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Development of Rice Varieties for Stress-Prone Tidal Ecosystem of Bangladesh

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Abstract: Evaluation of rice genotypes for stability and high yielding is crucial for maintaining rice production and ensuring food security. These evaluations are crucial, especially when the breeding program's goal is to choose lines with high adaptability and consistency. This research looked at how G and E interacted in 10 different contexts. Multi environment trials (MET) data were studied using the genotype of GGE main effect (G) and genotype by environment interaction (GE) biplot graphical tool. A two-dimensional GGE biplot was created using the first 2 main components (IPC1 and IPC2), which were utilized to account for percentages of 81.6% and 11.9%, respectively, of the square sums of the GE interaction. A joint ANOVA analysis of the grain yield data identified highly significant ($P < 0.01$) changes among all sources of variation. Environmental (E), genotypic (G) and G X E interactions accounted for 44.98, 34.42 and 17.48% of the total squares, respectively. Average tester opinion showed that genotype G2 had the highest average yield and genotype G1 had the highest stability. Of the nine environments, E4 and E7 were the most demanding (beneficial), while E6 and E9 were the brightest. G1 and G2 can be tailored to different environments in southern Bangladesh. GGE biplots suggested the presence of environments with G2 and G1 genotypes called BRRI dhan76 and BRRI dhan77, respectively. The ideal genotype biplots, rendering to genotypes G1 and G2, are the better genotypes, representing high average yields and high performance stability across test sites.

Key words: GGE · Multi-Environments · Genotype by Environment Interaction · Stability · Tidal Submergence · Rice (*Oryza sativa* L.)

INTRODUCTION

Rice (*Oryza sativa* L.) is the life of more than half of the human population on earth. It is the most important cereal grain that has received the most attention from experts on plant breeding and its production is rice (source). However, the yield of rice is low (< t/ha) and cannot meet the local demand. Yield gaps are due to various constraints such as flooding, sea level rise (SLR) and severe storm surges [1-3]. Bangladesh is the largest delta region on earth and its environment and climate provide fertile land for agricultural production. Nevertheless, its production is inadequate due to unfavorable environmental conditions. However, the country is also prone to flooding, sea level rise (SLR) and severe storm surge events. It is also a rich treasure trove of native rice and other native species. With the advent of high-yielding fertilizer-accepting varieties and the short-lived change in modern rice, farmers slowly abandoned domestic cultivation and native species have disappeared,

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leaving those that survived vulnerable. Conventional rice cultivation by farmers has been practiced only in areas where the agro ecological situation is not optimistic for high-yield cultivation. The most common rain-fed rice cultivars are large, long-lived, photoperiod-sensitive and have low yield potential. Barguna, Pirodipur, which cover the flood plains of the Jalakati tidal flats and a considerable part of the Southern Delta region, farmers in the adjoining areas of Patuakali district habitually grow rain-fed rice varieties. The area is close to the sea and inland estuaries, with high tides. The country is subject to seasonal flooding, which floods from July to October. Twice-daily high and low tides are characteristic of the Ganges floodplain ecosystem. Tidal floodplains form an important agro ecological zone covering large areas of the south-central coastal region of Bangladesh [4].

