot and root lengths were maintained by BHM 9 (22.43 cm; 28.27 cm) and BHM 7 (22.06 cm; 27.86 cm), while Mohor showed the lowest (18.32 cm; 21.74 cm). Among inbreds, Khoibhutta maintained relatively higher growth (19.77 cm; 26.01 cm).

In case of Salt Tolerance Index (STI), hybrids BHM 9, BHM 7, and BHM 6 had STI >0.85 for shoot length and root length at 15 dS m<sup>-1</sup>, while BHM 5 showed lower tolerance. Among inbreds, Khoibhutta had the highest STI (0.80–0.98), whereas Mohor had the lowest (0.76–0.96). Notably, BHM 7 and BHM 9 showed STI >1.0 for root

length at  $5 \text{ dS m}^{-1}$ , indicating initial root growth stimulation, likely due to efficient mobilization of seed reserves. These results suggest that shoot and root lengths are reliable selection criteria for early-stage salt tolerance in maize.

Salinity also significantly reduced shoot fresh weight (SFW) and root fresh weight (RFW) (Table 8). BHM 9 maintained the highest SFW (1.26–1.07 g) and RFW (0.98–0.86 g) across salinity levels, followed by BHM 7 and BHM 6. Hybrid BHM 5 and inbred Mohor were most affected, showing the lowest SFW (0.82 g, 0.38 g) and RFW (0.62 g, 0.27 g) at S4. Among inbreds, Khoibhutta maintained higher fresh weights under stress. STI values for fresh weight mirrored growth trends. Hybrids BHM 9, BHM 7, and BHM 6 and inbred Khoibhutta were the most salt-tolerant, whereas BHM 5 and Mohor were most susceptible. These findings align with previous studies reporting that NaCl stress reduces fresh and dry weights by limiting water uptake and growth [21, 30]. Considering shoot/root lengths, fresh weight, and STI, BHM 9 (hybrid) and Khoibhutta (inbred) can be identified as salt-tolerant maize cultivars, whereas BHM 5 (hybrid) and Mohor (inbred) are highly susceptible.

#### 4.9. Effect of Salt Tolerance Index (STI) Based on Shoot Length and Root Length

The Salt Tolerance Index (STI) for shoot fresh weight (SFW) and root fresh weight (RFW) at 5, 10, and 15  $\text{dS m}^{-1}$  (Table 8) revealed that there is a significant differences in salt tolerance among the eight maize cultivars.

**Shoot Fresh Weight (SFW):** At the highest salinity (15  $\text{dS m}^{-1}$ ), hybrids BHM 7 and BHM 9 maintained  $\text{STI} > 0.80$ , whereas BHM 5 and BHM 6 showed lower  $\text{STI} (< 0.70$  and  $< 0.80$ , respectively). All inbreds recorded  $\text{STI} < 0.70$ . Across salinity levels, BHM 9 had the highest  $\text{STI}$  (0.85, 0.93, 0.95), followed by BHM 7 (0.81, 0.90, 0.94) and BHM 6 (0.75, 0.86, 0.92), while BHM 5 showed the lowest (0.69, 0.82, 0.90). Among inbreds, Khoibhutta had the highest  $\text{STI}$  (0.66, 0.80, 0.89), followed by Shuvra (0.58, 0.75, 0.87), and Mohor the lowest (0.40, 0.64, 0.81), followed by Barnali (0.48, 0.68, 0.83).

**Root Fresh Weight (RFW):** Similar trends were observed. Hybrids BHM 7 and BHM 9 maintained  $\text{STI} > 0.80$  at 15  $\text{dS m}^{-1}$ , whereas BHM 5 and BHM 6 had lower  $\text{STI} (< 0.70$  and  $< 0.80$ , respectively). All inbreds recorded  $\text{STI} < 0.70$ . BHM 9 again showed the highest  $\text{STI}$  (0.88, 0.93, 0.98), followed by BHM 7 (0.80, 0.89, 0.96) and BHM 6 (0.73, 0.83, 0.93), with BHM 5 lowest (0.67, 0.80, 0.90). Among inbreds, Khoibhutta had the highest  $\text{STI}$  (0.59, 0.74, 0.87), followed by Shuvra (0.52, 0.70, 0.85), while Mohor (0.31, 0.56, 0.78) and Barnali (0.43, 0.65, 0.83) were most susceptible. Considering  $\text{STI}$  values for both SFW and RFW, BHM 9 (hybrid) and Khoibhutta (inbred) can be identified as salt-tolerant maize cultivars, while BHM 5 (hybrid) and Mohor (inbred) are highly susceptible.

Salinity caused a significant reduction in shoot dry weight (SDW) of all maize cultivars across salinity levels (Figure 1). Among hybrids, BHM 9 consistently showed the highest SDW (0.114, 0.104, 0.098, 0.087 g) at control, 5, 10, and 15  $\text{dS m}^{-1}$ , followed by BHM 7 (0.108, 0.094, 0.084, 0.071 g) and BHM 6 (0.099, 0.082, 0.071, 0.055 g). Hybrid BHM 5 had the lowest SDW among hybrids (0.095, 0.076, 0.060, 0.043 g). Among inbreds, Mohor recorded the lowest SDW (0.086, 0.055, 0.030, 0.004 g), followed by Barnali (0.088, 0.060, 0.040, 0.015 g) and Shuvra (0.090, 0.064, 0.046, 0.023 g), while Khoibhutta maintained the highest SDW (0.091, 0.067, 0.050, 0.031 g).

The reduction in dry weight with increasing salinity may result from the combined osmotic and ion-specific effects of  $\text{Na}^+$  and  $\text{Cl}^-$ , consistent with previous reports on maize [20, 31, 32, 33].

Salinity caused a significant reduction in root dry weight (RDW) of all maize cultivars (Figure 2), consistent with findings of Cicek and Cakirlar [30]. At the highest salinity level (15  $\text{dS m}^{-1}$ ), inbred Mohor showed a drastic reduction in RDW, while hybrid BHM 9 maintained RDW up to moderate salinity (10  $\text{dS m}^{-1}$ ). Among hybrids, BHM 9 had the highest RDW (0.083, 0.081, 0.076, 0.070 g) at control, 5, 10, and 15  $\text{dS m}^{-1}$ , followed by BHM 7 (0.081, 0.079, 0.072, 0.064 g) and BHM 6 (0.080, 0.076, 0.066, 0.056 g). BHM 5 had the lowest RDW among hybrids (0.079, 0.072, 0.060, 0.047 g).

