



RESEARCH ARTICLE

EFFECT OF SALINITY STRESS ON MORPHO-PHYSIOLOGICAL TRAITS OF MAIZE GENOTYPES

Shawon Mojumder^a, M M Abdur Razzaque^a, Md. Jewel Alam^{b*}^aDepartment of Agricultural Extension, Khamarbari, Farmgate, Dhaka-1215, Bangladesh.^bDepartment of Entomology, Bangladesh Agricultural University (BAU), Mymensingh-2202, Bangladesh.*Corresponding author email: agjewel32251@bau.edu.bd

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ABSTRACT

To evaluate and screen maize genotypes for salinity tolerance, an experiment was conducted in Shibganj Upazila, Bogura district, Bangladesh, during the period from November 2023 to March 2024. The study followed a Completely Randomized Design (CRD) with two factors and three replications. Factor A comprised three salinity levels: 0 dsm⁻¹ (control), 10 dsm⁻¹, and 15 dsm⁻¹, while Factor B included six maize genotypes (Mohor, BARI hybrid Butta-5, BARI hybrid Butta-7, BARI hybrid Butta-9, BARI hybrid Butta-10 and BARI hybrid Butta-12) obtained from the Bangladesh Agricultural Research Institute (BARI), Gazipur. In total, 54 plastic pots were used (6 genotypes × 3 salinity levels × 3 replications). The results of the present study demonstrated that salinity stress exerts a pronounced negative effect on germination, seedling growth, vegetative development, and yield attributes of maize. Increasing salinity from 0 dsm⁻¹ to 15 dsm⁻¹ resulted in progressive and significant reductions in all measured parameters, including germination percentage, root and coleoptile length, plant fresh weight, plant height, cob size, grain weight per cob, and grain yield. Across all salinity levels, marked genotypic variation was observed. Based on the results of yield performance, 10 dsm⁻¹ showed the best than other tested salinity level. Considering the salinity level at 10 dsm⁻¹ and the performance of genotypes, BARI Hybrid Butta-9 consistently recorded the highest values in both growth (germination-83.45%, Coleoptile length-10.36%, root length-13.47%, plant fresh weight-70.12g and plant height-171.59cm) and yield traits (Cob length-13.66cm, cob diameter-11.03cm, grain weight per cob-130.76g and yield-5.67t/ha), maintaining comparatively better performance under saline conditions, indicating strong salt tolerance. In contrast, BARI Hybrid Butta-7 exhibited the lowest values across parameters, reflecting high sensitivity to salinity stress. These findings highlight the importance of genotype selection for cultivation in saline-prone areas. Considering the salinity and the performance of genotype, BARI Hybrid Butta-9 emerged as the most promising genotype, capable of maintaining higher productivity under salt stress at 10 dsm⁻¹ and could be recommended for breeding programs and commercial cultivation in coastal and other salt-affected regions of Bangladesh.

KEYWORDS

Maize, salinity level, morpho-physiological and yield traits

1. INTRODUCTION

Maize (*Zea mays* L.) is second most important cereal crop in Bangladesh after rice, playing a vital role in national food security, livestock feed supply, and agro-industrial raw material production (Alam et al., 2024a, b). It is cultivated year-round in different agro-ecological zones due to its short growing period, high yield potential, and adaptability to diverse environments. In Bangladesh, maize is mainly grown during the Rabi season (November-March) under irrigated conditions, with major producing districts including Kushtia, Chuadanga, Dinajpur, Bogura, and Jashore (Alam et al., 2025). Over the past two decades, maize cultivation area and production have significantly increased, driven by demand from the poultry and livestock industries as a major component of compound feed (BBS, 2023). According to DAE statistics, the national average yield of maize under optimal conditions ranges from 8-10 t ha⁻¹, though this varies with variety, soil fertility, and management practices. However, maize production in Bangladesh faces multiple abiotic stresses, among which soil salinity is a major constraint, especially in the coastal and south-western regions. Salinity intrusion is aggravated by tidal flooding,

sea-level rise, and improper irrigation practices, which together reduce arable land quality and limit crop productivity (Alam et al., 2024a, b, c, d and Alam et al., 2025). Maize's growing importance in Bangladesh is linked to its demand from the poultry sector, which consumes over 60% of total maize production as feed. The crop is also processed into starch, corn oil, glucose, and various food products, making it economically significant. However, production is threatened by a range of abiotic stresses-among which salinity is a key constraint, especially in the south-western coastal belt (Ahmad, 2013).

Salinity adversely affects maize growth and yield by disrupting physiological and biochemical processes. High salt concentration in the root zone leads to osmotic stress, ion toxicity (especially Na⁺ and Cl⁻ accumulation), and nutrient imbalance (notably K⁺, Ca²⁺, and NO₃⁻ deficiencies). In maize, salinity stress manifests through reduced seed germination, stunted seedling growth, chlorosis, reduced leaf area, decreased photosynthetic activity, and impaired reproductive development (Zhao et al., 2020; Zhu et al., 2012). In Bangladesh, maize grown in saline-prone areas such as Satkhira, Khulna, Bagerhat, and parts of Barisal often experiences yield reductions of 20-60% depending on

