



## ADOPTION AND ADAPTABILITY OF MODERN AMAN RICE CULTIVARS IN FARIDPUR REGION - BANGLADESH

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### SUMMARY

Rice is not just a staple food; but it is at the center of culture, politics, and economy of Bangladesh. The determinants affecting the adoption of modern rice cultivars and their adaptability in the *Aman* season (June to November) at the Faridpur region in Bangladesh were discussed. A total of 500 farmers from five different districts such as, Faridpur, Madaripur, Shariatpur, Rajbari, and Gopalganj through multistage sampling technique participated in the survey. Before the survey, 15 farmers were selected for the cultivation of eight modern *T. Aman* rice cultivars in their fields during three consecutive years 2018 to 2020 in the mentioned five districts of Bangladesh. A structured questionnaire was used to identify the determinants associated with the adoption of modern rice cultivars by replacing the popular old ones. Results revealed that beyond preferences, some other determinants (age, education, risk aversion, land size, yield, and perception of modern rice cultivars and their seed availability) directed the decision to adopt or not. Considering the average grain yield of the tested rice cultivars, the genotypes BRRi dhan72 (G-6) and BRRi dhan87 (G-8) were the high yielding cultivars for the above five districts. Despite having a comparatively low yield, the cultivars BRRi dhan71 (G-4) and BRRi dhan49 (G-3) were more stable compared to other cultivars in the Faridpur region of Bangladesh.

**Keywords:** Adoption, adaptability, heritability, GGE, *Aman* rice

**Key findings:** Beyond yield superiority, other important factors, i.e., demographics, risk averted mind of farmers, input availability, varietal characteristics, and cultivars adaptation also determine that whether the cultivar is adopted or not. In the Faridpur region - Bangladesh, the rice cultivars BRRi dhan72 and BRRi dhan87 were preferred due to their yield superiority despite their low adaptability. However, in the context of adaptability and stability, rice genotypes BRRi dhan49 and BRRi dhan71 were found more stable for the *Aman* season.

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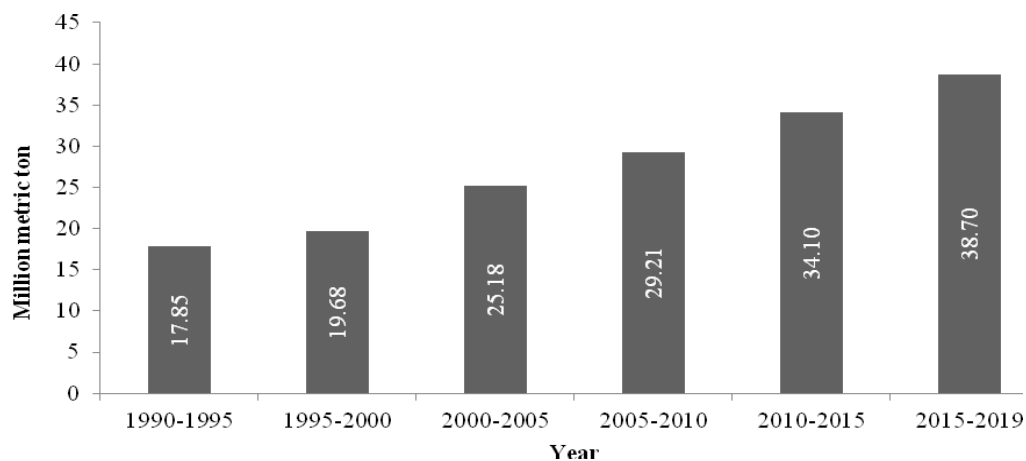
## INTRODUCTION

Rice growing area is about 10.5 million hectares (ha) and 13 million farming families are growing rice in Bangladesh (Hasan, 2015). Bangladesh has produced 38.70 million tons during 2019 (Figure 1) and secured the third position among the rice producing countries (USDA 2021; The Daily Star, Friday, November 5, 2021). The country's rice requirement was about 27.26 million tons during 2020 (Khatun *et al.*, 2020). However, the population is increasing at an alarming position, and net cultivable land for rice crop will be assumed at 7.9 million ha which is not sufficient to meet the ever-increasing demand in Bangladesh (Rahman, 2018; Sayeed and Yunus, 2018). Therefore, the vertical improvement through increased yield and varietal replacement by developing high-yielding modern rice cultivars is the only way to combat the issue.