Among inbreds, Mohor recorded the lowest RDW (0.073, 0.059, 0.042, 0.021 g), followed by Barnali (0.073, 0.062, 0.046, 0.029 g) and Shuvra (0.076, 0.067, 0.054, 0.037 g). Khoibhutta maintained the highest RDW among inbreds (0.077, 0.069, 0.056, 0.042 g). Hassan *et al.* [21] reported that moderate (100 mM NaCl) and high stress (200 mM NaCl) caused over 20% and 40% reduction in RDW for Barnali, Mohor, and BARI Maize 5, while

Khoibhutta showed lower reductions (12% and 33%). Salt stress likely increases metabolic energy costs and reduces carbon gain, limiting photosynthesis and thereby reducing root dry weight [34].

According to Konuskan *et al.* [36], salt tolerance indexes (STI) were commonly higher in the lower salinity levels while lower in increased salinity levels. The highest STI (91.45) and the lowest STI (77.33) were found by them in DKC 6589 and PG1610 maize cultivar, respectively regarding the parameters emergence index, shoot length, root length, shoot and root dry weight for all salinity levels (0, 4, 6, 8 and 10 dSm<sup>-1</sup>). They documented that the cultivars which showed the highest STI value with better agronomic performance could be recommended for salinity stressed environments during germination and seedling growth of maize. Jaradat *et al.* [35] also reported that highest STI values showed the highest salinity tolerance of cultivars in maize.

#### 4.10. Salt Tolerance Index (STI) Based on Shoot Dry Weight and Root Dry Weight

Salt tolerance index (STI) based on shoot dry weight (SDW) and root dry weight (RDW) at 5, 10, and 15 dS m<sup>-1</sup> salinity levels (Figure 3) revealed clear differences among the eight maize cultivars.

Among hybrids, BHM 9 showed the highest STI (>0.70 at 15 dS m<sup>-1</sup>), followed by BHM 7 (0.70), BHM 6 (0.60), and BHM 5 (<0.50). Among inbreds, Khoibhutta had the highest STI (<0.40), followed by Shuvra (<0.30), Barnali (<0.20), and Mohor (<0.10). At 5 and 10 dS m<sup>-1</sup>, BHM 9 maintained the highest STI (0.912, 0.860), followed by BHM 7 (0.870, 0.778) and BHM 6 (0.828, 0.717), while BHM 5 had the lowest (0.800, 0.632). Among inbreds, Khoibhutta (0.736, 0.549) was highest, and Mohor (0.640, 0.349) the lowest.

Hybrid BHM 9 maintained STI >0.80 at 15 dS m<sup>-1</sup>, followed by BHM 7 (<0.80), BHM 6 (≤0.70), and BHM 5 (<0.60). Among inbreds, Mohor showed very low STI (<0.30), while Khoibhutta (<0.60) had the highest. At 5 and 10 dS m<sup>-1</sup>, BHM 9 had the highest STI (0.98, 0.92), followed by BHM 7 (0.98, 0.89) and BHM 6 (0.95, 0.83), whereas BHM 5 showed the lowest (0.91, 0.76). Among inbreds, Khoibhutta (0.90, 0.73) was highest, and Mohor (0.81, 0.58) lowest. Overall, BHM 9 (hybrid) and Khoibhutta (inbred) were identified as the most salt-tolerant cultivars, while BHM 5 (hybrid) and Mohor (inbred) were the most susceptible. These findings align with previous studies [35, 36], which reported that cultivars with higher Salt Tolerance Index (STI) values under salinity stress exhibited better germination and seedling growth, making them suitable for salinity-affected environments.

Among the measured traits, STI values of shoot and root length were generally higher than those of fresh and dry weights, indicating that reductions in these lengths were smaller compared to other growth parameters. The highest mean STI was observed for root length (0.93), while the lowest was for shoot dry weight (0.61). The lowest STI variance occurred in shoot and root lengths (0.001) whereas the highest variance was in shoot dry weight (0.030). The highest average STI across all traits was found in BHM 9 (0.91), followed by BHM 7 (0.89) (Table 8).

Accordingly, BHM 6, BHM 7, and BHM 9 were tolerant to 5 and 10 dS m<sup>-1</sup> NaCl, BHM 5, Shuvra, and Khoibhutta were medium tolerant, and Barnali and Mohor were susceptible. These results are consistent with the results of Rustikawati *et al.* [14].

The STI of root and shoot length were higher than other characters at highest salinity level (15 dSm<sup>-1</sup>). The highest mean STI calculated from root length was 0.84, while the lowest value was 0.41 from shoot dry weight. The STI variances of the shoot length and root length were 0.00 and the highest was 0.06 for shoot dry weight. The highest average STI was found in BHM 9 (0.84) that was followed by BHM 7 (0.80) (Table 8, Figure 3). The very lowest STI (0.05) calculated from shoot dry weight for the inbred cultivar Mohor and its average STI was <0.50 for all characters. It indicates, Mohor was at risk to grow at highest salinity level (15 dSm<sup>-1</sup>). At 15 dSm<sup>-1</sup> salinity level, based on a mean value of STI = 0.66 and  $\sqrt{\sigma^2} = 0.13$ , the cultivar was tolerant if STI > 0.73, medium tolerant  $0.60 \leq \text{STI} \leq 0.73$ , and susceptible STI < 0.60 (Table 8). Based on these criteria, three cultivars BHM 6, BHM 7, BHM 9 were classified tolerant to 15 dSm<sup>-1</sup> NaCl and BHM 5, Khoibhutta cultivars were medium tolerant while Barnali, Shuvra cultivars were susceptible, and Mohor was very susceptible.