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salinity level and genotype tolerance (Khodarahmpour et al., 2012). Experimental studies have shown that maize varieties differ widely in their salt tolerance; for example, BARI Hybrid Butta-9 performs relatively better under moderate salinity (6-10 dSm^{-1}) compared to sensitive varieties like Mohor, which show sharp declines in grain yield beyond 4-6 dSm^{-1} . Salinity stress in maize not only reduces yield but also shortens grain-filling duration, lowers kernel weight, and decreases biomass accumulation. This impact is particularly concerning for coastal Bangladesh, where around 1.05 million hectares of land are affected by varying degrees of salinity (Khatun et al., 2010). Considering the increasing salinity due to climate change and sea-level rise, breeding and adopting salt-tolerant maize varieties, coupled with improved irrigation and soil management practices, are essential for sustaining maize production in affected areas. Salinity levels in the coastal belt range widely from 2 to more than 15 dSm^{-1} , depending on location, time of year, and soil type (Rafique et al., 2020). Soils with salinity above 4 dSm^{-1} are generally harmful to sensitive crops like maize, as the high osmotic potential makes it difficult for plants to absorb water, and toxic ions like Na^+ and Cl^- disrupt physiological processes (Memon et al., 2010). Keeping the facts mentioned above in mind, the current experiment was carried out to screening the maize genotypes under the effect of salinity as well as to determine the optimum salinity level on morpho-physiological traits of maize in Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental Site, Period, and Design

To evaluate and screen maize genotypes for salinity tolerance, an experiment was conducted in Shibganj Upazila, Bogura district, Bangladesh, during the period from November 2023 to March 2024. The study followed a Completely Randomized Design (CRD) with two factors and three replications. Factor A comprised three salinity levels: 0 dSm^{-1} (control), 10 dSm^{-1} , and 15 dSm^{-1} , while Factor B included six maize genotypes obtained from the Bangladesh Agricultural Research Institute (BARI), Gazipur. In total, 54 plastic pots were used (6 genotypes \times 3 salinity levels \times 3 replications). Salinity treatments were prepared by dissolving crude salt in water until the desired electrical conductivity (EC) level was reached, as measured with an EC meter. The control treatment used only tap water. Salinity was imposed 10 days after sowing (DAS) and continued until 30 DAS.

2.2 Preparation of Salinity Solution

The required salinity levels were obtained by diluting seawater sourced from the Bay of Bengal (initial EC: 36.9 dSm^{-1}) with distilled water, and the final concentrations were verified using an electrical conductivity (EC) meter (Model HI98331, Hanna Instruments). The control treatment consisted solely of distilled water.

2.3 Set up of Experiment, Details of Treatments and Data Collection

The experiment was conducted in plastic pots, each containing a salinity treatment or a control. Six genotypes were tested as experimental materials, requiring a total of 54 pots. Seeds of all genotypes were sown on 1 November 2024. Salinity levels were prepared by dissolving crude salt collected from the seashore in water until the desired concentration was reached, as verified using an electrical conductivity (EC) meter. The control treatment (0 dSm^{-1}) was maintained with distilled water only. Salinity was imposed 10 days after sowing (DAS) and maintained until 30 DAS. All necessary intercultural operations were performed as required. Data were collected on germination percentage, coleoptile length, root length, plant fresh weight, plant height, cob length and diameter (without husk), grain weight, and yield. Plant height (cm) was measured from the root base to the tip of the longest leaf at the time of seedling uprooting. Root length for each seedling was measured with a ruler, and the average was calculated from data on nine seedlings. Roots were carefully separated from the seedlings, washed with tap water, and finally rinsed with distilled water.

2.4 Data Analysis

The collected data were statistically analyzed following a Completely Randomized Design (CRD) using the Statistix 10 computer software package. Analysis of variance (ANOVA) was performed to determine the significance of treatment effects, and mean separation was conducted using Tukey's Honest Significant Difference (HSD) test (Gomez and Gomez, 1984). All graphical representations were prepared using Microsoft Excel 2010.

3. RESULTS

3.1 Germination Test (%)

In term of Germination (%), the germination percentage of maize was significantly influenced by salinity levels, with a consistent decline as salinity increased from 0 dSm^{-1} (control) to 15 dSm^{-1} (Figure 1). Under control conditions, germination ranged from 90.22% in BARI Hybrid Butta-7 to 96.35% in BARI Hybrid Butta-9, with statistically significant differences ($p < 0.01$). At 10 dSm^{-1} , germination was reduced in all varieties, varying from 57.69% (BARI Hybrid Butta-7) to 83.45% (BARI Hybrid Butta-9), and differences were significant ($p < 0.05$). The highest germination at this salinity was observed in BARI Hybrid Butta-9, followed by Mohor, while BARI Hybrid Butta-7 recorded the lowest. At 15 dSm^{-1} , germination percentages further declined, ranging from 41.36% (BARI Hybrid Butta-7) to 64.53% (BARI Hybrid Butta-9). Across all salinity levels, BARI Hybrid Butta-9 consistently exhibited the highest germination performance, indicating better salt tolerance at the germination stage. In contrast, BARI Hybrid Butta-7 showed the lowest germination percentages under salinity stress, suggesting higher sensitivity. The coefficient of variation (CV) values ranged from 5.98% to 8.45%, indicating acceptable experimental precision. Overall, the results demonstrate a clear negative impact of salinity on maize germination, with varietal differences in tolerance levels.