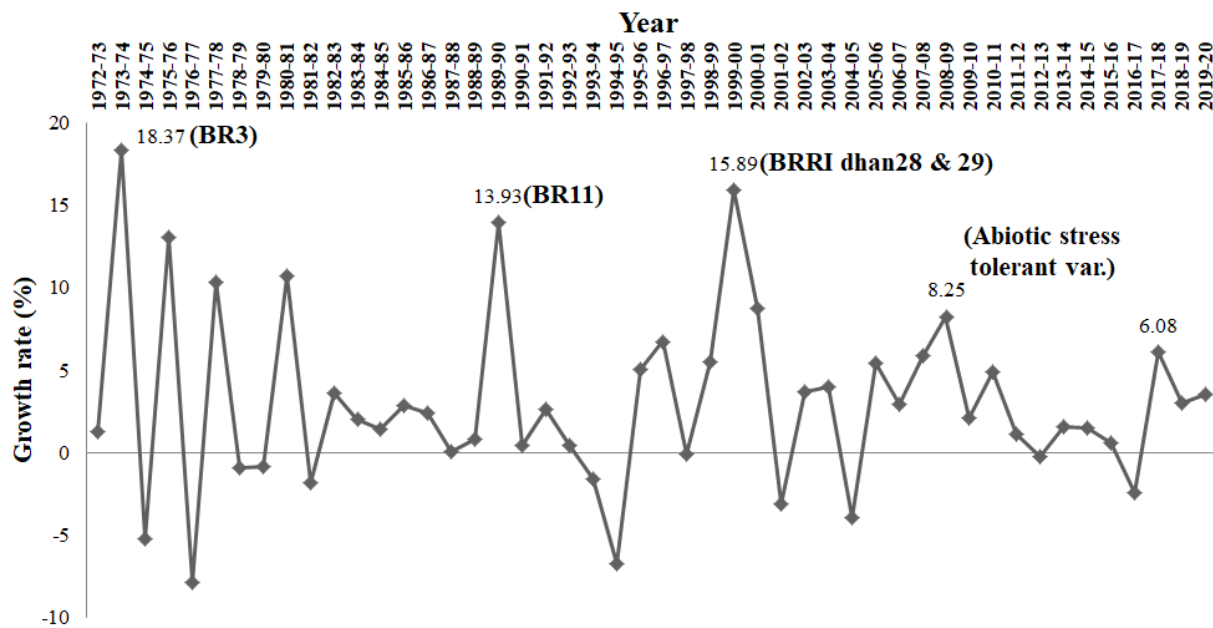
The Bangladesh Rice Research Institute (BRRI) has developed 106 rice cultivars since its inception in 1970. After its establishment, the rice cultivar BR3 accelerated the rice growth rate of 18.37% during 1973 to 1974. By adopting the elite rice cultivar BR11 in the *Aman* season, rice growth rate reached 13.93% in 1989 to 90. The popular two rice cultivars BRRI dhan28 and BRRI dhan29 in the *Boro* season contributed to the growth

rate of 15.89% during 1990 to 2000 (Figure 2) (BBS, 2020)

To narrow the adoption time of modern rice cultivars, the Department of Agricultural Extension (DAE) played an important role through different demonstrations and farmer's training (Chowdhury *et al.*, 2014). To ensure sustainable food security and double the productivity before 2030, the development of region-specific modern rice cultivars is running so fast. Therefore, a large number of rice cultivars are available to extension personnel and farmers that make a dilemma for adoption (Singh *et al.*, 2020). Regarding this, instead of a single varietal demonstration, a head-to-head demonstration would be the solution. By using head-to-head demonstration, farmers can get the chance to choose the superior cultivars considering grain yield, growth duration, and grain quality. The head-to-head demonstration concept was originated at BRRI through the transforming rice breeding (TRB) project. Here the first 'head' means popular aged cultivar which is covered a large area in the specific region, e.g., BRRI dhan39 is a popular cultivar in Faridpur region which is relayed with jute and covered a larger area in the *Aman* season. The last 'head' represents the targeted (new) cultivar which can replace the popular one by farmer's own choice.



**Figure 1.** The phenomenon of rice production from 1990-1995 to 2015-2019.



**Figure 2.** The year-wise growth rate of rice production in Bangladesh shows the growth rate increase in % with the advent of few milestone rice cultivars (BR3, BR11, BRRi dhan28, BRRi dhan29 and abiotic stress tolerant varieties).

For cultivar development, the greater adaptation of rice cultivar with minimum genotype-environment interaction has attained more importance rather than yield superiority (Tiongco and Hossain, 2015; Walker *et al.*, 2015). By exploring the grain yield stability in different areas, it would be possible to select suitable and well-adaptive cultivars in specific regions which can mitigate the problem. By the supervision of BRRi Regional Station in Bhanga, Faridpur, the studies were conducted during three consecutive years of 2018, 2019, and 2020 each in the five districts, i.e., Faridpur, Madaripur, Shariatpur, Rajbari, and Gopalganj to determine: a) the causes for time to adoption of modern rice cultivars, b) the suitable, stable, and well-adapted rice cultivar to replace the popular aged cultivars, and c) the enhancement in rice productivity in Faridpur region of Bangladesh.

## MATERIALS AND METHODS

### Study area

The multi-location study was conducted during three consecutive years of 2018 to 2020 at five different upazilas of five districts namely, Sadar upazila, Faridpur; Rajoir upazila, Madaripur; Zajira upazila, Shariatpur; Sadar upazila, Rajbari; Muksudpur upazila, Gopalganj and were denoted as E1, E2, E3, E4, and E5, respectively. These areas belong to different agro-ecological zones (AEZ), i.e., AEZ - 12 (Lower Ganges River Floodplain), AEZ - 14 (Gopalganj-Khulna Bills), and AEZ - 19 (Old Meghna Estuarine Floodplain) (Brammer, 2017).

### Study materials and design

In *Aman* 2018, six modern rice cultivars (BRRi dhan49, BRRi dhan71, BRRi

dhan72, BRR1 dhan75, BRR1 dhan80, and BRR1 dhan87) along with two check cultivars (BRR1 dhan39 and BINA dhan-7) were evaluated in a randomized complete block design (RCBD) with three replications (three dispersed locations in one upazila considered as three replications) at five different upazila. After harvesting, around 100 farmers attended participatory cultivar selection (Louwaars) each at five study sites to provide the ranking among these rice cultivars considering grain yield, growth duration, and grain quality. The response of each farmer was recorded and was provided each with 5 kg seed of ranked one rice cultivar for cultivating in next season. Then the farmers were evaluated whether they cultivated these genotypes or not. During the next season, the evaluated farmers were screened based on the same criteria and identified the prime causes behind the adoption and rejection.