Under controlled NaCl treatments, maize cultivars exhibited genetically determined tolerant or sensitive responses. Growth reductions under salinity stress were used to evaluate cultivar tolerance. The Stress Tolerance Index (STI) is a reliable measure for estimating relative tolerance, as it reflects the ability of a genotype to maintain high performance under both stress and non-stress conditions [37, 38]. An STI value of 1 or higher indicates no

reduction in performance under stress compared to the non-stress mean. Salinity significantly decreased growth compared to control. As reported by Kholova *et al.* [39] and Irin and Hasanuzzaman [1] stated that, salinity stress reduces relative water content, chlorophyll and carotenoid content, membrane stability, and essential ions ( $K^+$ ,  $Ca^{2+}$ ), while increasing reactive oxygen species (ROS), proline, glycine betaine, total soluble sugars, sodium accumulation, and ionic ratios ( $Na^+:K^+$ ,  $Na^+:Ca^{2+}$ ). Excess sodium interferes with potassium uptake [14, 40, 41], causing stomatal dysfunction and leaf tip necrosis [42]. Tolerant cultivars can mitigate these negative effects, maintaining consistently high STI values across traits.

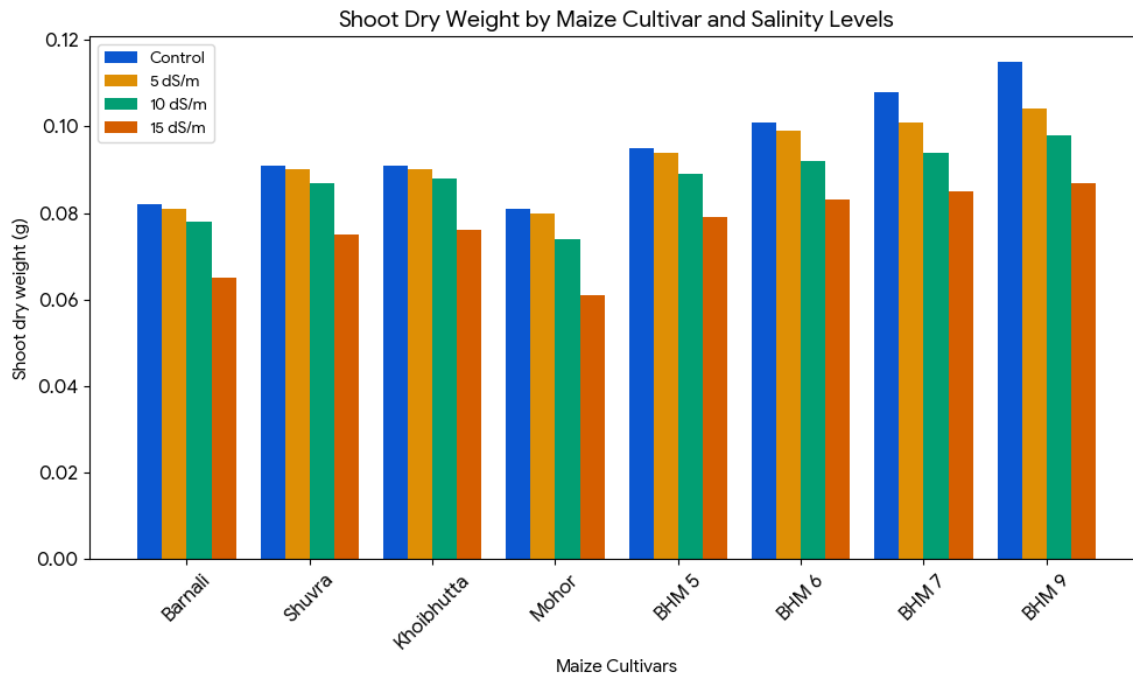


Figure (1): Shoot dry weight (g) of different maize cultivars as influenced by salinity levels.

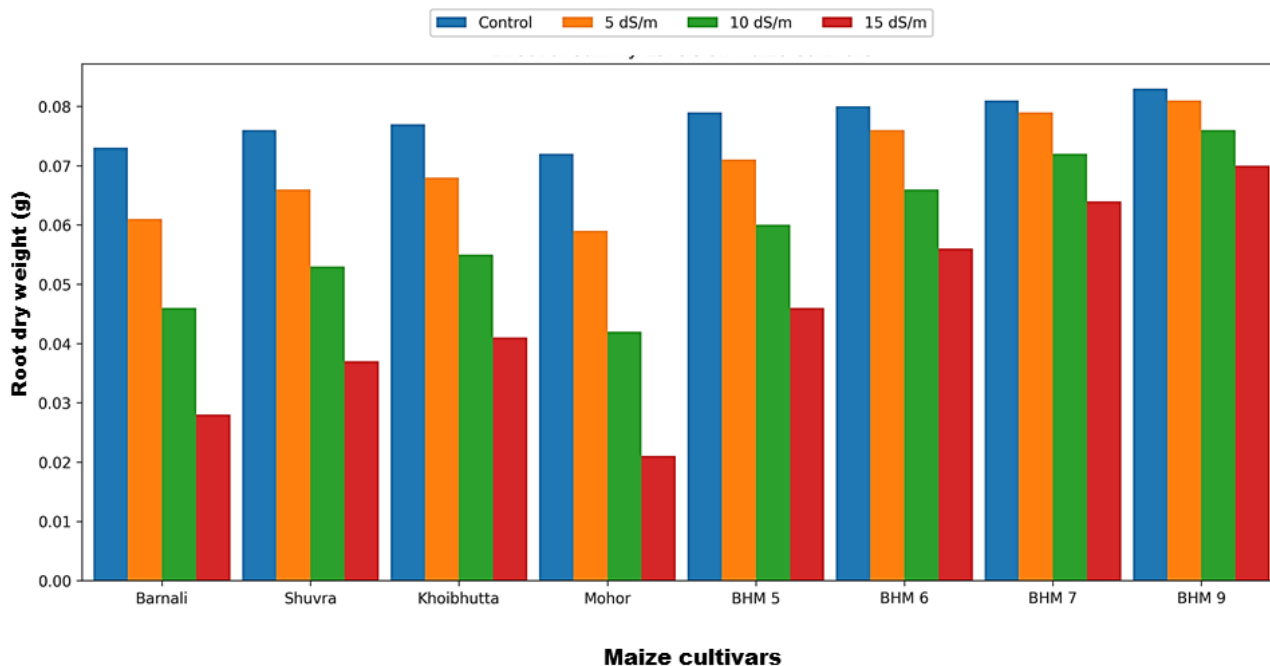


Figure (2): Root dry weight (g) of different maize cultivars as influenced by salinity levels.