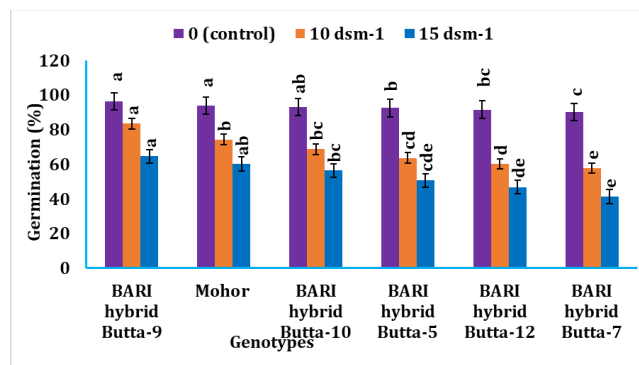


Figure 1: Percentage of germination of maize in response to different level of salinity

3.2 Shoot and Root Growth

As regards of shoot growth, coleoptile length of maize seedlings was significantly influenced by salinity, with a consistent reduction observed as salinity levels increased from 0 dSm^{-1} (control) to 15 dSm^{-1} (Figure 2). Under control conditions, coleoptile length ranged from 9.22 cm (BARI Hybrid Butta-7) to 12.65 cm (BARI Hybrid Butta-9), with significant differences among varieties ($p < 0.01$). At 10 dSm^{-1} , coleoptile length decreased across all varieties, ranging from 3.45 cm (BARI Hybrid Butta-7) to 10.36 cm (BARI Hybrid Butta-9), and differences were statistically significant ($p < 0.05$). At the highest salinity level (15 dSm^{-1}), coleoptile length was markedly reduced, with values ranging from 2.43 cm (BARI Hybrid Butta-7) to 6.47 cm (BARI Hybrid Butta-9), and varietal differences were highly significant ($p < 0.001$). Across all salinity levels, BARI Hybrid Butta-9 maintained the longest coleoptile length, suggesting greater salt tolerance and stronger early seedling vigor. Conversely, BARI Hybrid Butta-7 consistently recorded the shortest coleoptiles, indicating higher susceptibility to salinity stress. The coefficient of variation (CV) ranged from 6.74% to 7.76%, indicating good experimental precision. Overall, the results demonstrate that salinity adversely affects coleoptile elongation in maize, with varietal differences indicating potential for selecting salt-tolerant genotypes for cultivation in saline-prone areas.

In case of root growth, root length of maize seedlings was markedly affected by increasing salinity levels, with a progressive reduction observed from 0 dSm^{-1} (control) to 15 dSm^{-1} (Figure 3). Under control conditions, root length ranged from 18.78 cm (BARI Hybrid Butta-7) to 23.65 cm (BARI Hybrid Butta-9), with statistically significant differences ($p < 0.05$). At 10 dSm^{-1} , root length decreased notably, varying from 9.98 cm (BARI Hybrid Butta-7) to 13.47 cm (BARI Hybrid Butta-9), and differences among varieties were highly significant ($p < 0.001$). Therefore, BARI Hybrid Butta-9 showed the highest root growth (13.47 cm) under salinity condition compared to other tested level of salinity. Besides, at the highest salinity level (15 dSm^{-1}), root length was further reduced across all varieties, ranging from 3.55 cm (BARI Hybrid Butta-7) to 7.42 cm (BARI Hybrid Butta-9), with significant differences ($p < 0.05$). Across all salinity treatments, BARI Hybrid Butta-9 consistently produced the longest roots, suggesting superior tolerance to salinity stress during the early growth stage. Conversely, BARI Hybrid Butta-7 exhibited the shortest roots under all salinity levels, indicating higher sensitivity. Moreover, the coefficient of variation (CV) values ranged from 7.56% to 9.66%, reflecting acceptable experimental precision. These findings indicate that salinity stress adversely affects root development in maize,

with varietal differences in tolerance potential, and that root length reduction is more pronounced at higher salinity levels.

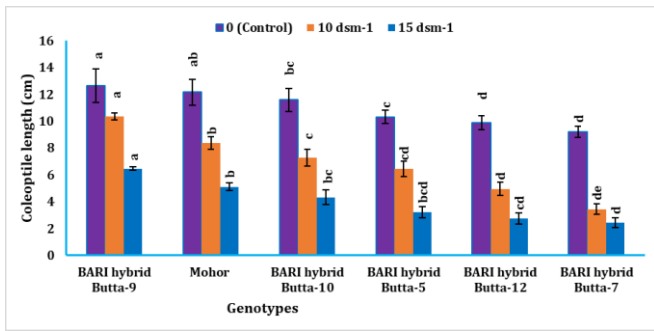


Figure 2: Coleoptile length (cm) of maize in response to different level of salinity