### Data collection and analysis

For all tested cultivars along with checks, the yield (kg/10 m<sup>2</sup>) in three replications at different sites was recorded. Then conversion to t ha<sup>-1</sup> was done using the following formula:

$$\text{Yield} \left( \frac{\text{t}}{\text{ha}} \right) = \text{Yield} \left( \frac{\text{kg}}{10\text{m}^2} \right) \cdot \left( \frac{100 - \text{estimated moisture \%}}{100 - 14} \right)$$

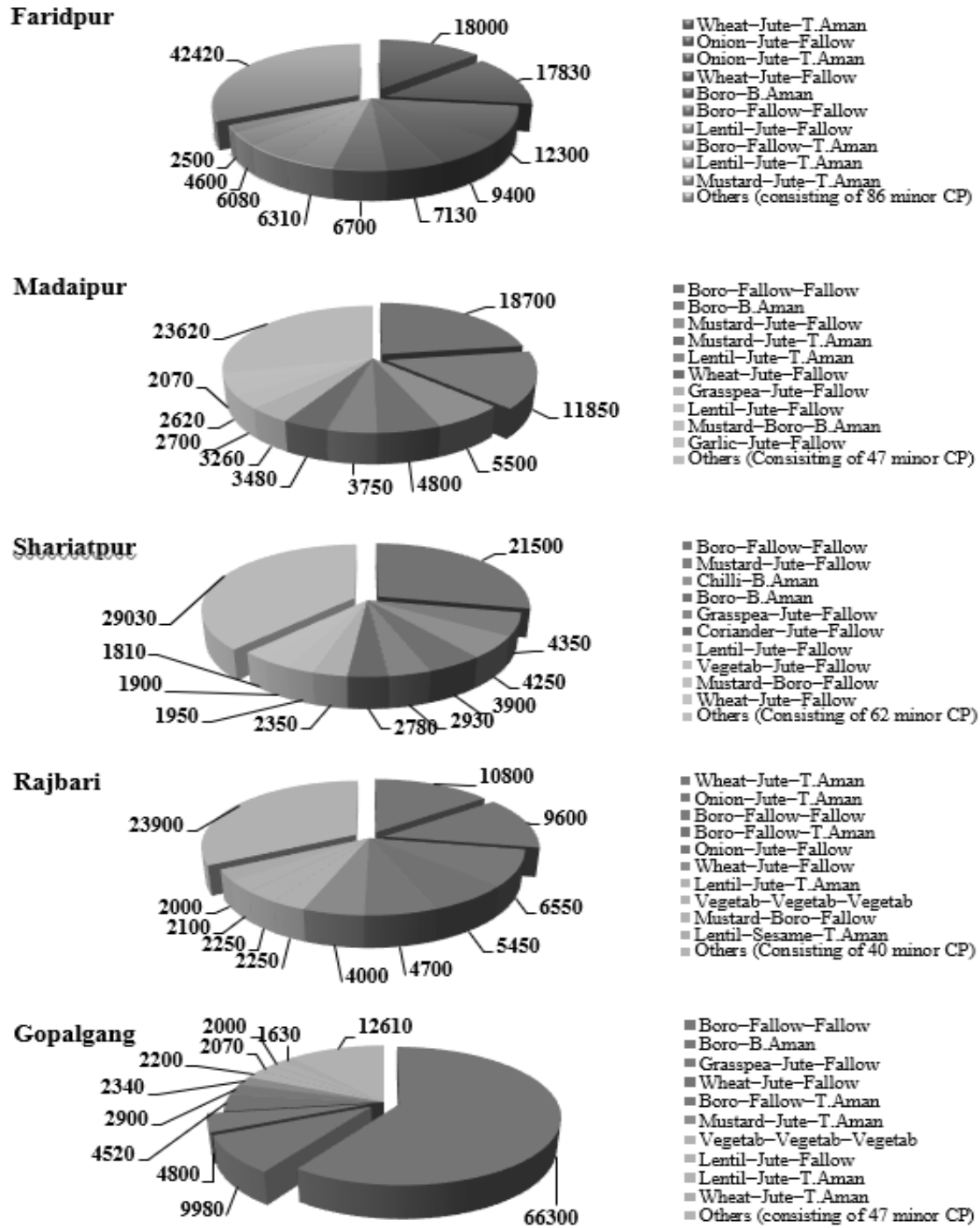
Here, rice grain yield is calculated at 14% moisture.

The frequency of preference and adoption by farmers was counted in PVS and two consecutive seasons. Through scheduled interviews, the factors responsible for adoption beyond preference were identified and stratified based on priority. Descriptive statistics was incurred using STAR V 2.0.1 (IRRI, 2014), and PTools V 1.4. (IRRI, 2014) were used for GGE (Generalized Gielis equation) analysis to determine the adaptability of those cultivars.

## RESULTS AND DISCUSSION

Secondary data of the Annual Report of DAE, 2017 showed that *T. Aman* coverage is highly predominant over other minor crops in the existing cropping pattern of Faridpur except for the Shariatpur region. It is continuously increasing due to the inclusion of modern *Aman* rice cultivars in this region. In 10 major cropping patterns of districts: Faridpur, Madaripur, Rajbari, and Gopalganj; *T. Aman* hold 1<sup>st</sup>, 4<sup>th</sup>, 1<sup>st</sup>, and 5<sup>th</sup> positions, respectively (Figure 3). Therefore, by considering *T. Aman* as a major crop, it would be possible to increase the productivity in the Faridpur region by replacing the existing cultivars through suitable, adaptive, and high-yielding rice cultivars.