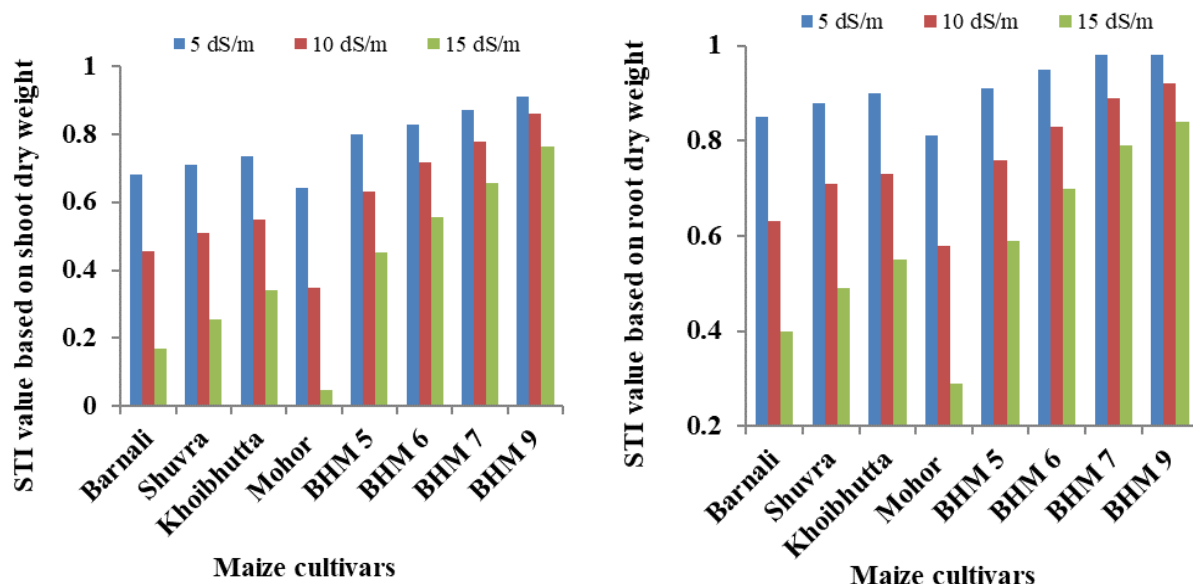


Figure (3): Salt tolerance index (STI) based on shoot dry weight and root dry weight of different maize cultivars under different salinity levels.

Table (1): Characteristics of maize cultivars used in the present study.

Cultivars	Source and Releasing Year	Life span (days)	1000-grains weight (g)	Specificity	Yield (tha <sup>-1</sup> )
Barnali	BARI 1986	R (Rabi): 140-145 K (Kharif): 95-100	245-320	It's a composite variety. Plant height is 200-210 cm. Its cobs are large in size and pointed at the tip, almost resistant to diseases and pests.	R: 5.5-6.0 K: 4.0-4.5
Shuvra	BARI 1986	R: 135-145 K: 95-105	300-310	The kernel color of the composite variety is white and semi-flint type. Plant height is 180-200 cm. Ears are conical shaped. Grain white, large size and ear fulfill with grain. Almost resistant to diseases and pests.	R: 4.5-5.5 K: 3.5-4.5
Khoibhutta	BARI 1986	R: 125-130 K: 90-100	140-150	It is a composite variety of popcorn. Plant height is 165-180 cm. Kernels are small size, yellow, flint type. Almost resistant to diseases and pests.	R: 3.5-4.0 K: 2.5-3.5
Mohor	BARI 1990	R: 135-145 K: 95-105	180-300	It is a composite variety. Plant height is 195-200 cm. This is suitable for fodder purpose; cob girth of this variety is large.	R: 5.0-5.5 K: 3.5-4.5

BARI Hybrid Maize 5	BARI 2004	R: 140-145 K: 95-105	290-310	It is single cross hybrid. Plant height is 195-200 cm. Ear is tightly covered with husk. This cultivar has resistant capacity to diseases, pests and lodging.	R: 9.0-10.0 K: 7.0-7.5
BARI Hybrid Maize 6	BARI 2006	R: 142-146 K: 95-105	380-390	A high yielding three-way cross hybrid. Plant height is 200-210 cm. Kernels are bold, yellow color and semi flint type. It is also resistant to diseases, pests and lodging.	R: 9.8-10.0 K: 7.5-8.0
BARI Hybrid Maize 7	BARI 2006	R: 154-155 K: 100-105	340-360	It is high yielding composite variety. Plant height is 190-194 cm. Plants are strong, stout, heavy and hard and also vigorous in growth. Kernels are yellow, dent shape and large; Resistant to tursicum leaf blight (TLB).	R: 10.5-11.5 K: 8.0-8.5
BARI Hybrid Maize 9	BARI 2007	R: 145-150 K: 105-110	340-360	It is single cross hybrid. Plant height is 208-239 cm. Kernels are yellow color and dent type. Ears are covered with tight husk.	R: 11.5-12.5 K: 8.5-9.0

**Table (2):** Germination characters of maize as influenced by different salinity levels.

Salinity Level	GP (%)	RG (%)	CG	VI
S <sub>1</sub>	90.22 a	92.77 a	9.67 a	11.47 a
S <sub>2</sub>	80.79 b	84.58 b	8.69 b	10.71 b
S <sub>3</sub>	69.31 c	75.23 c	7.88 c	9.83 c
S <sub>4</sub>	58.59 d	64.77 d	7.27 d	8.68 d
Level of significance	**	**	**	**
CV (%)	1.34	1.47	2.57	1.93

Values having same letter(s) do not differ significantly as per DMRT at  $p \leq 0.05$  level.

S<sub>1</sub> = Control, S<sub>2</sub> = 5 dSm<sup>-1</sup>, S<sub>3</sub> = 10 dSm<sup>-1</sup>, S<sub>4</sub> = 15 dSm<sup>-1</sup>.

**Table (3):** Germination percentage (GP) and rate of germination (RG) of different maize cultivars as influenced by salinity levels and its salt tolerance index (STI).