Genotypic selection based on yield assessment in multiple environments is an important step in cultivar development [5-7]. The efficiency of selecting superior genotypes is affected by differences in the response of test genotypes in the target test environment, called the genotype-environment interaction (GEI). Therefore, genotype evaluation in Multi-Environment Trials (MET) is critical to properly identify and grade candidate genotypes to identify high-yielding and stable genotypes for breeding or cultivar recommendations. Multi-environmental testing (MET) has shown that the yield stability and performance of genetic material can be estimated under changing environmental conditions [8-12]. Mature genotypes in different environments often show significant differences in yield performance. These variations are influenced by different environmental conditions and are called environment-induced genotypic (GE) interactions [13, 14]. Nevertheless, GE interactions reduce genetic progress in plant breeding programs by reducing the link between genotypic and phenotypic values [15, 16]. Therefore, GE interactions must also be exploited by selecting better genotypes for each precise objective environment. Alternatively, it should be avoided by selecting genotypes that are successfully adapted and contiguous across different environments [17-20]. Different methodologies like coefficient relapse [21], amount of squared deviations relapse [22], change in security [23], target coefficient [24], coefficient of variety [25] as well as moderate fundamental impacts and multiplicative collaborations (AMMI) [26-28] have frequently been utilized to notice the information TEM to uncover examples of GE cooperation's. Yan *et al.* [10] gave one more technique known as GGE Biplot in GE Graphical Cooperation Model to picture MET information with many benefits. The GGE biplot as an information imaging gadget can obviously show the GE communication pattern. It is a powerful instrument for distinguishing mega habitats, yield-based genotype evaluation, steadiness and appraisal of test conditions for separation. The point of this review was to measure genotype by the impact of natural collaboration utilizing the GGE biplot to evaluate the impact of the degree of GE connection on the five wheat yield genotypes tried at nine destinations to choose the best genotypes for sore restriction and decide genotype yield and steadiness, recognize mega habitats and examine ideal genotypes and conditions for rice creation in southern piece of Bangladesh.

MATERIALS AND METHODS

Plant Materials: A total of five genotypes consisting of two advanced lines BR7941-116-1-2-1 (G1) and BR7961-41-2-2-2-4 (G2) and three checks varieties Sadamota (L. ck.) (G3), Dudhkolom (L. ck.) (G4) and BRRI dhan44 (S. ck.) (G5) were used as experimental materials (Table 1). And Test Sites Study Sites Field trials were conducted at nine selected sites in Bangladesh. These experiments were performed to study GE interactions on grain yield. At 9 locations: Amtali, Barguna (E1), Bakergang, Barishal (E2), Dumki, Patuakhali (E3), Kawkhali, Pirojpur (E4), Kolapara, Patuakhali (E5), Nolcity, Jhalokati (E6), Patharghata, Barguna Enforcement (E7), Sadar, Pirojpur (E8), Zianagar and Pirojpur (E9) represent nine different environments in the Barisal region during the 2015-16 rainy season (Table 2).

Field Experiment and Experimental Design: This experiment was conducted in the Tidal ecosystem. Experiments at each site were performed in a three-replicate randomized complete block (RCBD) design. Each genotype was planted in a plot consisting of rows. The line was 6m long. Seeds were planted m apart in a single row. Were the seeds planted hill by hill and plant two weeks after germination. 40-45 day old seedlings were grown in plot sizes of 6.0 m x 5.0 m using 3-4 seedlings per hill while maintaining 20 cm x 20 cm spacing. Mineral fertilization was carried out according to the required standards. He applied urea at three equal intervals of 15 DAT, 30 DAT and 45 DAT depending on the time of low/no water in the field. TSP, MP and gypsum fertilizer doses were applied at 171.81.67.23:97.11: 59.76: kg/ha urea, TSP, MP or gypsum [29]. All fertilizers except urea were suitable as basal doses as well as urea.

Table 1: Location and season of the trials for high yielding wet season rice lines in Bangladesh

Sl. No.	Code	Location	Season
1	E1	Amtali, Barguna	Wet Season
2	E2	Bakergang, Barishal	Wet Season
3	E3	Dumki, Patuakhali	Wet Season
4	E4	Kawkhali, Pirojpur	Wet Season
5	E5	Kolapara, Patuakhali	Wet Season
6	E6	Nolcity, Jhalokati	Wet Season
7	E7	Patharghata, Barguna	Wet Season
8	E8	Sadar, Pirojpur	Wet Season
9	E9	Zianagar, Pirojpur	Wet Season

Table 2: Advanced breeding lines for GGE study, Bangladesh, Wet season

Sl.No.	Code	Genotype	Parentage	Remarks
1	G1	BR7941-116-1-2-1	IR75862-208-8-B-B-HR1/BR6110-10-1-2	BRRI lines
2	G2	BR7961-41-2-2-2-4	IR75862-208-8-B-B-HR1/BR6110-10-1-2	BRRI lines
3	G3	Sadamota (L. ck.)	Local Traditional Genotype	Local Check
4	G4	Dudhkolom (L. ck.)	Local Traditional Genotype	Local Check
5	G5	BRRI dhan44 (S. ck.)	BR10/BRRI dhan31	BRRI Vatiety