The analysis of variance for grain yield of the eight cultivars tested in five environments is presented in Table 1. It represents the combined analysis of variance for the grain yield of the eight rice cultivars. Cultivars (G) and cultivar × environment interactions (GEI) were highly significant ( $P < 0.001$ ), while environments (E) were simply significant ( $P < 0.05$ ) for grain yield. The highly significant interactions between cultivars and environments revealed that the cultivars would be selected for adaptation to specific environments, which is aligned with some findings of G × E interaction effects of hybrid rice genotypes and cassava genotypes, respectively (Xu *et al.*, 2014; Akter *et al.*, 2015). Partitioning of explained SS (sum of square) showed that genotypes (cultivars) accounted for 70.71% variation and contribution of environments and their interactions was 4.23% and 11.57% respectively of the total variation (Table 1). Hence, G × E interaction effects demonstrated that genotypes responded differently to the various environmental conditions (soil type, weather, flood inundation, insect and disease prevalence), which brings the



**Figure 3.** Status of existing cropping pattern in Faridpur region, Bangladesh, comprised of five districts. (Clockwise fragmentation represents the cropping pattern list respectively).

**Table 1.** Combined analysis of variance of grain yield for eight rice cultivars evaluated at five environments.

Source of variation	d.f.	S.S.	Explained SS (%)	M.S.S.	Pr (> F)
Environment (E)	4	1.5462	4.25	0.3866*	0.0425
Block within Environment	10	1.045	2.87	0.1045*	0.05
Cultivar (G)	7	25.7255	70.7	3.6751***	0.0002
Environment × Cultivar (GEI)	28	4.2098	11.57	0.1504***	0.0004
Pooled Error	70	3.8534	10.58	0.055	-
Total	119	36.38		-	-

**Table 2.** Varietal performance and heritability across different environments in Faridpur region, Bangladesh.

Cultivars	Environ. 1	Environ. 2	Environ. 3	Environ. 4	Environ. 5
BINA Dhan7 (Check)	4.72 bc	4.77 bc	4.83 bc	4.73 c	5.21 b
BRRi dhan39 (Check)	4.58 bc	4.4 c	4.56 c	4.57 c	4.42 cd
BRRi dhan49	4.41 c	4.77 bc	4.78 bc	4.89 bc	4.42 cd
BRRi dhan71	4.73 bc	5.09 ab	5.23 b	5.63 a	5.17 b
BRRi dhan72	5.07 b	4.85 bc	5.35 b	5.41 ab	4.93 bc
BRRi dhan75	5.03 b	4.80 bc	5.07 bc	4.89 bc	4.74 b-d
BRRi dhan80	4.38 c	4.26 c	4.78 bc	4.47 c	4.17 d
BRRi dhan87	6.40 a	5.50a	6.31 a	5.79 a	5.88 a
Heritability	0.98	0.86	0.93	0.92	0.93
LSD <sub>0.05</sub>	0.5986				
CV (%)	4.74				

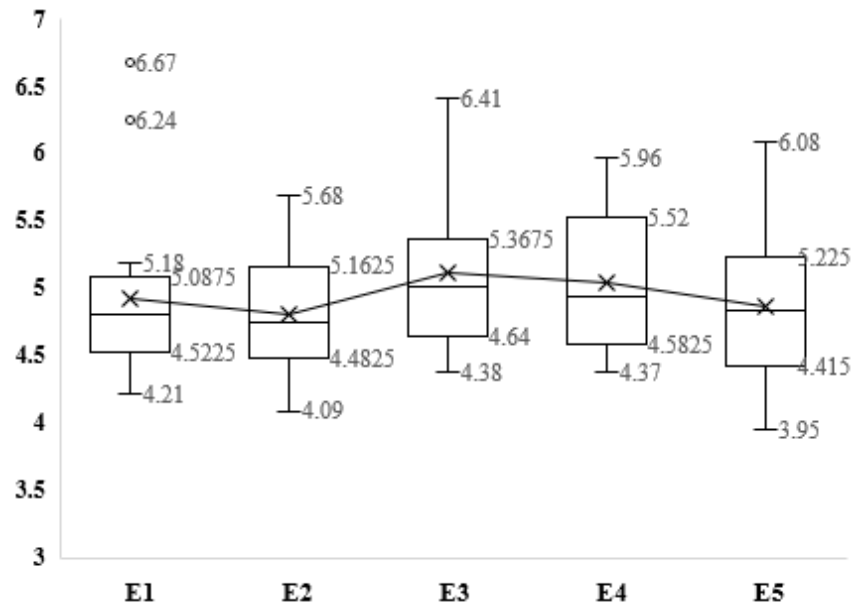
E1 = Sadar upazila, Faridpur; E2 = Rajoir upazila, Madaripur; E3 = Zajira upazila, Shariatpur; E4 = Sadar upazila, Rajbari, E5 = Muksudpur upazila, Gopalganj

need of testing rice cultivars at multiple locations. Louwaars (2018) stated that plant breeders also face lots of problems and must work very hard in selecting new cultivars for specific regions and agro-ecological zones due to ever existing environmental and genotype effects.