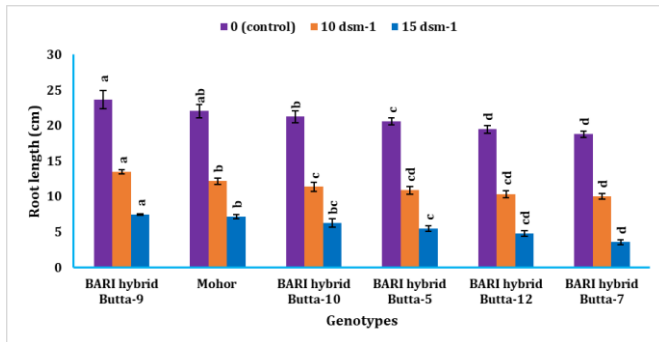


Figure 3: Root length (cm) of maize in response to different level of salinity

3.3 Plant Fresh Weight (g)

Plant fresh weight of maize seedlings at 20 DAS declined progressively with increasing salinity levels, showing significant varietal differences across treatments. Under control conditions (0 dSm⁻¹), fresh weight ranged from 84.69 g (BARI Hybrid Butta-7) to 92.45 g (BARI Hybrid Butta-9), with differences statistically significant ($p < 0.01$) (Table 1). At 10 dSm⁻¹, fresh weight decreased noticeably, varying from 58.66g (BARI Hybrid Butta-7) to 70.12g (BARI Hybrid Butta-9), and varietal differences remained significant ($p < 0.05$). So, BARI Hybrid Butta-9 explored the highest plant fresh weight (70.12g) under salinity condition than others. At the highest salinity level (15 dSm⁻¹) fresh weight was reduced drastically, ranging from 22.48 g (BARI Hybrid Butta-7) to 40.23 g (BARI Hybrid Butta-9), with significant differences among varieties ($p < 0.01$). Across all salinity levels, BARI Hybrid Butta-9 maintained the highest fresh weight, suggesting a greater ability to sustain biomass accumulation under saline conditions. In contrast, BARI Hybrid Butta-7 consistently recorded the lowest fresh weight, indicating high sensitivity to salt stress. The coefficient of variation (CV) ranged from 6.67% to 7.42%, reflecting good experimental precision. These findings confirm that salinity exerts a substantial negative effect on plant biomass production in maize, with genotypic variation in tolerance, and that BARI Hybrid Butta-9 exhibits superior performance under salt stress during the early growth stage.

Table 1: Plant fresh weight of maize genotypes under different levels of salinity

Genotypes	Plant fresh weight (g) at 20 DAS		
	0 (Control)	10 dsm ⁻¹	15 dsm ⁻¹
Mohor	90.06a	68.42b	33.12b
BARI hybrid Butta-5	86.34bcd	65.97cde	26.05cd
BARI hybrid Butta-7	84.69e	58.66e	22.48d
BARI hybrid Butta-9	92.45a	70.12a	40.23a
BARI hybrid Butta-10	88.59ab	66.19bc	29.14c
BARI hybrid Butta-12	85.16de	60.49de	24.16cd
Level of significant	**	*	**
CV (%)	6.87	7.42	6.67

Different letters represent significant differences within a column. *means at 5% level of probability and **means at 1% level of probability

3.4 Plant Height (cm)

Plant height of maize at 50 DAS was significantly affected by increasing salinity, with clear varietal differences across treatments. Under control conditions (0 dsm⁻¹), plant height ranged from 170.26 cm in BARI Hybrid Butta-7 to 183.45 cm in BARI Hybrid Butta-9, showing significant variation ($p < 0.05$) (Figure 4). At 10 dsm⁻¹, height decreased to between 148.66 cm (BARI Hybrid Butta-7) and 171.59 cm (BARI Hybrid Butta-9), with highly significant varietal differences ($p < 0.01$). The tallest plants (171.59 cm) were consistently recorded in BARI Hybrid Butta-9, while the shortest (148.66 cm) occurred in BARI Hybrid Butta-7 under salinity stress. At 15 dsm⁻¹, plant height declined further, ranging from 133.49 cm in BARI Hybrid Butta-7 to 153.14 cm in BARI Hybrid Butta-9, with significant varietal differences ($p < 0.05$). Across all salinity levels, BARI Hybrid Butta-9 maintained the greatest height, indicating superior tolerance and growth potential under saline conditions, whereas BARI Hybrid Butta-7 exhibited the greatest reduction, reflecting higher sensitivity. The coefficient of variation (CV) ranged from 7.88% to 9.44%, confirming reliable experimental precision. Overall, results indicate that salinity stress significantly limits stem elongation and vegetative growth in maize, but varietal tolerance is evident, with BARI Hybrid Butta-9 showing the best performance across salinity treatments.

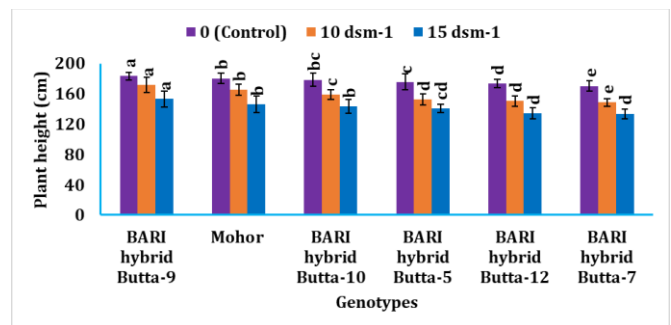


Figure 4: Plant height (cm) of maize genotypes under different levels of salinity

