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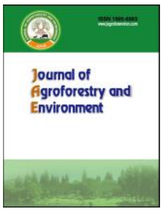

Germination Capacity of Different Wheat Genotypes Under Salt Stress

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Abstract: Salinity stress can negatively impact the growth and productivity of young wheat seedlings, leading to diminished grain yield and quality. Poor salinity management can cause soil sodicity in farming soils, where sodium (Na) binds to negatively charged clay, causing clay swelling and dispersal, subsequently decreasing the crop yield. Thus, the use of salinity tolerant varieties can be a plausible solution. This article investigates the effects of salinity stress on the germination and early seedling growth of 15 wheat genotypes in Bangladesh. The seeds were exposed to four levels of salinity (0, 6, 9, and 12 dS/m) and various germination parameters were measured, such as water imbibition, germination rate, seedling tissue water content, and seedling vigour index. The results showed significant differences among the genotypes and the salinity levels for all the parameters. BARI Gom 25 was found to be the most tolerant genotype, followed by BARI Gom 24, BARI Gom 29, and Binagom-1. The article also discussed the implications of these findings for saline soil remediation and wheat production in coastal areas of Bangladesh.

Keywords: Genotype; Salinity; Water imbibition; Germination rate; Seedling tissue water content; Seedling vigour index.

INTRODUCTION

One of the most important issues facing Bangladesh's coastal districts is salinity. Different levels of soil salinity have an impact on the cultivable regions in coastal districts. Tidal estuaries and river floodplains are found throughout Bangladesh's coastal and offshore regions, particularly in the south along the Bay of Bengal. The Ganges River floodplain to the south and other coastal locations of Chittagong are home to tidal floodplain land. Saline soils are unsuitable for conventional farming methods due to their high soluble salt content. Season and tidal flooding severity are the key factors that affect salinity (SRDI, 2010). The main rivers' water being taken upstream, which causes the land to dry up, is making Bangladesh's salinity issue worse. Depending on the amount of salinity present throughout the crucial growth stages, it damages crops and lowers production; in extreme situations, the entire yield is lost. In coastal regions, the range of soil response values (pH) is 6.0 to 8.4. Additionally, the soils have a relatively low organic matter level (1.0–1.5%). In saline soils, nutrient deficits primarily involve N and P. Micronutrient deficiencies are common, especially with regard to Cu and Zn. Among all the grain crops, wheat holds great importance. Expanding the area under cultivation on recently recovered areas and boosting productivity per unit area are two significant national goals for wheat production. Enhancing agronomic procedures and raising high-yielding salinity-tolerant cultivars could increase productivity per unit area, especially in saline media. Asrar and Elhindi, 2011; Kumar et al., 2010; Parádi et al., 2002; Abdel-Fattah et al., 2002) arbuscular mycorrhizal fungi are frequently more tolerant of environmental challenges and more competitive than non-mycorrhizal related plants. One of Bangladesh's most serious issues with the coastal districts is salinity. Coastal districts have varied degrees of soil salinity that impair cultivable areas.In Bangladesh's southern region along the Bay of Bengal, there are river floodplains and tidal estuaries. The Ganges River floodplain to the south and other coastal locations of Chittagong are home to tidal

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floodplain land. Saline soils are unsuitable for conventional farming methods due to their high soluble salt content. Season and tidal flooding severity are the key factors that affect salinity (SRDI, 2003). Bangladesh's coastal regions are made up of 19 districts that together account for 32% of the nation's land area and house over 35 million people (Huq and Rabbani 2011). A climacteric concern for the people living in Bangladesh's coastal regions is the rising salinity. 83.3 million hectares of Bangladeshi land were afflicted by saline in 1973; this amount rose to 102 million hectares in 2000 and continued to rise, reaching 105.6 million hectares in 2009 (SRDI 2010). The salinity of coastal areas affects about 53% of them. Salinity creates an adverse hydrological condition and environment that limits annual average agricultural productivity. Mainly two factors cause the development of soil salinity, one is tidal flooding during the wet season (June to October), and another is lateral movement of groundwater during the dry season (November to May) (Rasel et al., 2013). Thus, the objective of this study is to select salinity tolerant wheat variety(ies) for the coastal saline area.