BRRI: Bangladesh Rice Research Institute

In accordance with BRRI recommendations, regular agricultural practices were followed and phytosanitary measures were essential. Two rows of fringes were used to reduce the fringing effect. The data (tha-1) collected for grain yield data collection was 14% moisture. Harvested seed yields were determined for each genotype in each test environment and averages were calculated according to the experimental design. Grain yield was calculated using the following formula:

Statistical Analysis: Grain yield data from five genotypes use Star version 2.0.1 statistical analysis package software (developed by IRRI) to test the significance of G×E interactions prior to subsequent analysis. It was subjected to a combined analysis of variance with the RCBD method. The GGE Biplot software [30] was used to display the analyzed data and derive GE interactions. His MET data for the rice genotypes investigated were visualized using the GGE biplot method, which consists of two concepts: the biplot concept [31] and the GGE concept [10] bottom. In this method, biplots were used to indicate factors (G and GE) that are important in genotyping and also various sources of GE-interacting MET data analysis [30]. This experimental chart represents I) environmental assessment based on judgement, not just representativeness. II) genotypic performance in the correct environment. III) Relative ranking of genotypes to ideal genotypes. IV) GGE biplot MET data analysis polygon view.

RESULTS AND DISCUSSION

Genotype, Environment and Genotype x Environment Effects Combined Analysis of Variance: The combined analysis of variance for grain yield is presented in Table 3. The effects of genotype, environment and genotype-environment interaction were significant for grain yield ($p<0.001$). The pooled ANOVA results of the wheat yield data showed that the interaction effects of genotype (G), environment (E) and GxE were 44.98, 34.42 or 17.48% of the sum of squares (Table 1). Significant changes for all sources of variation resulted in environmental effects on GE interaction, genetic variability between genotypes and stable genotype selection. There are many reports of GxE interaction analysis of rice yield data from multiple sites using the Eberhart and Russell [22] model. In all these studies, the GxE interaction was significant, indicating differential response of genotypes to environmental changes, with some genotypes showing stable performance in different environments, while many others showed unstable performance due to high GxE interaction. Therefore, highly significant G×E effects suggest careful selection of genotypes to be appropriate for specific environments. This is consistent with the results of Aina *et al.* [31 and Xu Fei-fei *et al.* [32] on the effects of cassava genotypes on the G × E interaction significant effects of the genotype-environment interaction showed that the genotypes responded inappropriately to changes in

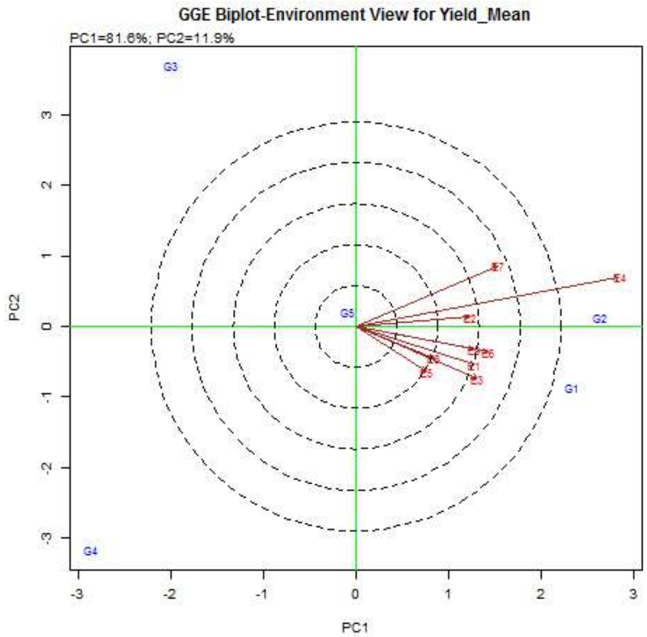

Fig. 1: GGE biplots of the combined analysis for grain yield grain yield (tha-1) of 5 rice genotypes (G) and nine environments (E) using genotypic and environmental scores.