3.5 Cob Length (cm)

Cob length without husk was significantly affected by salinity, with a consistent decline as salinity levels increased from 0 dsm⁻¹ to 15 dsm⁻¹ (Table 2). Under control conditions, cob length ranged from 15.44 cm (BARI Hybrid Butta-7) to 16.55 cm (BARI Hybrid Butta-9), with statistically significant differences ($p < 0.05$). At 10 dsm⁻¹, cob length decreased notably, varying from 7.57 cm (BARI Hybrid Butta-7) to 13.66 cm (BARI Hybrid Butta-9), and varietal differences were highly significant ($p < 0.01$). Therefore, BARI Hybrid Butta-9 exhibited the highest cob length (13.66 cm) under different level of salinity compared to other tested genotypes. At the highest salinity level (15 dsm⁻¹), cob length was further reduced, ranging from 5.98 cm (BARI Hybrid Butta-7) to 10.24 cm (BARI Hybrid Butta-9), with significant varietal variation ($p < 0.05$). Across all salinity treatments, BARI Hybrid Butta-9 consistently recorded the longest cobs, indicating greater tolerance to salinity stress during reproductive development. In contrast, BARI Hybrid Butta-7 exhibited the shortest cobs, reflecting higher susceptibility to salt-induced yield reduction. The coefficient of variation (CV) ranged from 6.75% to 8.45%, demonstrating acceptable experimental precision. Overall, results indicate that salinity adversely affects cob length in maize, with genotypic differences in tolerance, and that BARI Hybrid Butta-9 shows superior performance in maintaining cob development under saline conditions.

Table 2: Cob length without husk (cm) of maize genotypes under different levels of salinity

Genotypes	Cob length without husk (cm)		
	0 (Control)	10 dsm ⁻¹	15 dsm ⁻¹
Mohor	16.42ab	12.01b	8.78b
BARI hybrid Butta-5	16.03bc	10.02c	7.24bc
BARI hybrid Butta-7	15.44d	7.57e	5.98d
BARI hybrid Butta-9	16.55a	13.66a	10.24a
BARI hybrid Butta-10	16.30abc	11.48bc	7.76b
BARI hybrid Butta-12	15.84cd	8.96d	6.34c
Level of significant	*	**	*
CV (%)	6.75	6.87	8.45

Different letters represent significant differences within a column. *means at 5% level of probability and **means at 1% level of probability

3.6 Cob Diameter (cm)

Cob diameter without husk in maize was markedly affected by salinity stress, showing a steady reduction as salinity increased from 0 dsm⁻¹ (control) to 15 dsm⁻¹. Under control conditions, cob diameter ranged from 12.74 cm in BARI Hybrid Butta-7 to 14.22 cm in BARI Hybrid Butta-9, with highly significant varietal variation ($p < 0.001$) (Figure 5). At 10 dsm⁻¹, cob diameter decreased substantially, from 6.48 cm (BARI Hybrid Butta-7) to 11.03 cm (BARI Hybrid Butta-9), with significant differences among varieties ($p < 0.05$). The largest cob diameter (11.03 cm) was consistently observed in BARI Hybrid Butta-9, while the smallest (6.48 cm) occurred in BARI Hybrid Butta-7. At 15 dsm⁻¹, cob diameter declined further, ranging from 5.87 cm in BARI Hybrid Butta-7 to 8.62 cm in BARI Hybrid Butta-9, with significant varietal differences ($p < 0.01$). Across all salinity treatments, BARI Hybrid Butta-9 maintained the largest cob girth, reflecting greater salt tolerance during reproductive growth, whereas BARI Hybrid Butta-7 consistently showed the smallest measurements, indicating higher susceptibility. The coefficient of variation (CV) ranged from 6.89% to 9.46%, indicating good experimental reliability. Overall, these findings demonstrate that salinity stress significantly reduces cob diameter in maize, with clear genotypic variation, and highlight BARI Hybrid Butta-9 as the most resilient genotype under saline conditions.

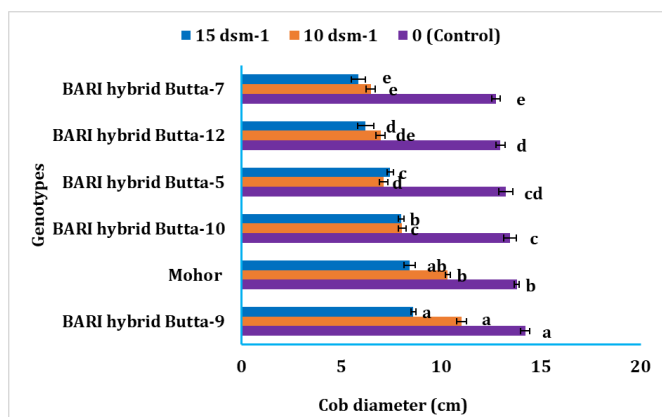


Figure 5: Cob diameter with husk (cm) of maize genotypes under different levels of salinity

3.7 Grain Weight Per Cob (g)

Grain weight per cob of maize was significantly affected by salinity, with progressive reductions observed as salinity increased from 0 dsm⁻¹ (control) to 15 dsm⁻¹. Under control conditions, grain weight ranged from 135.47 g (BARI Hybrid Butta-7) to 140.36 g (BARI Hybrid Butta-9), with significant varietal differences ($p < 0.01$) (Table 3). At 10 dsm⁻¹, grain weight decreased notably, varying from 112.49 g (BARI Hybrid Butta-7) to 134.76 g (BARI Hybrid Butta-9), and differences were highly significant ($p < 0.001$). So, BARI Hybrid Butta-9 showed the maximum grain weight per cob (134.76 g) and the minimum grain weight per cob (112.49 g) was noted from the genotype of BARI Hybrid Butta-7 under different salinity stress compared to other tested genotypes. At the highest salinity level (15 dsm⁻¹), grain weight declined sharply, ranging from 68.49 g (BARI Hybrid Butta-7) to 104.27 g (BARI Hybrid Butta-9), with significant varietal variation ($p < 0.05$). Across all salinity levels, BARI Hybrid Butta-9 consistently produced the heaviest grain weight per cob, indicating a superior capacity to maintain grain filling under saline conditions. In contrast, BARI Hybrid Butta-7 recorded the lowest values, reflecting higher sensitivity to salt stress. The coefficient of variation (CV) ranged from 5.88% to 8.76%, indicating good experimental precision. These results confirm that salinity exerts a strong negative influence on grain yield components in maize, with distinct genotypic differences, and highlight BARI Hybrid Butta-9 as the most salt-tolerant genotype among those tested.