MATERIALS AND METHODS

The laboratory experiment was conducted at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh from November to December, 2018.

Design of the experiment

The experiment consisted of Randomized Complete Block Design for four salinity levels with three replications. The experiment includes two factors. The first factor 4 levels of saline water. Effect of salt stress induced by 0, 6, 9, and 12 dS/m of saline water (diluted saline water from river) on germination and early seedling development of wheat were studied. The river water was collected from Ichamoti river, Satkhira during April to May, 2018. The second factor include 15 wheat genotypes (BARI Gom 19, BARI Gom 20, BARI Gom 21, BARI Gom 22, BARI Gom 23, BARI Gom 24, BARI Gom 25, BARI Gom 26, BARI Gom 27, BARI Gom 28, BARI Gom 29, BARI Gom 31, BARI Gom 32, BARI Gom 33 and Binagom-1) were collected from BARI and BINA to investigate the better performer genotypes under salt stress. The seeds were germinated in Petri-dishes (11 cm) containing 2 layered filter paper (90 mm). The selected seeds of each genotype were first sterilized in sodium hypochlorite (1%) solution and then washed in deionized water. Then Petri-dishes containing double layer filter paper were moistened by respective prepared saline solutions. Electrical conductivity of the solution was measured by using digital conductivity meter (Model F 538, WTW, Germany).

Percentage of germination

100 seeds of each variety were placed in Petri dishes (Figure 1). In each Petri dish, 2 layers of filter paper were moistened with 10 ml of salinity treatments. The plates were placed into an incubator (40% relative humidity at 30"C) for 7 days. The papers were altered once after every 2 days to prevent salt accumulation (Rehman et al., 1996). The number of seeds germinated was expressed as percentage under each treatment. After 7 days, different parameters were tested for germination for screening of wheat genotypes.

Figure 1. Seed preparation for germination test

Growth Parameters

After 7 days the seedlings were harvested and the following observations were made: Shoot length, root length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight. Ten seedlings were randomly chosen from each Petri dish at the completion of germination measurements.

Germination related characteristics

The following parameters were tested for germination screening of wheat varieties:

Water uptake percent: Water uptake percent will be calculated following Mujeeb-ur-Rahman et al. (2008).

$$WU = \frac{W2-W1}{W1} \times 100$$

Where, W1 = Initial weight of seed and W2 = Weight of seed after absorbing water in a particular time.

Germination percentage: Germination percentage (GP) will be calculated according to the International Seed Testing Association (ISTA) method

$$GP = \frac{\text{Number of normally germinated seeds}}{\text{Total number of seeds placed for germination}} \times 100$$

Tissue water content (TWC): TWC will be calculated according to the formula by Black and Pritchard (2002).

$$TWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

Seedling vigour index (SVI): SVI will be calculated following modified formula of Abdul-Baki and Anderson (1973).

SVI = Germination percentage x seedling length

Statistical Analysis

All data of this study were statistically analyzed according to the technique of variance (ANOVA) for the factorial Randomized Complete Block Design.

RESULTS AND DISCUSSION

Germination characteristics

The fifteen genotypes that were chosen for the experiment each had different germination-related parameters researched and analyzed. The results showed significant differences were present among the genotypes for the studied characteristics. In terms of the percentage of water that was imbibed, BARI Gom 25 had the greatest imbibition rate, which was 42.85%, followed by BARI Gom 24, which had a rate of 41.73. The participant with the lowest water intake was BARI Gom 33, with a percentage of 33.75%. This was followed by BARI Gom 27, with a percentage of 34.60%, and BARI Gom 32, with a percentage of 34.85% (Table 1).