Table 3: Combined Analysis of Varience (ANOVA) for grain yield data of five genotypes on nine environment

Source	DF	Sum of Square	Mean Square	% SST
Genotype (G)	4	53.05	13.26***	34.42
Enviroment (E)	8	69.32	8.66***	44.98
G:E	32	26.95	0.84***	17.48
Pooled Error	72	3.87	0.05	
Total	134	154.12		

*** indicates 1% level of significant

environmental conditions at the site. This demonstrates the need to test rice mutations at multiple sites. This also confirms the problems breeders have had when selecting new variants for release. A large sum of squares for the genotypes showed that the genotypes varied, with large variations between genotype means causing the largest variations in grain yield, consistent with the results of Das *et al*. [33] and Fentie *et al*. [34] in rice production.

Relationship among environments Figure 1 show the relationship among environments. The lines that connect the biplot origin and the markers for the environments are environment vectors and the angle between the vectors of two environments is relatedto the correlation coefficient.

Evaluation of Environment Based on Discrimination & Representativeness: A longer vector indicates a locus where there is a broader range of genotypic performance, i.e. H. a larger vector is more discriminatory (more informative). Therefore, of the nine environments, E4 and E7 were the most demanding (informative) and E8 and E5 the least discriminatory (Figure 4). Fairly non-discriminatory (non-informative) test beds provide little information about genotypes and should therefore not be used as test beds. The cosine of the angle between the two environments is proportional to their correlation coefficient. If two rooms form an angle < 90° environments are positively correlated. If the angle is > 90°, the rooms are negatively correlated. The expected yield of a biplot, given explicitly for each combination of genotype and environment, can be calculated from Figure 1 according to Gauch *et al.* [35] proposed standard procedure. Similar results were reported by Das *et al.* [33] and Kulsum *et al.* [36]. They suggest that the interaction of the 12 rice genotypes with the four environments was predicted by the first three genotypes and environment components, consistent with the confirmation of Sivapalan *et al.* [37].

The default environment (indicated by the circle at the end of the arrow) contains the average settings of all test environments and the Average Environment Axis (AEA) is the line through the average environment and the start of the biplot. A test environment at a slight angle to the AEA best illustrates other test environments. Therefore, E6 and E9 are the most representative, while E5 and E7 are the least illustrative. Test environments that are both challenging and representative (e.g., E6) are good test environments for the selection of generally altered

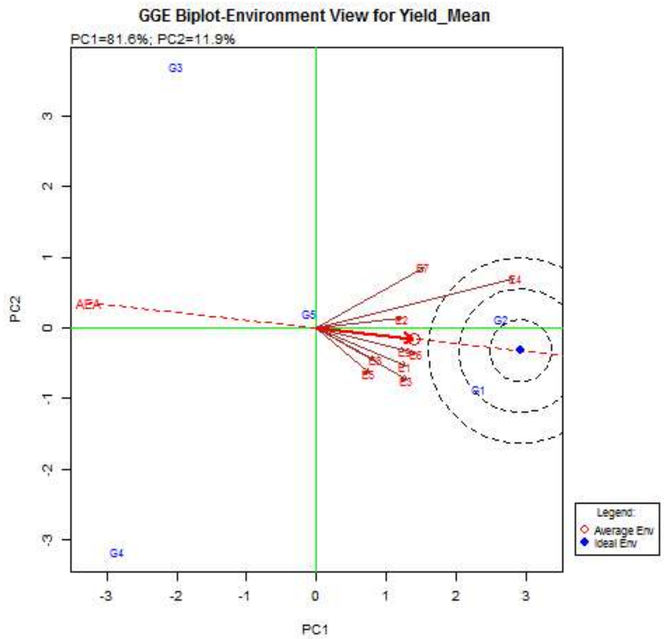

Fig. 2: Different genotypes in a given Mean performance and stability of 5 rice genotypes (G) in nine environments (E)

genotypes. Selective but non-representative test environments (e.g. E4 and E7) are useful for selecting refined genotypes when the target environments can be subdivided into mega-environments. Demanding but unrepresentative test environments (e.g. E4) are useful to reject unstable genotypes when the target environment is a single mega environment. Non-discriminatory testing environments (those with very short courses such as E5 and E8) are less useful as they provide insufficiently detailed information about genotypes. Adugna *et al.* [38] and Anandan *et al.* [39] reported a similar interaction pattern.