Table 3: Grain weight per cob of maize genotypes under different levels of salinity

Genotypes	Grain wt./cob (g)		
	0 (Control)	10 dsm ⁻¹	15 dsm ⁻¹
Mohor	138.76b	130.14b	96.75b
BARI hybrid Butta-5	136.24cde	120.47d	85.48cd
BARI hybrid Butta-7	135.47e	112.49f	68.49f

Table 3(Cont.): Grain weight per cob of maize genotypes under different levels of salinity

BARI hybrid Butta-9	140.36a	134.76a	104.27a
BARI hybrid Butta-10	137.42bc	125.48c	90.49c
BARI hybrid Butta-12	135.89de	115.69e	78.36e
Level of significant	**	***	*
CV (%)	5.88	6.74	8.76

Different letters represent significant differences within a column. *means at 5% level of probability, **means at 1% level of probability and ***means at 0.1% level of probability

3.8 Yield (t/ha)

Grain yield of maize was significantly reduced with increasing salinity, with clear genotypic differences across treatments. Under control conditions (0 dsm⁻¹), yield ranged from 6.36 t ha⁻¹ (BARI Hybrid Butta-7) to 7.68 t ha⁻¹ (BARI Hybrid Butta-9), with significant variation ($p < 0.05$) (Table 4). At 10 dsm⁻¹, yields declined substantially, varying from 3.66 t ha⁻¹ (BARI Hybrid Butta-7) to 5.67 t ha⁻¹ (BARI Hybrid Butta-9), with significant varietal differences ($p < 0.05$). At the highest salinity level (15 dsm⁻¹), yield dropped markedly, ranging from 2.46 t ha⁻¹ (BARI Hybrid Butta-7) to 4.06 t ha⁻¹ (BARI Hybrid Butta-9), with varietal variation significant ($p < 0.01$). Across all salinity treatments, BARI Hybrid Butta-9 consistently maintained the highest yields, indicating strong salt tolerance and the ability to sustain productivity under stress. Conversely, BARI Hybrid Butta-7 recorded the lowest yields, reflecting high sensitivity to salinity. The coefficient of variation (CV) ranged from 5.96% to 7.79%, indicating acceptable experimental precision. Overall, these results confirm that salinity stress exerts a strong negative impact on maize productivity, but varietal tolerance exists, with BARI Hybrid Butta-9 emerging as the most promising genotype for saline-prone environments.

Table 4: Yield of maize genotypes under different levels of salinity

Genotypes	Yield (t/ha)		
	0 (Control)	10 dsm ⁻¹	15 dsm ⁻¹
Mohor	7.42b	4.96b	3.88b
BARI hybrid Butta-5	6.98d	4.46cd	3.02d
BARI hybrid Butta-7	6.36f	3.66f	2.46f
BARI hybrid Butta-9	7.68a	5.67a	4.06a
BARI hybrid Butta-10	7.18c	4.67c	3.42c
BARI hybrid Butta-12	6.76e	4.02e	2.87e
Level of significant	*	*	**
CV (%)	6.78	5.96	7.79

Different letters represent significant differences within a column. *means at 5% level of probability and **means at 1% level of probability

4. DISCUSSIONS

The effects of salinity on germination, seedling growth, vegetative development, and yield of maize genotypes are presented in Tables 1-9. In all measured parameters, increasing salinity from 0 dsm⁻¹ (control) to 15 dsm⁻¹ caused a progressive and significant reduction in performance, although the degree of reduction varied among genotypes, indicating differential tolerance. Across traits, BARI Hybrid Butta-9 consistently outperformed other genotypes, while BARI Hybrid Butta-7 was the most adversely affected. In term of germination percentage, salinity significantly reduced germination percentage in all maize genotypes (Figure 1). Under control conditions, germination ranged from 90.22% (BARI Hybrid Butta-7) to 96.35% (BARI Hybrid Butta-9). At 10 dsm⁻¹, germination fell sharply, particularly in BARI Hybrid Butta-7 (57.69%), while BARI Hybrid Butta-9 retained 83.45%. At 15 dsm⁻¹, germination dropped to 41.36% in BARI Hybrid Butta-7 compared to 64.53% in BARI Hybrid Butta-9. The results suggest that salt stress impairs seed metabolic activity and reduces water uptake during germination, in agreement with earlier findings by who reported significant germination inhibition under saline conditions (Ahmad et al., 2012).

As regards of root length, root development was also suppressed by salinity (Figure 2). Under control conditions, root length ranged from 18.78 cm (BARI Hybrid Butta-7) to 23.65 cm (BARI Hybrid Butta-9). At 10 dsm⁻¹ and 15 dsm⁻¹, root length reductions were more severe, with BARI

Hybrid Butta-9 maintaining relatively longer roots (13.47 cm and 7.42 cm, respectively) compared to BARI Hybrid Butta-7 (9.98 cm and 3.55 cm). Shorter root systems under high salinity may limit water and nutrient absorption, exacerbating growth inhibition (Ahmad, 2013).