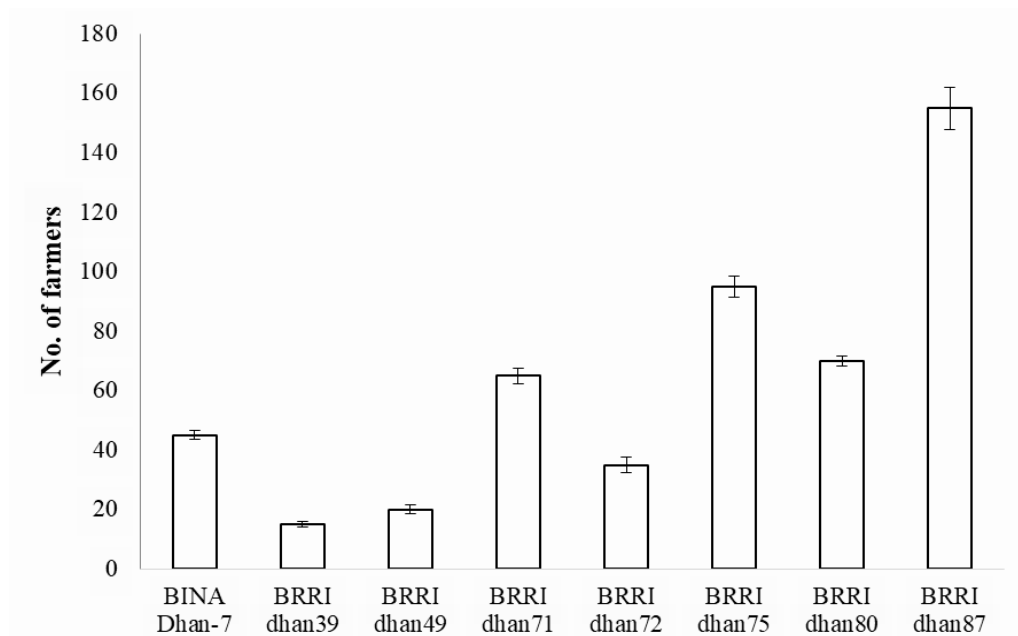
In the context of yield performance, cultivar BRRi dhan87 was the superior among all tested environments. In contrast, BRRi dhan80 was identified as the poorest cultivar in E1, E2, E4, and E5. However, in E3, genotype BRRi dhan39 produced significantly lowest grain yield. Rice cultivars with similar means showed nonsignificant differences among them. Plant breeders use heritability to estimate the precision in single field trials and the series of field trials (Piepho and Mooring, 2007; Oladosu *et al.*, 2014). Here in E1, the heritability was the highest (0.98) which indicated that 98% proportion of

phenotypic variance (yield performance) among the population was due to heritable genetic effects (Table 2).

The box plots explained overall patterns of varietal yielding response in a group from under different environments (Figure 4). The range and other characteristics of responses were visualized for a larger group here. In E5, the median was close to the mean revealing that there was an existing lot of variation in the performance of tested cultivars. In E4, the 50% population yielded 4.50 to 5.52 tons ha<sup>-1</sup> which accounted in the middle box, and the maximum population was accounted for the higher grain yield. In E1, two outliers were present and accounted for 1.6% of the total population but the inter-quartile box was comparatively short to others which represents that the performance of the tested populations were close to each other (Bruno *et al.*, 2017).



**Figure 4.** Boxplot of tested varietal yield performance in environments.



**Figure 5.** Farmer’s preferences in the tested cultivars.

By summarizing the 500 farmers in the five specific upazilas, the genotype BRRi dhan87 was preferred by 155 farmers due to higher grain yield (Figure 5). The second preference was the cultivar BRRi dhan75 for short duration by 95

farmers. This cultivar got popularity in other regions, i.e., Rangpur and Dinajpur for its compatibility in three crop-based systems along with potentiality to escape moisture (Kabir *et al.*, 2019). The third highest choice was the rice genotype BRRi

ghan-80 for long slender premium quality grain. The rainfall pattern was sporadic due to climate change, and the drought-tolerant cultivar BRRRI dhan71 in rainfed *Aman* season got the preference of 65 farmers as it is highly accepted in Rangpur and Dinajpur regions where drought is common in *Aman* season (Kabir *et al.*, 2019). For Zn enrichment in cultivar BRRRI dhan72, 35 farmers showed their willingness to cultivate in the next season and further. Rice is the important staple food that contributes 70% per capita of caloric intakes in Bangladesh (FAO, 2009). So, to ensure dietary Zn sufficiency, modifications to the zinc content of rice would be possible through bio-fortification (Dipti *et al.*, 2017). The grain size of the cultivar BRRRI dhan49 is close to a local cultivar 'Nizersail', considering this character and the 20 farmers showed their interest in it. A total of 45 and 15 farmers were found happy with their existing rice cultivar BINA Dhan7 and BRRRI dhan39, respectively in the *Aman* season.

In 2018, the seed of the preferred rice cultivar was provided to farmers for cultivation in the next season. During 2019, the highest farmers' preference (78.6%) was achieved in the genotype BRRRI dhan80 due to its fine grain (Figure 6). High yielding cultivars BRRRI dhan87 and BRRRI dhan75 obtained 77.4% and 74.7%, respectively because of their short duration in maturity. However, the lowest (42.9%) was observed in BRRRI dhan72 despite its Zn content (Figure 6). In 2020, a heavy flood happened in Bangladesh, and consequently, the Faridpur region was tremendously affected as it lay in flood affected areas. Almost the entire *Aman* rice crop was affected due to the inundation of the seedbed and main field. Recovery was done by getting the seed support of photosensitive cultivars (BR22, BR23, and local cultivar Nizersail) which were popular cultivars in flood prone areas (Hossain, 2015). For that reason, in 2020, the cultivation percentage was drastically reduced at the experimental sites. However, due to cultivation in medium high lands and existing embankment, the high yielding cultivar BRRRI dhan87