Performance of Genotypes in Specific Environment: The line through the biplot origin, defined by the average PC1 and PC2 values for all environments, is called the mean environment coordinate (AEC). The performance of a genotype in the environment is above average if the angle between its vector and the environment vector is < 90 > 90°. It is close to the mean when the angle is around 90°. Because of this, the G1 genotype performs better in all environments except E7 and the G2 genotype performs better in all environments, while the G3, G4 and G5 genotypes perform poorly but have good stability. In the GGE biplot methodology, the estimation of trait performance and genotype stability was performed using the mean environmental coordinates (AEC) method [22, 33].

Ranking of Genotypes Relative to Ideal Genotype: The ideal genotype should have both a high average yield and high stability in different environments. The ideal genotype is a dot on the positive side of the AEA whose vector length is equal to the vector length of the longest genotype on the positive side. The further away from the origin the projection of the genotype on the positive side of the AEA is, the greater its GGE effect. The further the genotype is from the AEA axis, the more unstable it is. The ranking of the genotypes results from the genotype table of the so-called "ideal" genotype (Fig. 3). The ideal genotype is defined as the one that performs best in test environments and is also categorically stable in performance (first place in all test environments) [40, 41]. Although such an "ideal" genotype does not exist in reality, it can be used as a reference for genotyping [20]. The genotype is needed more when it is closer to the "ideal" genotype [19, 20]. The closest to the "ideal" genotype were both G1 and G2. The classification of further genotypes based on the ideal genotype is G5 > G3 > G4. In other words, the underperforming genotypes (G3, G4 and G5) were far from the ideal genotype. The relative contribution of stability and grain yield to identifying the desired genotype found in this study using the GGE biplot ideal genotype process is similar to that found in other crop stability studies [32, 43]. An interesting application of the GGE biplot is the assessment of genotypes that qualify as ideal genotypes. The ideal genotype, which comes closest to the genotype,

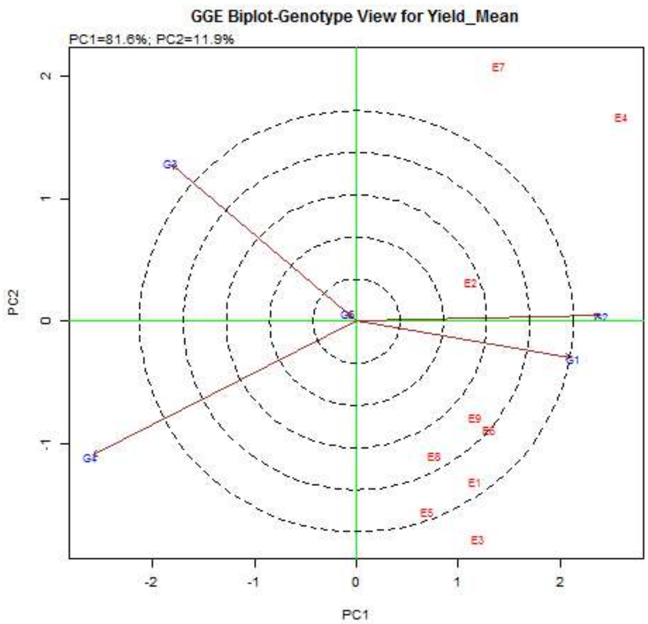

Fig. 3: Ranking of environments based on the performance of highest yielding genotype