In case of coleoptile length, coleoptile elongation followed a similar trend (Figure 3). Control plants exhibited coleoptile lengths between 9.22 cm (BARI Hybrid Butta-7) and 12.65 cm (BARI Hybrid Butta-9). At 15 dsm⁻¹, coleoptile length decreased drastically, with BARI Hybrid Butta-9 maintaining 6.47 cm compared to 2.43 cm in BARI Hybrid Butta-7. Reduced coleoptile growth under saline conditions may delay seedling emergence and establishment. These results are consistent with the findings of (Akram, 2010). They reported that the coleoptile is an important protective sheath that guides the emerging shoot during seed germination and early seedling establishment. Its length is a crucial parameter for successful seedling emergence, particularly under stress conditions such as soil salinity. In the present study, increasing salinity levels markedly reduced coleoptile length in maize, indicating that salt stress adversely affects early shoot growth. Under control conditions (0 dsm⁻¹), maize seedlings exhibited the maximum coleoptile length, suggesting that optimal osmotic balance and ion homeostasis favor rapid cell elongation and tissue development (Akram et al., 2010). However, with the application of moderate salinity (10 dsm⁻¹), coleoptile length was significantly reduced, and the decline was more severe under high salinity (15 dsm⁻¹).

On the other hand, salinity stress markedly reduced biomass accumulation in maize seedlings, as evidenced by the significant decline in plant fresh weight at 20 DAS (Table 1). Under control conditions (0 dsm⁻¹), fresh weight ranged from 84.69 g in BARI Hybrid Butta-7 to 92.45 g in BARI Hybrid Butta-9, indicating optimal growth when osmotic and ionic conditions were favorable. However, at high salinity (15 dsm⁻¹), biomass dropped sharply to 22.48 g in BARI Hybrid Butta-7 and 40.23 g in BARI Hybrid Butta-9, reflecting the strong inhibitory effects of salt stress on early plant growth. These outcomes are in agreement with the conclusions of (Bakht et al., 2011). They found that the substantial reduction in biomass under saline conditions can be attributed to salt-induced osmotic stress, which limits water uptake and disrupts cellular turgor pressure, thereby restricting cell expansion and overall growth. Additionally, excessive accumulation of Na⁺ and Cl⁻ ions in plant tissues can impair chlorophyll synthesis, enzyme activity, and nutrient balance, ultimately reducing photosynthetic efficiency. Reduced photosynthesis under salt stress has been widely reported as a key driver of biomass loss in glycophytic crops such as maize (Farooq, 2015).

In case of plant height, salinity stress significantly reduced plant height in maize at 50 DAS, with the magnitude of reduction increasing with higher salt concentrations (Figure 4). Under control conditions (0 dsm⁻¹), plant height ranged from 170.26 cm in BARI Hybrid Butta-7 to 183.45 cm in BARI Hybrid Butta-9, indicating robust vegetative growth in the absence of salt stress. However, at the highest salinity level (15 dsm⁻¹), plant height declined markedly to 133.49cm and 153.14cm for BARI Hybrid Butta-7 and BARI Hybrid Butta-9, respectively. These findings are consistent with previous studies. Some researcher reported that salt stress limits shoot elongation by reducing leaf expansion rates and internode growth in glycophytic crops (Gurbanow and Molazem, 2009). Similarly, a group researcher observed that maize genotypes exposed to salinity showed significant reductions in plant height, with the extent of reduction varying among varieties (Horie et al., 2012). In the present study, BARI Hybrid Butta-9 maintained a relatively greater height than BARI Hybrid Butta-7 under high salinity, suggesting that varietal differences in salt tolerance exist. Such differences may be due to better osmotic adjustment, efficient ion compartmentalization, or greater maintenance of cell wall extensibility in tolerant genotypes (Akram et al., 2010). This indicates the potential for breeding or selecting varieties that can sustain better growth under saline conditions.

In the context of cob length without husk, salinity stress substantially reduced cob length without husk in maize, with greater reductions observed at higher salt concentrations (Table 2). Under control conditions (0 dsm⁻¹), cob length ranged from 15.44 cm in BARI Hybrid Butta-7 to 16.55 cm in BARI Hybrid Butta-9, reflecting optimal reproductive development in the absence of stress. However, at 15 dsm⁻¹, cob length declined sharply to 5.98 cm in BARI Hybrid Butta-7 and 10.24 cm in BARI Hybrid Butta-9. Such reductions in cob size under saline conditions have direct implications for grain yield potential, as shorter cobs typically bear fewer kernels and lower total grain mass. Similar observations have been reported in earlier studies. Hossain and Dietz found that maize plants exposed to salinity exhibited shorter cob length and reduced grain yield due to restricted assimilate partitioning to reproductive organs (Hossain and Dietz, 2016). A group researcher also reported that reproductive structures are more sensitive to salt stress

than vegetative parts, leading to a disproportionate decline in yield parameters (Khatoun et al., 2010). A group researchers highlighted that salinity affects both pre-and post-fertilization processes, resulting in fewer kernels and smaller cob size (Khadrahmpour et al., 2012). The relatively greater cob length of BARI Hybrid Butta-9 compared to BARI Hybrid Butta-7 at high salinity suggests that genetic variability exists in the tolerance of reproductive traits to salt stress. Such tolerance may be associated with better osmotic adjustment, more efficient ion regulation, or sustained photosynthate allocation during reproductive development (Ahmad, 2013).