Cultivar	Salinity level	Germination percentage (%)	STI for GP	Rate of germination (%)	STI for RG
Barnali	S <sub>1</sub>	86.29 fgh	-	89.45 ef	-
	S <sub>2</sub>	74.08 m	0.86	79.54 klm	0.89
	S <sub>3</sub>	61.43 p	0.71	67.47 p	0.75
	S <sub>4</sub>	49.38 s	0.57	53.98 r	0.60
Shuvra	S <sub>1</sub>	86.88 fgh	-	90.38 def	-

	S <sub>2</sub>	75.21 lm	0.87	81.17 ijkl	0.90
	S <sub>3</sub>	62.71 op	0.72	69.79 op	0.77
	S <sub>4</sub>	51.01 rs	0.59	57.37 r	0.63
Khoibhutta	S <sub>1</sub>	87.81efg	-	92.32 cde	-
	S <sub>2</sub>	77.53 kl	0.88	83.38 hij	0.90
	S <sub>3</sub>	65.11 o	0.74	73.45 no	0.80
	S <sub>4</sub>	54.02 qr	0.62	62.15 q	0.67
Mohor	S <sub>1</sub>	84.67 ghi	-	87.71 fg	-
	S <sub>2</sub>	70.30 n	0.83	76.56 mn	0.87
	S <sub>3</sub>	55.60 q	0.66	61.69 q	0.70
	S <sub>4</sub>	42.34 t	0.50	47.49 s	0.54
BHM 5	S <sub>1</sub>	91.00 cde	-	93.69 bcd	-
	S <sub>2</sub>	82.62 ij	0.91	85.63 gh	0.91
	S <sub>3</sub>	70.77 n	0.78	76.74 mn	0.82
	S <sub>4</sub>	59.93 p	0.66	66.15 p	0.71
BHM 6	S <sub>1</sub>	92.23 bcd	-	94.42 abc	-
	S <sub>2</sub>	84.51 hi	0.92	87.61 fg	0.93
	S <sub>3</sub>	75.35 lm	0.82	80.59 jkl	0.85
	S <sub>4</sub>	65.87 o	0.71	71.86 o	0.76
BHM 7	S <sub>1</sub>	94.34 b	-	96.54 ab	-
	S <sub>2</sub>	89.28 def	0.95	90.37 def	0.94
	S <sub>3</sub>	79.65 jk	0.84	84.59 ghi	0.88
	S <sub>4</sub>	70.76 n	0.75	77.43 lm	0.80
BHM 9	S <sub>1</sub>	98.51 a	-	97.61 a	-
	S <sub>2</sub>	92.78 bc	0.94	92.40 cde	0.95
	S <sub>3</sub>	83.90 hi	0.85	87.56 fg	0.90
	S <sub>4</sub>	75.42 lm	0.77	81.72 ijk	0.84
Level of significance		**		**	
CV (%)		1.34		1.47	

Values having same letter(s) do not differ significantly as per DMRT at  $P \leq 5\%$  level.

$S_1$  = Control,  $S_2$  = 5 dSm<sup>-1</sup>,  $S_3$  = 10 dSm<sup>-1</sup>,  $S_4$  = 15 dSm<sup>-1</sup>.

**Table (4):** Coefficient of germination (CG) and vigor index (VI) of different maize cultivars as influenced by salinity levels and its change over control.

Cultivar	Salinity level	Coefficient of germination	Change over control (%)	Vigor index	Change over control (%)
Barnali	S <sub>1</sub>	9.05 efg	-	10.42 ijk	-
	S <sub>2</sub>	7.80 ijk	-13.81	9.44 lmn	-9.40
	S <sub>3</sub>	6.81 mn	-24.75	6.96 p	-19.67
	S <sub>4</sub>	6.01 op	-33.59	8.37 o	-33.21
Shuvra	S <sub>1</sub>	9.18 def	-	10.91 ghi	-
	S <sub>2</sub>	8.04 hij	-12.42	10.02 kl	-8.16
	S <sub>3</sub>	7.11 klm	-22.55	7.74 o	-17.14
	S <sub>4</sub>	6.32 no	-31.15	9.04 n	-29.06
Khoibhutta	S <sub>1</sub>	9.45 cde	-	11.16 fgh	-
	S <sub>2</sub>	8.45 ghi	-10.58	10.35 ijk	-7.26
	S <sub>3</sub>	7.63 jkl	-19.26	8.22 o	-15.68
	S <sub>4</sub>	6.95 lmn	-26.46	9.41 lmn	-26.34
Mohor	S <sub>1</sub>	8.98 efg	-	10.24 jk	-
	S <sub>2</sub>	7.63 jkl	-15.03	9.17 mn	-10.45
	S <sub>3</sub>	6.47 mno	-27.95	6.45 p	-22.17
	S <sub>4</sub>	5.58 p	-37.86	7.97 o	-37.01
BHM 5	S <sub>1</sub>	9.78 bcd	-	11.81 bcde	-
	S <sub>2</sub>	8.86 efg	-9.41	11.10 fgh	-6.01
	S <sub>3</sub>	8.09 hij	-17.28	9.17 mn	-13.21
	S <sub>4</sub>	7.51 jkl	-23.21	10.25 jk	-22.35
BHM 6	S <sub>1</sub>	10.02 abc	-	12.14 abcd	-
	S <sub>2</sub>	9.20 def	-8.18	11.53 defg	-5.02
	S <sub>3</sub>	8.53 fgh	-14.87	9.80 klm	-11.29
	S <sub>4</sub>	8.06 hij	-19.56	10.77 hij	-19.26

BHM 7	S <sub>1</sub>	10.23 ab	-	12.42 ab	-
	S <sub>2</sub>	9.53 cde	-6.84	11.88 bcd	-4.35
	S <sub>3</sub>	8.92 efg	-12.81	10.29 ijk	-9.74
	S <sub>4</sub>	8.54 fgh	-16.52	11.21 efgh	-17.15
BHM 9	S <sub>1</sub>	10.60 a	-	12.66 a	-
	S <sub>2</sub>	9.98 abc	-5.85	12.21 abc	-3.55
	S <sub>3</sub>	9.46 cde	-10.75	10.77 hij	-8.29
	S <sub>4</sub>	9.18 def	-13.40	11.61 cdef	-14.93
Level of Significance		**		**	
CV (%)		2.57		1.93	

Values having same letter(s) do not differ significantly as per DMRT at  $P \leq 5\%$  level.

S<sub>1</sub> = Control, S<sub>2</sub> = 5 dSm<sup>-1</sup>, S<sub>3</sub> = 10 dSm<sup>-1</sup>, S<sub>4</sub> = 15 dSm<sup>-1</sup>.