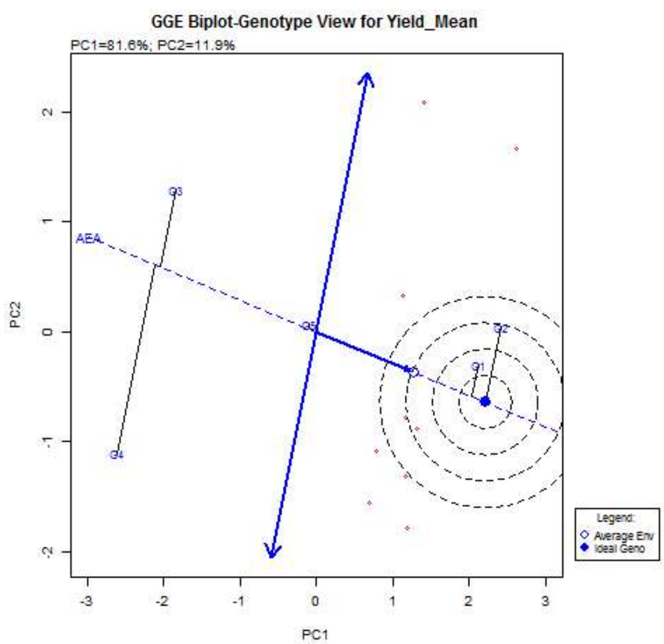

Fig. 4: GGE biplot based on genotype - focused scaling for comparison. Ranking of genotypes based on mean and stability

is one that has both high average performances of this specific trait in test environments and fully stable performance [11, 44]. A genotype is more desirable if it is closer to the "ideal genotype" [19, 20].

Polygon View of GGE Biplot Analysis of MET Data: The average seedling height, which is a very important factor for the survival of rice in the unsalted tidal ecosystem, of all advanced lines tested ranged from 54 to 56 cm, which was longer than the BRRI control variety dhan44 (38 cm) (Table 4). The seedling height of lines BR7941-116-1-2-1 was 56 cm and BR7941-41-2-2-2-4 was 54 cm, which was very similar to the seedlings of espalier varieties Sadamota (66 cm) and Dudkalam (66 cm) a seedling of about 45 days, which in this experiment was similar to the plant height of BR7941-116-1-2-1 and

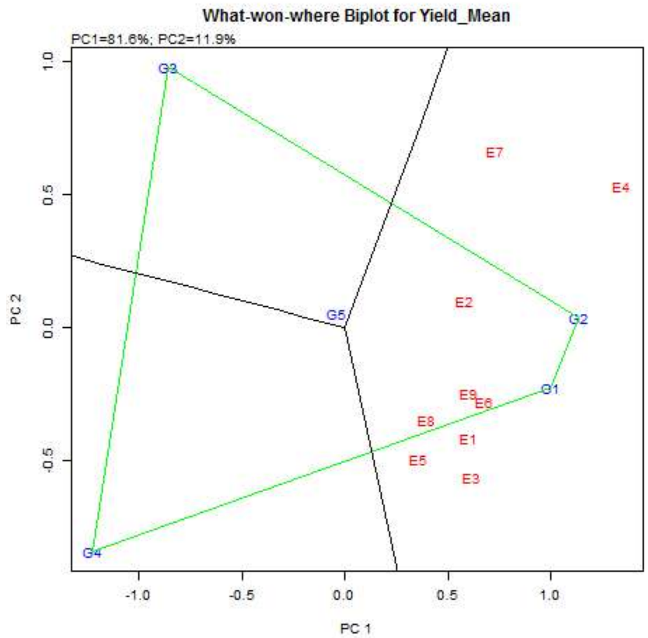

Fig. 5: Polygon view of genotype - environment interaction for rice advance lines over nine test environment.