The BARI Gom 25 sample had the greatest germination rate, which was discovered to be 85.25%, followed by the BARI Gom 24 sample, which had 84.29%. Both BARI Gom 32 and BARI Gom 33 were found to have a germination rate of 72.97%, making them the two with the lowest percentage.

The percentage of water detected in the seedling tissue that was found to be the greatest was found in BARI Gom 25, which was 79.47%, followed by BARI Gom 24, which was 76.43%. The bari gom with the lowest percentage of tissue water content was determined to be BARI Gom 23, with 67.85%, followed by BARI Gom 33, with 67.98%.

After calculating the seedling vigour based on the collected data, it was discovered that the seeds of the BARI Gom 25 were the most vigorous, followed by those of the BARI Gom 24, BARI Gom 29, and Binagom-1. In the case of BARI Gom 28, the seeds were determined to have the least amount of vitality, followed by BARI Gom 22.

Numerous studies have shown a positive relationship between water imbibition and germination rates in various plant species. Koller, (1959)found that water uptake by seeds of the desert plant Anastatica hierochuntica was essential for germination and that seedlings emerged only after the seeds had absorbed sufficient water. Similarly, a study by Haider et al., (2023) showed that water uptake was positively correlated with germination rates in seeds of Satureja hortensis, a medicinal plant. Another study by Waqas et al., (2019) investigated the effects of water imbibition on seed germination in rice (Oryza sativa). The authors found that soaking rice seeds in water for 48 hours significantly increased germination rates compared to seeds that were not soaked. Moreover, the researchers also showed that water imbibition improved the seedling growth and development.

Table 1: Effect on different germination parameters of fifteen wheat genotypes

Genotype	Water Imbibed (%)	Germination rate (%)	Seedling Tissue Water Content (%)	Seedling Vigour Index
BARI Gom 19	36.170 g	77.307 h	70.879 d	2154.8 ef
BARI Gom 20	35.599 h	75.622 l	69.356 e	2055.5 i
BARI Gom 21	35.243 i	75.140 m	68.123 f	2129.8 g
BARI Gom 22	37.821 e	80.529 e	68.171 f	1974.7 j
BARI Gom 23	38.191 d	80.264 f	67.849 fg	2065.4 i
BARI Gom 24	41.732 b	84.292 b	76.437 b	2403.1 b
BARI Gom 25	42.857 a	85.255 a	79.477 a	2496.2 a
BARI Gom 26	35.176 i	79.475 g	67.877 fg	2060.3 i
BARI Gom 27	34.605 j	76.826 j	68.633 ef	2097.6 h
BARI Gom 28	35.847 h	77.067 i	67.183 g	1931.3 k
BARI Gom 29	36.957 f	83.569 c	72.828 c	2366.4 c
BARI Gom 31	35.673 h	76.344 k	69.187 e	2141.0 fg
BARI Gom 32	34.854 j	72.973 n	67.297 g	2151.5 ef
BARI Gom 33	33.753 k	72.973 n	67.978 fg	2162.8 e
Binagom-1	41.225 c	81.597 d	73.045 c	2249.9 d
P value	0.0000	0.0000	0.0000	0.0000

Different letters within each column denote significant differences ($p < 0.05$) between treatments.

Effect of salinity on germination characteristics

To observe the effect of different levels of salinity in the germination related characteristics the seeds of the selected genotypes were set for germination test. The results showed significant differences were present among the genotypes for the studied characteristics. Water imbibition rate was found the highest for the control that is non-salinized condition. The imbibition rate for the control was 45.95%. The trait showed gradual decrease with the increased level of salinity. The lowest water imbibition rate was found in the treatment 12 dS m-1 which was 29.26% (Table 2). In accordance with the water imbibition rate, germination rate was gradually decreased with the increased salinity level. The highest germination rate was found in the control treatment (85.60%) whereas the germination rate was the lowest in the treatment 12 dS m-1 (72.76%).