**Table (5):** Seedling growth characters of maize cultivars as influenced by different salinity levels.

Salinity Level	Shoot Length (cm)	Root Length (cm)	Shoot Fresh Weight (g)	Root Fresh Weight (g)	Shoot Dry Weight (g)	Root Dry Weight (g)
S <sub>1</sub>	24.87 a	30.65 a	1.14 a	0.93 a	0.097 a	0.078 a
S <sub>2</sub>	24.35 b	30.22 b	1.01 b	0.82 b	0.075 b	0.070 b
S <sub>3</sub>	22.62 c	28.40 c	0.92 c	0.71 c	0.060 c	0.059 c
S <sub>4</sub>	20.38 d	25.76 d	0.76 d	0.57 d	0.041 d	0.046 d
LSD	0.39	0.41	0.02	0.01	0.001	0.002
CV (%)	2.23	1.86	6.03	1.78	3.83	4.21

Values having same letter(s) do not differ significantly as per DMRT at  $p \leq 0.05$  level.

S<sub>1</sub> = Control, S<sub>2</sub> = 5 dSm<sup>-1</sup>, S<sub>3</sub> = 10 dSm<sup>-1</sup>, S<sub>4</sub> = 15 dSm<sup>-1</sup>.

**Table (6):** Seedling growth characters of different maize cultivars under salinity stresses.

Maize cultivars	Shoot length (cm)	Root length (cm)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)
Barnali	22.13de	26.84 d	0.76f	0.64 g	0.051 g	0.052f
Shuvra	22.38 d	28.82 c	0.86 e	0.72 f	0.056 f	0.058 e
Khoibhutta	22.65 cd	29.10 bc	0.95d	0.74 e	0.060 e	0.061 e
Mohor	21.64 e	25.54 e	0.68 g	0.57 h	0.044 h	0.049 g
BHM 5	23.28 bc	29.41 bc	1.01 cd	0.78 d	0.068 d	0.064 d
BHM 6	23.88 ab	29.54 b	1.07 bc	0.82 c	0.077 c	0.070 c
BHM 7	24.13 a	30.29 a	1.14 ab	0.87b	0.089 b	0.074 b
BHM 9	24.36 a	30.53 a	1.17 a	0.93a	0.101 a	0.078 a
LSD	0.66	0.69	0.07	0.02	0.003	0.003
CV (%)	2.23	1.86	6.03	1.78	3.83	4.21

Values having same letter(s) do not differ significantly as per DMRT at  $p \leq 0.05$  level.

**Table (7):** Salt Tolerance Index (STI) of germination and seedling growth characters of maize cultivars at 10 dSm<sup>-1</sup> salinity level.

Cultivars	GP	RG	SL	RL	SFW	RFW	SDW	RDW	Average STI	Salinity tolerance
Barnali	0.71	0.75	0.88	0.9	0.68	0.65	0.46	0.63	0.71	Susceptible
Shuvra	0.72	0.77	0.89	0.92	0.75	0.7	0.51	0.71	0.75	Medium tolerant
Khoibhutta	0.74	0.8	0.9	0.92	0.8	0.74	0.55	0.73	0.77	Medium tolerant
Mohor	0.66	0.7	0.87	0.88	0.64	0.56	0.35	0.58	0.66	Susceptible
BHM 5	0.78	0.82	0.91	0.93	0.82	0.8	0.63	0.76	0.81	Medium tolerant
BHM 6	0.82	0.85	0.94	0.94	0.86	0.83	0.72	0.83	0.85	Tolerant
BHM 7	0.84	0.88	0.94	0.96	0.9	0.89	0.78	0.89	0.89	Tolerant
BHM 9	0.85	0.9	0.95	0.96	0.93	0.93	0.86	0.92	0.91	Tolerant
Mean	0.77	0.81	0.91	0.93	0.80	0.76	0.61	0.76	0.79	
STDV ( $\sigma$ )	0.07	0.07	0.03	0.03	0.10	0.12	0.17	0.12	0.09	
Variance ( $\sigma^2$ )	0.005	0.005	0.001	0.001	0.010	0.015	0.030	0.014	0.010	

GP = Germination percentage, RG = Rate of germination, SL = Shoot length, RL = Root length, SFW = Shoot fresh weight, RFW = Root fresh weight, SDW = Shoot dry weight, RDW = Root dry weight.

**Table (8):** Salt Tolerance Index (STI) of germination and seedling growth characters of maize cultivars at 15 dSm<sup>-1</sup> salinity level.

Cultivars	GP	RG	SL	RL	SFW	RFW	SDW	RDW	Average STI	Salinity tolerance
Barnali	0.57	0.6	0.78	0.8	0.48	0.43	0.17	0.40	0.53	Susceptible
Shuvra	0.59	0.63	0.79	0.82	0.58	0.52	0.26	0.49	0.59	Medium tolerant
Khoibhutta	0.62	0.67	0.8	0.84	0.66	0.59	0.34	0.55	0.63	Medium tolerant
Mohor	0.5	0.54	0.76	0.77	0.4	0.31	0.05	0.29	0.45	Susceptible
BHM 5	0.66	0.71	0.82	0.85	0.69	0.67	0.45	0.59	0.68	Medium tolerant
BHM 6	0.71	0.76	0.86	0.86	0.75	0.73	0.56	0.70	0.74	Tolerant
BHM 7	0.75	0.8	0.87	0.89	0.81	0.8	0.66	0.79	0.80	Tolerant
BHM 9	0.77	0.84	0.88	0.89	0.85	0.88	0.76	0.84	0.84	Tolerant
Mean	0.65	0.69	0.82	0.84	0.65	0.62	0.41	0.58	0.66	
STDV ( $\sigma$ )	0.09	0.10	0.05	0.04	0.16	0.19	0.25	0.19	0.13	
Variance ( $\sigma^2$ )	0.01	0.01	0.00	0.00	0.02	0.04	0.06	0.04	0.02	

GP = Germination percentage, RG = Rate of germination, SL = Shoot length, RL = Root length, SFW = Shoot fresh weight, RFW = Root fresh weight, SDW = Shoot dry weight, RDW = Root dry weight.