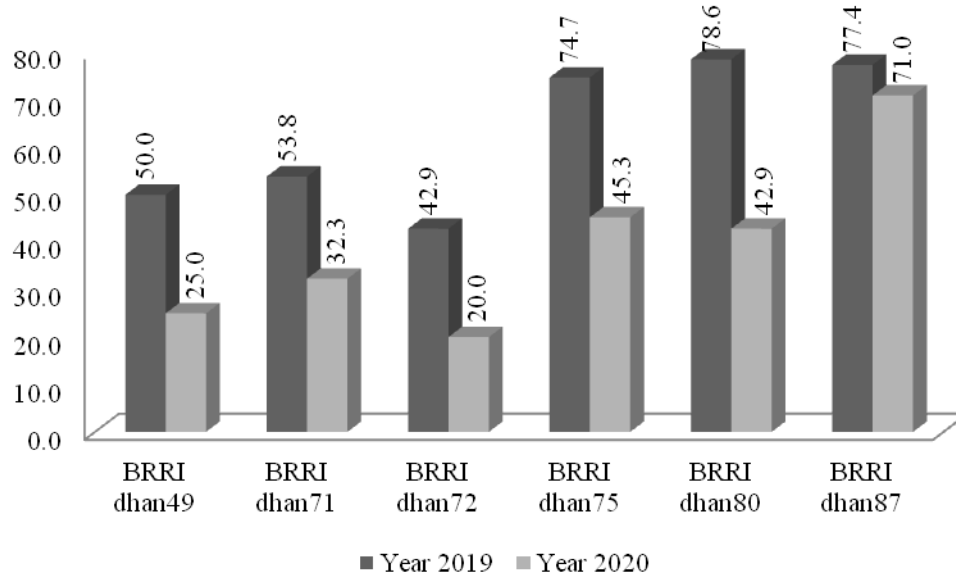
cultivation percentage was close to the previous year. After all those observations, a scheduled interview was conducted to identify the determinants associated with the adoption of modern rice cultivars. Ghimire *et al.* (2015) mentioned agro-ecological regions, extension services, and seeds all played important roles in adoption decisions.

Adoption of different rice cultivars depends on the independent variables, which are considered as demographic, management, production, and post-harvest characteristics. This is agreed with the utility maximization theory by Rahm and Huffman (1984). The adoption is far beyond the decision of farmers to adopt or not. Along with a lot of factors that is still anchored with it (Asaduzzaman, 1979; Hossain *et al.*, 2006; Ahmed *et al.*, 2016; Bannor *et al.*, 2020). Under these determinants, several sub-factors have been identified that influence the adoption of modern rice cultivars in the Faridpur region (Figure 7).

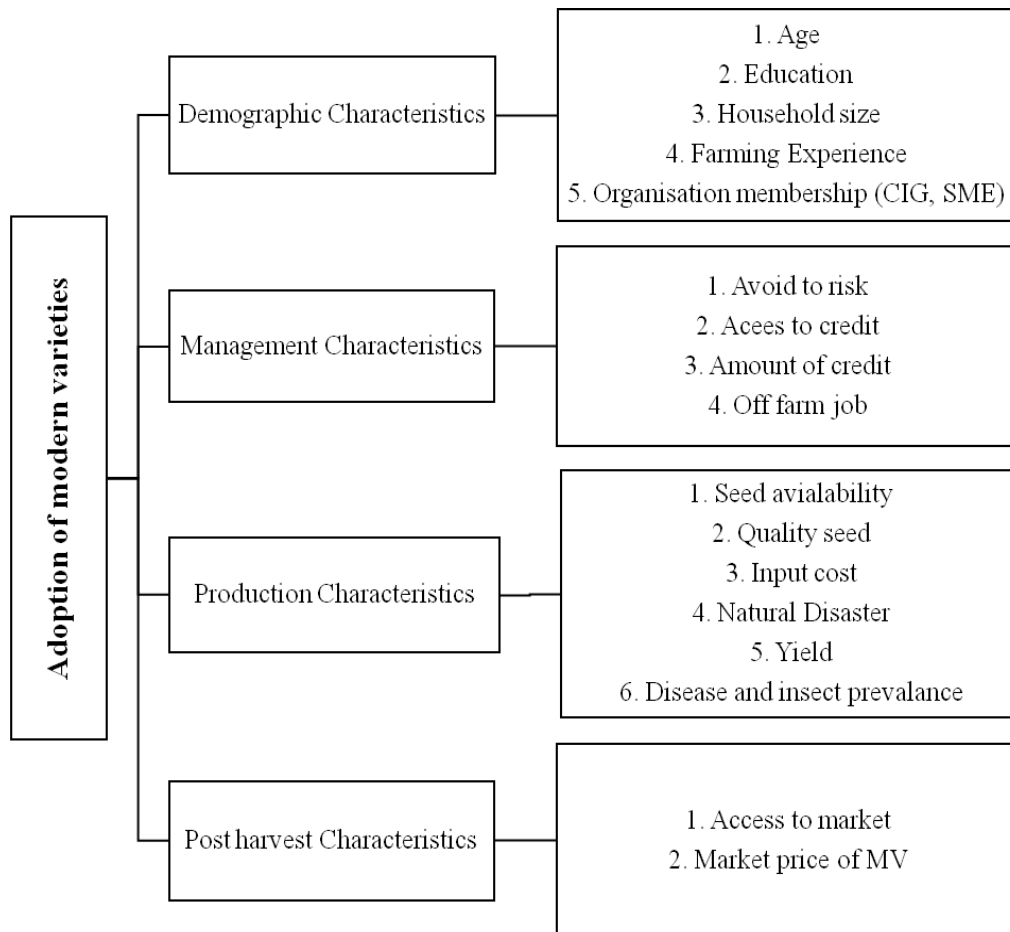
Polygon view through GGE analysis displayed the winning genotypes with their interaction behavior across the tested environments (Figure 8). A polygon was developed by joining the vertex cultivars (G4, G3, G7, and G8) with a solid straight line, and other cultivars (G1, G2, G5, and G6) remain within this polygon. The distance of the vertex cultivars was higher than other genotypes. It means that the vertex cultivars were more responsive to their environments than other cultivars and were considered as specially adapted cultivars (Yan and Rajcan, 2002; Ogunbayo *et al.*, 2014). In some environments, it performs well or poor along with farmer's preferences for their special traits (aroma, and slender grain). Genotypes G1, G5, and G6 were located closer to the origin of Biplot, were less responsive and more adaptive than other tested cultivars (Yan *et al.*, 2007).