Figure 2. Effect of salinity on germination of the studied genotypes

In case of seedling tissue water content, the highest seedling tissue water content was found in the control treatment (84.92%) whereas the germination rate was the lowest in the treatment 12 dS m-1 (58.62%).

The seedling vigour index was found the highest in the control treatment that was 2619.1 whereas the lowest vigour was found in the treatment 12 dS m-1 1762.7.

Table 2: Effect of Salinity (EC) level on different germination parameters of fifteen wheat genotypes

Salinity (EC)	Water Imbibed (%)	Germination rate (%)	Seedling Tissue Water Content (%)	Seedling Vigour Index
0 dS m-1	45.948 a	85.608 a	84.923 a	2619.1 a
6 dS m-1	39.305 b	80.051 b	73.345 b	2278.2 b
9 dS m-1	33.668 c	76.039 c	64.264 c	1990.8 c
12 dS m-1	29.267 d	72.764 d	58.620 d	1762.7 d
P value	0.0000	0.0000	0.0000	0.0000

Different letters within each column denote significant differences ($p < 0.05$) between treatments.

Salinity can have a significant impact on the germination rate of wheat, and this effect can be influenced by various factors, including soil type, water availability, and temperature. Several studies have investigated the interaction effect between salinity and germination rates of wheat, and found that salinity can reduce the germination rate of wheat, especially under high salinity levels. A study by Akgun et al., (2011) investigated the effect of salinity on the germination rate of wheat under different soil types and found that the germination rate of wheat was significantly reduced by salinity, especially under high salinity levels. The authors reported that as salinity levels increased from 0 to 300 mM, the germination rate of wheat decreased from 94% to 60%. Similarly, Hayat et al., (2020) investigated the effect of salinity on the germination rate of wheat under different water availability levels and found that the germination rate of wheat was significantly reduced by salinity, especially under water-deficient conditions. The authors reported that as salinity levels increased from 0 to 200 mM, the germination rate of wheat decreased from 88% to 43% under water-deficient conditions, while the decrease was from 94% to 60% under water-sufficient conditions.

Reduction of water imbibition rate in salt stress

The reduction in the water imbibition from the control treatment occurred in all the three levels of salinity viz. 6 dS/m, 9 dS/m and 12 dS/m. In 6 dS/m treatment, the highest reduction of water imbibition was found in BARI Gom 23 (19.90 %) followed by BARI Gom 28 and BARI Gom 32. The reduction rate was 19.27% in both the genotypes. The least amount of reduction was found in the BARI Gom 25 which was 10.85% (Table 3). These results indicated that BARI Gom 25 was the most capable genotype that could absorb water in 6 dS/m while BARI Gom 23, BARI Gom 28 and BARI Gom 32 were the least capable genotypes (Table 3).

In 9 dS/m salinity, the highest reduction of water imbibition was found in BARI Gom 20 and BARI Gom 32. The reduction rate was 31.89% in both the genotypes. These results were statistically similar to each other. The least amount of reduction was found in the BARI Gom 25 (20.07 %) which statistically different from the other genotypes. These results indicated that BARI Gom 25 was the most capable genotype that could absorb water in 9 dS/m while BARI Gom 20, and BARI Gom 32 were the least capable genotypes in 9 dS/m (Table 3).

In 12 dS/m salinity, the highest reduction of water imbibition was found in BARI Gom 27 (43.76 %). The least amount of reduction was found in the BARI Gom 25 (30.81 %) which statistically different from the other genotypes. These results indicated that BARI Gom 25 was the most capable genotype that could absorb water in 12 dS/m while BARI Gom 27 was the least capable genotypes in 12 dS/m.