## 5. Conclusions

This study, exposure of seeds to 5, 10, and 15 dS m<sup>-1</sup> NaCl affected germination and seedling growth. Based on STI values for all measured traits: Tolerant hybrid: BHM 9, followed by BHM 7 and BHM 6, Medium-tolerant: BHM 5 and Khoibhutta, Susceptible: Mohor, and Barnali close in susceptibility. Overall, the cultivars can be ranked for salt tolerance as: BHM 9 > BHM 7 > BHM 6 > BHM 5 > Khoibhutta > Shuvra > Barnali > Mohor. At control

and 5 dS m<sup>-1</sup> salinity generally show less stress impact for most cultivars. For subsequent pot experiments, salinity levels of 10, 15, and 20 dS m<sup>-1</sup> NaCl were selected. Considering tolerance and susceptibility, the cultivars BHM 9 (tolerant hybrid), BHM 5 (medium-tolerant hybrid), Khoibhutta (medium-tolerant inbred), and Barnali (susceptible inbred) were chosen as planting materials for further studies.

**Acknowledgement:** The author is thankful to the authority of Hajee Mohammad Daesh Science and Technology University, Khulna University and Khulna Agricultural University, Bangladesh for cordial supports to conduct the study.

**Conflict of Interest:** The authors declare that there are no conflicts of interest associated with this research project. We have no financial or personal relationships that could potentially bias our work or influence the interpretation of the results.

## References

- [1] I. J. Irin and M. Hasanuzzaman, "Role of organic amendments in improving the morphophysiology and soil quality of *Setaria italica* under salinity," *Heliyon*, vol. 10, Art. no. e38159, 2024.
- [2] C. Zorb, C. M. Geilfus, and K. J. Dietz, "Salinity and crop yield," *Plant Biology*, vol. 21, pp. 31–38, 2019.
- [3] E. Mwando *et al.*, "Genome-wide association study of salinity tolerance during germination in barley (*Hordeum vulgare* L.)," *Frontiers in Plant Science*, vol. 11, Art. no. 118, 2020.
- [4] I. J. Irin, M. N. Hoque, A. Hannan, and M. M. Alam, "Green manure for soil salinity reclamation—A comprehensive review," *Journal of Agriculture, Food and Environment*, vol. 3, no. 4, pp. 5–14, 2022, doi: 10.47440/JAFE.2022.3402.
- [5] M. U. Sikder, M. A. Haque, R. Jodder, T. Kumar, and D. Mondal, "Polythene mulch and irrigation for mitigation of salinity effects on maize (*Zea mays* L.)," *The Agriculturists*, vol. 14, no. 2, pp. 1–13, 2016.
- [6] R. Ahmed, M. H. K. Howlader, A. Shila, and M. A. Haque, "Effect of salinity on germination and early seedling growth of maize," *Progressive Agriculture*, vol. 28, no. 1, pp. 18–25, 2017.
- [7] S. A. Javed *et al.*, "Interactive effect of different salinity sources and their formulations on plant growth, ionic homeostasis and seed quality of maize," *Chemosphere*, 2021, doi: 10.1016/j.chemosphere.2021.132678.
- [8] I. J. Irin, K. Aktar, S. Rasul, T. Biswas, and M. M. Alam, "Mitigation of salinity stress on morpho-physiological and yield related parameters of rice using organic amendments," *Plant Science Today*, vol. 11, no. 4, pp. 604–611, 2024.
- [9] M. Akram, M. Y. Ashraf, R. Ahmad, M. Rafiq, I. Ahmad, and J. Iqbal, "Allometry and yield components of maize (*Zea mays* L.) hybrids to various potassium levels under saline conditions," *Archives of Biological Sciences*, vol. 62, pp. 1053–1061, 2010.
- [10] C. Qu *et al.*, "Impairment of maize seedling photosynthesis caused by a combination of potassium deficiency and salt stress," *Environmental and Experimental Botany*, vol. 75, pp. 134–141, 2012.
- [11] M. V. Mickelbart, P. M. Hasegawa, and J. Bailey-Serres, "Genetic mechanisms of abiotic stress tolerance that translate to crop yield stability," *Nature Reviews Genetics*, vol. 16, pp. 237–251, 2015.
- [12] K. Maghsoudi and M. J. Arvin, "Response of seed germination and seedling growth of wheat (*Triticum aestivum* L.) cultivars to interactive effects of salinity and salicylic acid," *Plant Ecophysiology*, vol. 2, pp. 91–96, 2010.
- [13] M. Goudarzi and H. Pakniyat, "Evaluation of wheat cultivars under salinity stress based on agronomic and physiological traits," *Journal of Agricultural and Social Sciences*, vol. 4, pp. 81–84, 2008.
- [14] M. Shahzad, K. Witzel, C. Zorb, and K. H. Mühling, "Growth-related changes in subcellular ion patterns in maize leaves (*Zea mays* L.) under salt stress," *Journal of Agronomy and Crop Science*, vol. 198, pp. 46–56, 2012.
- [15] M. Rahman, U. A. Soomro, M. Z. Haq, and S. Gul, "Effects of NaCl salinity on wheat (*Triticum aestivum* L.) cultivars," *World Journal of Agricultural Sciences*, vol. 4, no. 3, pp. 398–403, 2008.
- [16] P. Sabir and M. Ashraf, "Screening of local accessions of *Panicum miliaceum* L. for salt tolerance at the seedling stage," *Pakistan Journal of Botany*, vol. 39, no. 5, pp. 1655–1661, 2007.
- [17] M. Jamil, D. B. Lee, K. Y. Jung, M. Ashraf, S. C. Lee, and E. S. Rha, "Effect of salt (NaCl) stress on germination and early seedling growth of four vegetable species," *Journal of Central European Agriculture*, vol. 7, no. 2, pp. 273–282, 2006.