Biplot was divided into three sections by three perpendicular lines starting from the origin and extended over the polygon. The tested cultivars were partitioned and placed in these three sections. The 1<sup>st</sup> section contains two

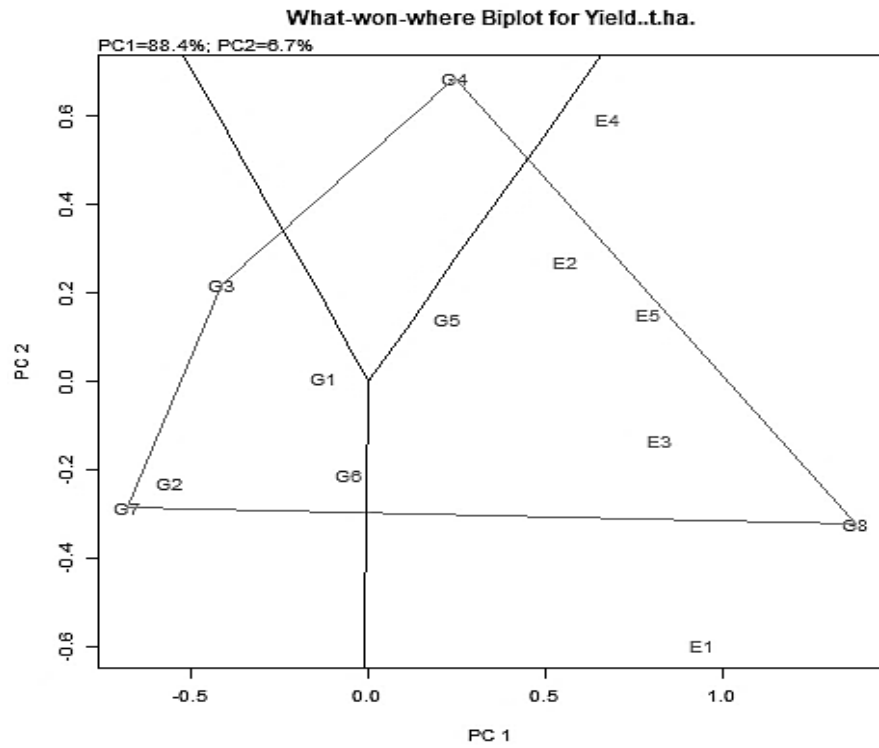




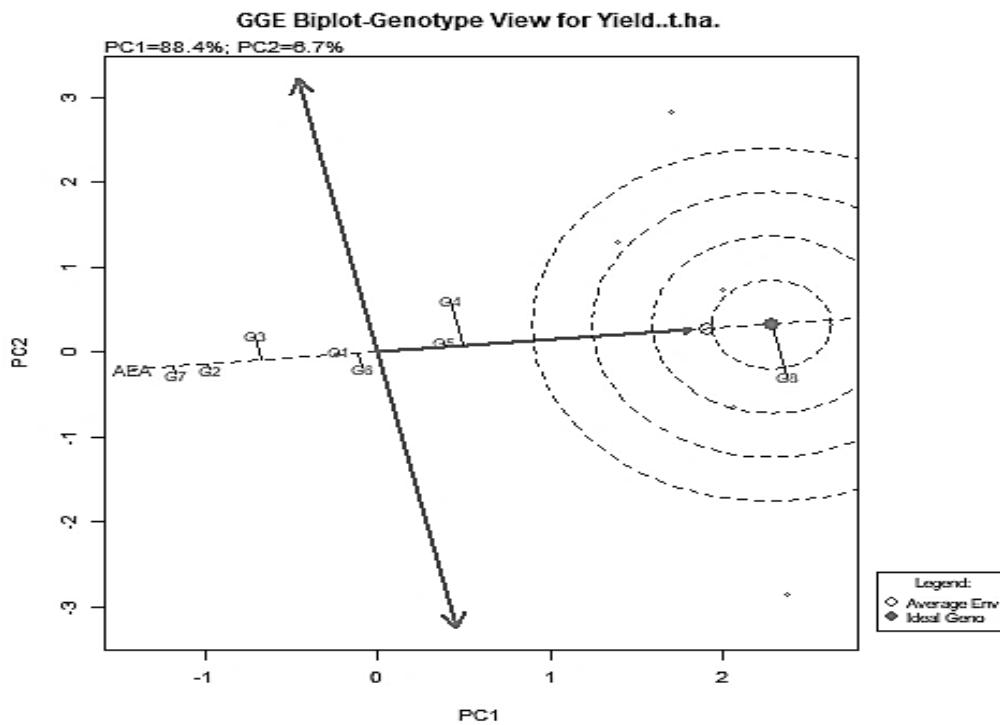
**Figure 6.** Percentage (%) of preferred cultivar cultivation in two consecutive years at the selected sites.