According to a study by Moud and Maghsoudi, (2008), wheat seed imbibition rates decreased as salinity levels increased. In their study, they exposed wheat seeds to varying levels of salinity (0, 50, 100, 150, and 200 mM NaCl) and measured the imbibition rate over time. They found that the imbibition rate decreased significantly at higher salinity levels, with the most significant decrease occurring at 200 mM NaCl. Similarly, another study by (Charushahi et al., 2015) found that wheat seed imbibition rate decreased as salinity levels increased. They exposed wheat seeds to different levels of salinity (0, 50, 100, 150, 200, and 250 mM NaCl) and measured the imbibition rate over time. They found that the imbibition rate decreased significantly at salinity levels above 100 mM NaCl.

Table 3: Reduction of different salinity (EC) level on water imbibed in fifteen wheat genotypes

Genotype	6 dS/m (%)	9 dS/m (%)	12 dS/m (%)
BARI Gom 19	15.641 f	30.40 c	39.93 c
BARI Gom 20	14.888 g	31.89 a	38.42 e
BARI Gom 21	12.479 i	31.24 b	37.995 f
BARI Gom 22	14.938 g	27.62 f	39.02 d
BARI Gom 23	19.904 a	27.35 f	37.69 f
BARI Gom 24	12.174 j	21.348 i	31.42 j
BARI Gom 25	10.855 l	20.071 j	30.81 k
BARI Gom 26	18.172 d	28.86 e	40.80 b
BARI Gom 27	13.720 h	30.36 c	43.76 a
BARI Gom 28	19.271 b	29.70 d	34.04 h
BARI Gom 29	11.840 k	21.20 i	32.82 i
BARI Gom 31	16.319 e	25.00 g	34.96 g
BARI Gom 32	19.271 b	31.89 a	40.62 b
BARI Gom 33	18.867 c	29.65 d	38.856 d
Binagom-1	12.618 i	23.374 h	31.42 j
P value	0.0000	0.0000	0.0000
CV	0.80	0.56	0.54

Different letters within each column denote significant differences ($p< 0.05$) between treatments.

Reduction of germination rate in salt stress

The reduction in the germination rate from the control treatment occurred in all the three levels of salinity viz. 6 dS/m, 9 dS/m and 12 dS/m. In 6 dS/m treatment, the highest reduction of germination rate was found in BARI Gom 20 (12.33 %) followed by BARI Gom 19 (12.23%) which was significantly different from the BARI Gom 20 (Table 4). The least amount of reduction was found in the BARI Gom 25 (7.47 %) which was which was statistically similar with BARI Gom 24 (7.86 %). These results indicated that BARI Gom 25 and BARI Gom 24 were the most capable genotype that could germinate in 6 dS/m while BARI Gom 19, BARI Gom 20 were the least capable genotypes (Table 4).

In 9 dS/m salinity, the highest reduction of germination rate was found in BARI Gom 21 (21.18 %) followed by BARI Gom 19 (18.65%) and BARI Gom 20 (18.82%). The least amount of reduction in germination rate was found in the BARI Gom 25 (9.88 %) followed by BARI Gom 24 (10.28) which were statistically different from the other genotypes. These results indicated that BARI Gom 25 and BARI Gom 24 were the most capable genotype that could germinate in 9 dS/m while BARI Gom 19, BARI Gom 20, and BARI Gom 21 were the least capable genotypes in 9 dS/m (Table 4).

In 12 dS/m salinity, the highest reduction of germination rate was found in BARI Gom 20 (25.32 %). The least amount of reduction was found in the BARI Gom 25 (10.96 %) which statistically different from the other genotypes. These results indicated that BARI Gom 25 was the most capable genotype that could germinate in 12 dS/m while BARI Gom 20 was the least capable genotypes in 12 dS/m (Table 4).

Several studies have investigated the effect of different levels of salinity on the germination rates of wheat seeds. For example, a study by Rasheed et al., (2022) found that wheat seed germination rates decreased as salinity levels increased. In their study, they exposed wheat seeds to varying levels of salinity (0, 50, 100, 150, and 200 mM NaCl) and measured the germination rate over time. They found that the germination rate decreased significantly at higher salinity levels, with the most significant decrease occurring at 200 mM NaCl. Similarly, Quamruzzaman et al., 2021 found that wheat seed germination rates decreased as salinity levels increased. They exposed wheat seeds to different levels of salinity (0, 50, 100, 150, and 200 mM NaCl) and measured the germination rate over time. They found that the germination rate decreased significantly at salinity levels above 100 mM NaCl.