- [18] C. Ucarli, "Effect of salinity on seed germination and early seedling stage," in *Abiotic Stress in Plants*. London, U.K.: IntechOpen, 2020, pp. 1–21.
- [19] N. B. Amor, K. B. Hamed, A. Debez, C. Grignon, and C. Abdelly, "Physiological and antioxidant responses of perennial halophyte *Crithmum maritimum* to salinity," *Plant Science*, vol. 168, no. 4, pp. 889–899, 2005.
- [20] M. Ashraf and M. R. Foolad, "Pre-sowing seed treatment—A shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions," *Advances in Agronomy*, vol. 88, pp. 223–271, 2005.
- [21] N. Hassan, M. K. Hasan, M. O. Shaddam, M. S. Islam, C. Barutcular, and A. E. L. Sabagh, "Responses of maize varieties to salt stress in relation to germination and seedling growth," *International Letters of Natural Sciences*, vol. 69, pp. 1–11, 2018.
- [22] R. Ahmed, M. H. K. Howlader, A. Shila, and M. A. Haque, "Effect of salinity on germination and early seedling growth of maize," *Progressive Agriculture*, vol. 28, no. 1, pp. 18–25, 2017.
- [23] P. M. Hasegawa, R. A. Bressan, J. K. Zhu, and H. J. Bohnert, "Plant cellular and molecular responses to high salinity," *Annual Review of Plant Physiology and Plant Molecular Biology*, vol. 51, pp. 463–499, 2000.
- [24] M. Khajeh-Hosseini, A. A. Powell, and I. J. Bingham, "The interaction between salinity stress and seed vigor during germination of soybean seeds," *Seed Science and Technology*, vol. 31, pp. 715–725, 2003.
- [25] R. Chaabane, H. Bchini, H. Ouji, H. B. Salah, K. Khamassi, S. Khoufi, E. Babay, and M. B. Naceur, "Behaviour of Tunisian durum wheat (*Triticum turgidum* L.) genotypes under saline stress," *Pakistan Journal of Nutrition*, vol. 10, no. 6, pp. 539–542, 2011.
- [26] M. M. I. Hoque, Z. Jun, and W. Guoying, "Impact of salinity stress on seed germination indices of maize (*Zea mays* L.) genotypes," *Kragujevac Journal of Science*, vol. 36, pp. 155–166, 2014.
- [27] S. A. Begum, M. Billah, N. Hossain, S. Aktar, and M. S. Uddin, "Detection of salt tolerant hybrid maize using germination indices and seedling growth performance," *Bulgarian Journal of Agricultural Science*, vol. 23, no. 5, pp. 793–798, 2017.
- [28] M. Akram, M. Y. Ashraf, R. Ahmad, E. A. Waraich, J. Iqbal, and M. Mohsan, "Screening for salt tolerance in maize (*Zea mays* L.) hybrids at an early stage," *Pakistan Journal of Botany*, vol. 42, pp. 141–151, 2010.
- [29] C. Qu *et al.*, "Impairment of maize seedling photosynthesis caused by a combination of potassium deficiency and salt stress," *Environmental and Experimental Botany*, vol. 75, pp. 134–141, 2012.
- [30] N. Cicek and H. Cakirlar, "The effect of salinity on some physiological parameters in two maize cultivars," *Bulgarian Journal of Plant Physiology*, vol. 28, nos. 1–2, pp. 66–74, 2002.
- [31] M. A. Turan, N. Turkmen, and N. Taban, "Effect of NaCl on stomatal resistance and proline, chlorophyll, Na, Cl, and K concentrations of lentil plants," *Journal of Agronomy*, vol. 6, pp. 378–381, 2007.
- [32] M. Usman, A. U. Haq, T. Ahsan, S. Amjad, Z. Riast, and M. Umar, "Effect of NaCl on morphological attributes of maize (*Zea mays* L.)," *World Journal of Agricultural Sciences*, vol. 8, no. 4, pp. 381–384, 2012.
- [33] E. B. Carpici, N. Celik, and G. Bayram, "Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars," *African Journal of Biotechnology*, vol. 8, no. 19, pp. 4918–4922, 2009.
- [34] G. W. Netondo, J. C. Onyango, and E. Beck, "Sorghum and salinity: II. Gas exchange and chlorophyll fluorescence of sorghum under salt stress," *Crop Science*, vol. 44, pp. 806–811, 2004.
- [35] A. A. Jaradat, M. Shahid, and A. Al-Maskri, "Genetic diversity in the batini barley landrace from Oman: II. Response to salinity stress," *Crop Science*, vol. 44, pp. 997–1007, 2004.
- [36] O. Konuskan, H. Gozubenli, I. Atis, and M. Atak, "Effects of salinity stress on emergence and seedling growth parameters of some maize genotypes (*Zea mays* L.)," *Turkish Journal of Agriculture–Food Science and Technology*, vol. 5, no. 12, pp. 1668–1672, 2017.
- [37] N. Bahari, B. B. Bighdilu, and L. Karpisheh, "Evaluation of drought tolerance of bread wheat genotypes by stress and sensitivity tolerance indices," *Annals of Biological Research*, vol. 4, pp. 43–47, 2013.
- [38] M. B. Collado, M. B. Aulicino, M. J. Arturi, and M. C. Molina, "Selection of maize genotypes with tolerance to osmotic stress associated with salinity," *Agricultural Sciences*, vol. 7, pp. 82–92, 2016.
- [39] J. Kholova, R. K. Sairam, R. C. Meena, and G. C. Srivastava, "Response of maize genotypes to salinity stress in relation to osmolytes, ion content, oxidative stress and antioxidant enzyme activity," *Biologia Plantarum*, vol. 53, pp. 249–256, 2009.
- [40] T. K. Roy, M. S. Islam, N. A. Mahiddin, S. A. Hossain, T. Biswas, U. B. Antu, S. A. Serity, J. F. Miti, S. Akter, S. Roy, and A. Biswas, "Application of nanoparticles (NPs) to ameliorate abiotic stress in economically important crop species: A potential review," *Journal of Crop Health*, vol. 77, no. 1, pp. 1–20, 2025, doi: 10.1007/s10343-024-01069-6.

- [41] T. K. Roy, M. S. Islam, U. B. Antu, M. J. Sumi, I. J. Irin, S. A. Hossain, K. Akter, M. Mazrin, N. A. Mahiddin, H. Z. Meem, A. A. Bakky, Z. Ismail, and A. M. Idris, "Exogenous application of ZnO nanoparticles (NPs) to palliate salinity-induced oxidative stress in lettuce (*Lactuca sativa* L.) plant," *Journal of Soil Science and Plant Nutrition*, vol. 25, no. 2, pp. 6398–6412, 2025, doi: 10.1007/s42729-025-02537-2.
- [42] A. Sumer, C. Zorb, F. Yan, and S. Schubert, "Evidence of sodium toxicity for vegetative growth of maize (*Zea mays* L.) during the first phase of salt stress," *Journal of Applied Botany*, vol. 78, pp. 135–139, 2004.