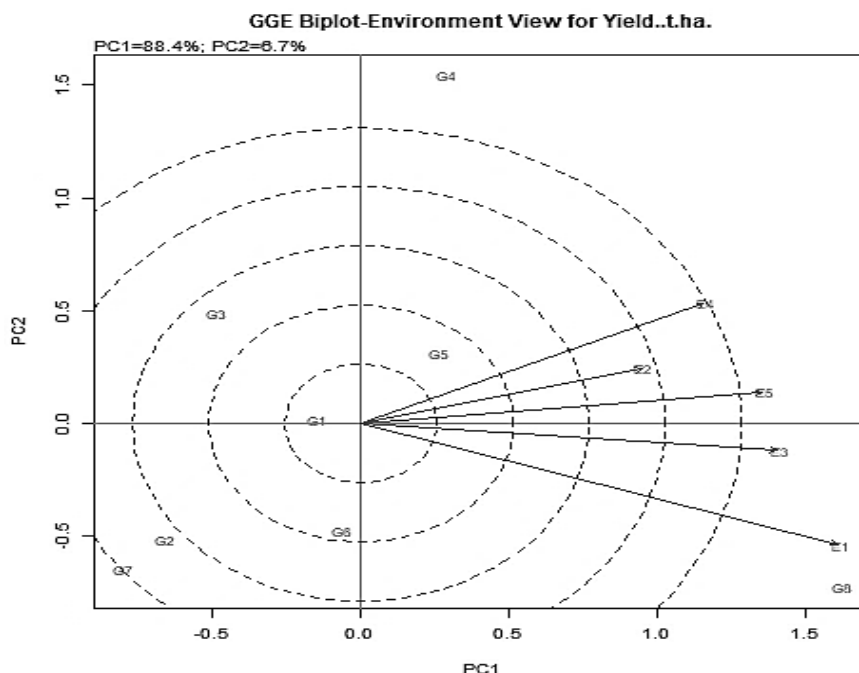
**Figure 7.** Determinants of adoption of modern cultivars.



**Figure 8.** Polygon view of GGE biplot analysis.



**Figure 9.** Ranking of genotypes based on mean yield and stability performance.



**Figure 10.** Relationship among environments.

cultivars named by BRRRI dhan72 (G6) and BRRRI dhan87 (G8) (Vertex cultivars) which were identified as the high yielding genotypes for these five locations. Only one cultivar BRRRI dhan71 (G4) was felt in 2<sup>nd</sup> section and the rest of these were in 3<sup>rd</sup> section. In the present investigations, GGE biplot analysis estimated 88.4% and 6.7% variations for PC1 and PC2 GGE sum of squares, respectively which explained 95.1% of the total variance.

The average grain yield performance and stability of tested rice cultivars were indicated in Figure 9. Average Environmental Axis (AEA) passes across the biplot origin. In the AEA, the central pointed blue circle corresponds to the average environment while the ideal cultivar was represented by a blue solid dot. High yielding rice cultivars were close to the blue circle in the AEA. The cultivars in the upper position on the AEA were identified as more stable and those that were below on the AEA were considered as less stable to the environments (Akter *et al.*, 2015; Donoso-Nanculao *et al.*, 2016; Pagi *et al.*, 2017). That cultivar had

large PC1 scores and was considered as high mean yield and small PC2 scores for high stability. Although such an 'ideal' cultivar may not be found in reality, but it could provide a reference for genotype evaluation (Mitrovic *et al.*, 2012). By considering these factors, BRRRI dhan87 (G8) was found as the high yielding rice cultivar. In the context of stability, rice cultivars BRRRI dhan71 (G4) and BRRRI dhan49 (G3) were found to be more stable than others. Results further revealed that the area of cultivars on the right side of the perpendicular line has shown the best performance and greater yield than mean yield and the genotypes on the left side which were observed with less grain yield compared to average yield. In the present study, the rice cultivars BRRRI dhan87 (G8), BRRRI dhan71 (G4), and BRRRI dhan72 (G5) were high yielding than all others. Stability parameters and breeding values based on pedigree information of different elite breeding lines for yield under salt stress were estimated in Bangladesh (Quddus *et al.*, 2019).

The GGE biplot model is an efficient method to visualize MET data analysis (Mohammadi *et al.*, 2011; Quddus *et al.*, 2019). GGE illustrated that a total variation of 95.1% was accounted which consisting of 88.4% and 6.7% attributed to the PC1 and PC2, respectively (Figure 10). The E2 and E4 environments were ideal for cultivar G5 (BRRI dhan-72). The E5 and E3 were considered as the least environments for all the cultivars. However, the E1 environment was the most suitable environment for cultivar G8 (BRRI dhan87). In the biplot environment view, the relationship among the environments was explicated by the relationship between the environments that were measured by their vector size and angle between the two environments (Yan *et al.*, 2001). The E1 and E3 had the longer vectors thus, they were the ideal environments for genetic discrimination of the cultivars but on considering the angle between these two environments, these environments were comparatively less discriminating than E5, E2, and E4. The environment E2 was the least representative environment in the present study because it has a shorter vector. The minimum angle between the vectors of E2 and E5 has shown a robust correlation that is in agreement with the past studies on hybrid rice in Bangladesh (Akter *et al.*, 2015).

## CONCLUSIONS

To mitigate the emerged problem of achieving sustainability in rice production, varietal replacement should be ensured. In Bangladesh, few rice cultivars are cultivated in the major rice growing areas for almost 22 years. Thus, the replacement of those cultivars should not be overlooked to ensure food security in the diversified agro-ecology along with the risk-averted farming community. It also confirms that these farmers prefer to keep pace with rice cultivars with assured yields rather than do experiment with new ones. For that reason, several complementary varietal performances were demonstrated

to increase the interest in new technologies and find a suitable, profit redeemed, and adaptable rice cultivar for the farming community. Therefore, it is a highly commendable job if it monitors the adoption, adaptability, and stability status of new rice cultivars promoted to the field level. In the Faridpur region, the cultivars BRRI dhan72 and BRRI dhan87 were identified as high yielding genotypes, followed by BRRI dhan49 and BRRI dhan71 as stable cultivars for the *Aman* season.

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