Table 4. Reduction of different salinity (EC) level on germination percentage in fifteen wheat genotypes

Genotype	6 dS/m	9 dS/m	12 dS/m (%)
BARI Gom 19	12.23 b	18.65 b	21.86 c
BARI Gom 20	12.33 a	18.82 b	25.32 a
BARI Gom 21	10.24 d	21.18 a	23.37 b
BARI Gom 22	9.02 h	12.23 h	16.51 i
BARI Gom 23	7.95 j	12.23 h	17.58 h
BARI Gom 24	7.86 jk	10.28 j	12.04 k
BARI Gom 25	7.477 k	9.88 j	10.96 l
BARI Gom 26	10.09 e	14.37 f	18.65 g
BARI Gom 27	10.24 d	15.71 d	21.18 d
BARI Gom 28	9.20 g	13.63 g	19.17 f
BARI Gom 29	8.90 i	11.00 i	13.09 j
BARI Gom 31	10.31 d	15.85 d	19.17 f
BARI Gom 32	11.69 c	17.43 c	19.72 e
BARI Gom 33	9.47 f	15.27 e	19.92 e
Binagom-1	7.95 j	11.16 i	13.08 j
P value	0.0000	0.0000	0.0000
CV	0.58	0.88	0.83

Different letters within each column denote significant differences ($p < 0.05$) between treatments.

Reduction of seedling tissue water content in salt stress

The reduction in the seedling tissue water content from the control treatment occurred in all the three levels of salinity viz. 6 dS/m, 9 dS/m and 12 dS/m. In 6 dS/m treatment, the highest reduction of seedling tissue water content was found in BARI Gom 28 (19.07) followed by BARI Gom 33, BARI Gom 23, BARI Gom 22, BARI Gom 21 and BARI Gom 20. These genotypes are statistically similar with each other but differed significantly from the other genotypes (Table 5). The least amount of reduction was found in the BARI Gom 25 (10.84 %). These results indicated that BARI Gom 25 was the most capable genotype that could retain water in their tissues in 6 dS/m while BARI Gom 28, BARI Gom 33, BARI Gom 23, BARI Gom 22, BARI Gom 21 and BARI Gom 20 were the least capable genotypes (Table 5).

In 9 dS/m treatment, the highest reduction of seedling tissue water content was found in BARI Gom 28 (30.31) followed by BARI Gom 26, BARI Gom 22, BARI Gom 21 and BARI Gom 20. These genotypes are statistically similar with each other but differed significantly from the other genotypes (Table 4.6). The least amount of reduction was found in the BARI Gom 25 (17.93 %). These results indicated that BARI Gom 25 was the most capable genotype that could retain water in their tissues in 9 dS/m while BARI Gom 28, BARI Gom 26, BARI Gom 22, BARI Gom 21 and BARI Gom 20 were the least capable genotypes (Table 5).

In 12 dS/m treatment, the highest reduction of seedling tissue water content was found in BARI Gom 21 (37.13 %) followed by BARI Gom 26, BARI Gom 23 and BARI Gom 20. These genotypes are statistically similar with each other but differed significantly from the other genotypes (Table 5). The least amount of reduction was found in the BARI Gom 25 (26.24 %). These results indicated that BARI Gom 25 was the most capable genotype that could retain water in their tissues in 12 dS/m while BARI Gom 21, BARI Gom 26, BARI Gom 23 and BARI Gom 20 were the least capable genotypes (Table 5).