Table 4: Performance (Seedling Height, cm) of the advance lines in proposed variety trial (PVT) for the development of varieties for tidal submergence tolerant

Designation	E1	E2	E3	E4	E5	E6	E7	E8	E9	Ave.
BR7941-116-1-2-1	58	63	53	58	56	53	53	58	52	56
BR7961-41-2-2-2-4	55	56	56	54	55	56	49	55	46	54
Sadamota (L. ck.)	56	82	76	57	59	76	68	56	63	66
Dudhkolom (L. ck.)	58	84	72	58	56	70	71	57	65	66
BRRI dhan44 (S. ck.)	37	47	39	38	36	38	37	36	35	38
CV	5.26	9.29	6.07	6.00	5.30	6.74	3.07	6.53	6.44	
LSD (5%)	2.27	5.05	2.94	2.59	2.76	3.23	1.39	2.80	2.75	

Table 5: Performance (Plant Height, cm) of the advance lines in proposed variety trial (PVT) for the development of varieties for tidal submergence tolerant

Designation	E1	E2	E3	E4	E5	E6	E7	E8	E9	Ave.
BR7941-116-1-2-1	135	120	150	114	136	136	148	124	131	133
BR7961-41-2-2-2-4	135	127	148	120	130	135	148	131	133	134
Sadamota (L. ck.)	149	132	148	135	146	140	157	149	145	145
Dudhkolom (L. ck.)	144	137	141	133	145	140	146	144	136	140
BRRI dhan44 (S. ck.)	121	103	131	103	110	113	110	116	102	112
CV	1.98	1.77	3.50	3.77	1.42	3.39	1.80	2.40	1.38	
LSD (5%)	2.21	1.79	4.14	3.72	1.54	3.67	2.09	2.61	1.46	

Table 6: Performance (Yield, t/ha) of the advance lines in proposed variety trial (PVT) for the development of varieties for tidal submergence tolerant

Designation	E1	E2	E3	E4	E5	E6	E7	E8	E9	Ave.
BR7941-116-1-2-1	4.76	5.00	6.11	5.57	4.65	6.14	4.76	4.02	4.07	5.01
BR7961-41-2-2-2-4	5.12	4.93	6.40	5.70	3.75	6.14	5.13	3.64	4.52	5.04
Sadamota (L. ck.)	2.95	4.11	4.12	3.92	2.80	4.44	4.81	2.65	2.80	3.62
Dudhkolom (L. ck.)	4.02	3.50	5.35	2.38	3.68	4.75	2.60	3.07	3.10	3.61
BRRI dhan44 (S. ck.)	4.79	4.66	5.38	3.75	3.56	5.74	4.68	3.07	3.27	4.32
CV	4.98	4.34	4.77	6.57	9.36	3.87	4.51	5.30	4.05	
LSD (5%)	0.18	0.16	0.21	0.23	0.28	0.17	0.16	0.14	0.12	

Table 7: Performance of the advance lines in proposed variety trial (PVT) for the development of varieties for tidal submergence tolerant

Designation	Growth duration (days)	Seedling height (cm)	Plant height (cm)	Grain yield (t/ha)
BR7941-116-1-2-1	154	56	133	5.01
BR7961-41-2-2-2-4	163	54	134	5.04
Sadamota (L. ck.)	173	66	145	3.62
Dudhkolom (L. ck.)	155	66	140	3.61
BRRI dhan44 (S. ck.)	160	38	112	4.32
CV	2.06	9.56	4.17	12.42
LSD (5%)	3.1	5.3	5.1	0.5

BR7941-41-2-2-2-4 133 cm and 134 cm, respectively, while the bars were 145 cm, 140 cm and 112 cm for Sadamot, Dudkolom and BRRI dhan44, respectively (Table 5). The mean growth time of the studied advanced lines BR7941-116-1-2-1 was 154 days and BR7941-41-2-2-2-4 163 days, for Dudkalam 155 days, for BRRI dhan 160 days44 and 173 days for Sadamota (Table 7). Although, it depends on the tidal pressure of the season.

CONCLUSION

This current study revealed that the GGE biplot endorses the existence of environments with winning genotypes G2 and G1, termed BRRI dhan76 and BRRI dhan77, respectively. According to the ideal genotype biplot, both G1 and G2 genotypes are the superior genotypes, showing high average yield and high performance stability across test sites. Average tester views showed that genotype G2 had the highest average yield and genotype G1 scored the highest stability. Among the nine environments, E4 and E7 were the most discriminatory (beneficial) and E6 and E9 were the most representative. Both G1 and G2 are flexible enough to accommodate different environments in southern Bangladesh.

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