On the subject of cob diameter without husk, cob diameter without husk declined significantly with increasing salinity, indicating the strong sensitivity of reproductive growth to salt stress (Figure 5). In the control treatment, cob diameter ranged from 12.74cm in BARI Hybrid Butta-7 to 14.22cm in BARI Hybrid Butta-9. At 15 dsm⁻¹, the values dropped sharply to 5.87cm and 8.62cm, respectively, reflecting substantial losses in kernel set and grain filling. Reduced cob diameter under salinity can be attributed to osmotic stress limiting water and nutrient uptake, coupled with ionic toxicity disrupting reproductive processes such as silk emergence, pollen viability, and fertilization (Memon et al., 2010). These effects lower the number of grains per row and reduce assimilate partitioning to the developing cob (Rafique et al., 2020). The comparatively smaller reduction in BARI Hybrid Butta-9 suggests superior tolerance, possibly due to better osmotic adjustment and more efficient use of available assimilates under stress (Zewdu, 2021).

In the framework of grain weight per cob, grain weight per cob was significantly reduced by salinity, with progressive declines as salt concentration increased (Table 3). In the control, grain weight ranged from 135.47g in BARI Hybrid Butta-7 to 140.36 g in BARI Hybrid Butta-9, while at 10 dsm⁻¹ it fell to 112.49g and 134.76g, respectively. The sharpest reductions occurred at 15 dsm⁻¹ where BARI Hybrid Butta-7 dropped to 68.49 g and BARI Hybrid Butta-9 to 104.27g. These reductions can be attributed to osmotic stress, which limits water and nutrient uptake, and ionic toxicity, which impairs photosynthesis, pollen viability, and assimilate transport to the developing kernels (Zhang et al., 2010). Similar patterns have been reported in maize under saline conditions (Zhao et al., 2020). The consistent superiority of BARI Hybrid Butta-9 suggests better osmotic adjustment, efficient ion regulation, and sustained grain filling under salt stress.

With regard to grain yield (t/ha), grain yield of maize declined significantly with increasing salinity, with pronounced genotypic differences (Table 4). Under control conditions (0 dsm⁻¹), yields ranged from 6.36 t ha⁻¹ (BARI Hybrid Butta-7) to 7.68 t ha⁻¹ (BARI Hybrid Butta-9), while at 10 dsm⁻¹ they fell to 3.66 t ha⁻¹ and 5.67 t ha⁻¹, respectively. The most severe reduction occurred at 15 dsm⁻¹, with yields dropping to 2.46 t ha⁻¹ in BARI Hybrid Butta-7 and 4.06 t ha⁻¹ in BARI Hybrid Butta-9. Yield loss under salt stress is primarily due to reduced photosynthetic efficiency, impaired nutrient uptake, and increased reproductive failure from pollen sterility and poor grain filling (Zhu et al., 2012). Comparable yield declines have been reported in maize under saline irrigation (Akram, 2010; Ahmad, 2013). Across salinity levels, BARI Hybrid Butta-9 consistently outperformed other genotypes, suggesting superior osmotic adjustment, ion homeostasis, and stress resilience. These findings highlight the potential of salt-tolerant hybrids for sustaining maize production in salinity-affected regions (Alam et al., 2020a, b, c, d). Across all measured parameters, BARI Hybrid Butta-9 consistently recorded the highest values under both control and saline conditions, indicating superior salt tolerance. Conversely, BARI Hybrid Butta-7 consistently performed the poorest, reflecting high susceptibility. This pattern suggests that salt tolerance in maize is associated with the ability to maintain higher germination rates, stronger seedling growth, and better reproductive development under stress.

5. CONCLUSION

The present study demonstrated that salinity stress exerts a pronounced negative effect on germination, seedling growth, vegetative development, and yield attributes of maize. Increasing salinity from 0 dSm⁻¹ to 15 dSm⁻¹ resulted in progressive and significant reductions in all measured parameters, including germination percentage, root and coleoptile length, plant fresh weight, plant height, cob size, grain weight per cob, and grain yield. Across all salinity levels, marked genotypic variation was observed. Considering the salinity level at 10dsm⁻¹ and the performance of genotypes, BARI Hybrid Butta-9 consistently recorded the highest values in both growth (germination-83.45%, Coleoptile length-10.36%, root length-13.47%, Plant fresh weight-70.12g and plant height-171.59cm) and yield traits (Cob length-13.66cm, cob diameter-11.03cm, grain weight per cob-130.76g and yield-5.67t/ha), maintaining comparatively better performance under saline conditions, indicating strong salt

tolerance. In contrast, BARI Hybrid Butta-7 exhibited the lowest values across parameters, reflecting high sensitivity to salinity stress. These findings highlight the importance of genotype selection for cultivation in saline-prone areas. Considering the salinity and the performance of genotype, BARI Hybrid Butta-9 emerged as the most promising genotype, capable of maintaining higher productivity under salt stress at 10 dsm⁻¹ and could be recommended for breeding programs and commercial cultivation in coastal and other salt-affected regions of Bangladesh.

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