Table 5. Reduction of different salinity (EC) level on seedling tissue water content in fifteen wheat genotypes

Genotype	6 dS/m (%)	9 dS/m (%)	12 dS/m (%)
BARI Gom 19	16.84 bc	27.75 c	34.70 c
BARI Gom 20	17.92 abc	29.01 abc	35.67 abc
BARI Gom 21	18.05 abc	29.28 abc	37.13 a
BARI Gom 22	18.14 ab	29.32 abc	34.96 bc
BARI Gom 23	18.19 ab	28.46 bc	36.36 ab
BARI Gom 24	13.03 e	23.47 de	28.02 f
BARI Gom 25	10.84 f	17.93 f	26.24 g
BARI Gom 26	18.03 abc	30.04 ab	36.70 a
BARI Gom 27	17.78 abc	28.89 abc	34.44 c
BARI Gom 28	19.07 a	30.31 a	34.81 c
BARI Gom 29	13.47 e	23.28 e	31.34 de
BARI Gom 31	13.82 e	25.12 d	32.33 d
BARI Gom 32	16.20 cd	24.48 de	31.86 d
BARI Gom 33	18.20 ab	28.24 c	34.24 c
Binagom-1	14.44 de	23.06 e	29.94 e
P value	0.0000	0.0000	0.0000
CV	6.98	3.79	2.76

Different letters within each column denote significant differences ($p < 0.05$) between treatments.

Different levels of salinity have been reported to affect seedling tissue water content in various plant species. For example, In a study conducted by (Ullah et al., 2022) on wheat (Triticum aestivum L.) seedlings, it was found that increasing salinity levels reduced the tissue water content in both shoot and root tissues. The authors reported that at the highest salinity level (200 mM NaCl), the tissue water content in shoots and roots decreased by 20% and 40%, respectively. In another study, Sengupta and Majumder, (2009) investigated the effect of salinity on rice (Oryza sativa L.) seedlings. The authors reported that increasing salinity levels resulted in a significant decrease in tissue water content in both shoot and root tissues. At the highest salinity level (150 mM NaCl), the tissue water content in shoots and roots decreased by 34% and 39%, respectively. Similarly, in a study conducted by Rasheed et al., (2022) on maize (*Zea mays* L.) seedlings, it was found that increasing salinity levels resulted in a significant reduction in tissue water content in both shoot and root tissues. At the highest salinity level (150 mM NaCl), the tissue water content in shoots and roots decreased by 25% and 29%, respectively.

Reduction of seedling vigour index in salt stress

The reduction in the seedling vigour index from the control treatment occurred in all the three levels of salinity viz. 6 dS/m, 9 dS/m and 12 dS/m. In 6 dS/m treatment, the highest reduction of seedling vigour index was found in BARI Gom 28 (18.47 %) followed by BARI Gom 23 (17.12 %) (Table 6). The least amount of reduction was found in the BARI Gom 25 (8.71 %). These results indicated that BARI Gom 25 had the most vigorous seedling in 6 dS/m while BARI Gom 28 and BARI Gom 23 were the least vigorous genotypes (Table 6).

In 9 dS/m treatment, the highest reduction of seedling vigour index was found in BARI Gom 23 (32.53 %) followed by BARI Gom 26 (30.94 %) (Table 6). The least amount of reduction was found in the BARI Gom 25 (17.84 %). These results indicated that BARI Gom 25 had the most vigorous seedling in 9 dS/m while BARI Gom 23 and BARI Gom 26 were the least vigorous genotypes (Table 6).

In 12 dS/m treatment, the highest reduction of seedling vigour index was found in BARI Gom 27 (39.64 %) followed by BARI Gom 26 (38.49 %) (Table 6). The least amount of reduction was found in the BARI Gom 25 (30.29 %). These results indicated that BARI Gom 25 had the most vigorous seedling in 12 dS/m while BARI Gom 23 and BARI Gom 26 were the least vigorous genotypes (Table 6).

Table 6. Reduction of different salinity (EC) level on seedling vigour index in fifteen wheat genotypes

Genotype	6 dS/m (%)	9 dS/m (%)	12 dS/m (%)
BARI Gom 19	13.37 h	25.03 f	35.68 e
BARI Gom 20	13.87 g	25.99 e	37.05 d
BARI Gom 21	12.34 i	18.81 i	34.56 g
BARI Gom 22	14.41 f	23.98 g	38.54 b
BARI Gom 23	17.12 b	32.53 a	37.93 c
BARI Gom 24	9.30 k	18.25 j	33.58 h
BARI Gom 25	8.71 l	17.84 k	30.29 i
BARI Gom 26	15.95 c	30.94 b	38.49 b
BARI Gom 27	15.67 d	30.37 c	39.64 a
BARI Gom 28	18.47 a	27.02 d	38.54 b
BARI Gom 29	11.50 j	21.61 h	34.40 f
BARI Gom 31	13.37 h	21.36 h	35.68 e
BARI Gom 32	13.37 h	25.03 f	35.68 e
BARI Gom 33	13.37 h	25.03 f	35.68 e
Binagom-1	14.87 e	24.09 g	34.34 f
P value	0.0000	0.0000	0.0000
CV	1.06	0.84	0.59

Different letters within each column denote significant differences ($p< 0.05$) between treatments.

Table 7. Tolerance index sorted in discending order for 15 wheat genotypes

Genotypes	Tolerance index
BARI Gom 25	12.00
BARI Gom 24	11.62
BARI Gom 29	11.11
Binagom-1	11.04
BARI Gom 23	10.20
BARI Gom 19	10.18
BARI Gom 22	10.13
BARI Gom 31	10.13
BARI Gom 26	9.94
BARI Gom 21	9.93
BARI Gom 20	9.88
BARI Gom 27	9.87
BARI Gom 32	9.83
BARI Gom 33	9.80
BARI Gom 28	9.77

According to Hussain et al. (2018), it was found that increasing salinity levels had a significant negative impact on the seedling vigor of wheat. The authors reported that at the highest salinity level (150 mM NaCl), the seedling vigor index decreased by 50% compared to the control. Similarly, in a study by (Ashraf and Bashir, 2003), it was found that increasing salinity levels had a significant negative impact on the seedling vigor of wheat. The authors reported that at the highest salinity level (200 mM NaCl), the seedling vigor index decreased by 65% compared to the control. In another study, conducted by Koo et al., (2021), it was found that increasing salinity levels had a significant negative impact on the root growth and development of wheat seedlings, which in turn affected seedling vigor. The authors reported that at the highest salinity level (100 mM NaCl), the root growth was reduced by 60% compared to the control, and this reduction in root growth was correlated with a decrease in seedling vigor. Overall, these studies

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suggest that increasing salinity levels have a negative impact on the seedling vigor of wheat, which could affect the overall growth and development of the crop.

Stress tolerance index

Stress tolerance index ranked the genotypes based on their performance in different germination related characteristic in different levels of salinity. It was found that BARI gom 25 had the highest tolerance index (12.00) followed by BARI Gom 24, BARI Gom 29 and Binagom-1. So, based on the results of this study, BARI Gom 25 was found as the best genotype that can cope with the negative effects of salinity. Similarly, BARI Gom 24, BARI Gom 29 and Binagom-1 were also found to be tolerant to different levels of salinity while considering the germination related characteristics. However, BARI Gom 26, BARI Gom 21, BARI Gom 20, BARI Gom 27, BARI Gom 32, BARI Gom 33 and BARI Gom 28 were the least performing genotypes in this regard (Table 7).

CONCLUSION

As a result of the screening experiments, four genotypes were revealed as salt tolerance viz. BARI Gom 24, BARI Gom 25, BARI Gom 29, Binagom-1. So, it can be recommended that these varities can be used as superior genotypes for getting more production in the coastal saline regions as well as future breeding programme of salinity tolerant wheat in Bangladesh.

Conflict of Interest

There are no conflicts of interest declared by the authors.

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