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Article

Participatory Variety Testing to Replace Old Mega Rice Varieties with Newly Developed Superior Varieties in Bangladesh

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Abstract: The Bangladesh Rice Research Institute (BRRI) has released more than 100 inbred rice varieties. Still, an old mega variety BRRI dhan28 dominates the farmers' fields during the dry winter (*Boro* season: November–June) season. This variety is very susceptible to different diseases and insects, causing lower yield performance than its potential. To replace this variety, current on-farm research was planned to evaluate the newly developed four superior rice varieties: BRRI dhan58, BRRI dhan63, BRRI dhan67, and BRRI dhan74 during *Boro* season in 2017 and 2018. The objective was to create data and popularize new varieties among farmers all over the country. We conducted 15 on-farm trials with farmers' active participation at Senbag, Fulgazi, and Mirsarai Upazila of Noakhali, Feni, and Chattogram districts, respectively, in Bangladesh. The results demonstrate that BRRI dhan74 produced the highest grain yield among the tested varieties, followed by BRRI dhan67, BRRI dhan63, and BRRI dhan58, while BRRI dhan28 produced the lowest. However, BRRI dhan67 obtained the highest preference scores from the farmers and extension personnel due to its medium and slender grains, shorter growth duration, resistance to lodging, less disease, and less insect invasion. Moreover, stability indices for yield revealed that BRRI dhan67 was the most stable, adaptive, and appropriate variety, followed by BRRI dhan74, across the locations. Farmers showed keen interest to grow BRRI dhan67 by themselves instead of BRRI dhan28 all over the study locations. The neighboring farmers also expressed their curiosity about cultivating BRRI dhan67 over BRRI dhan28 by collecting seeds from the participating farmers. Thus, BRRI dhan67 could be a perfect replacement for BRRI dhan28. However, conducting participatory varietal evaluation trials across the agroecological zones of the country is recommended to validate the results of this study.

Keywords: disease and insect resistance; farmers' preference; on-farm trial; yield stability

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1. Introduction

Rice (*Oryza sativa* L.), in addition to being a staple grain, is a significant source of employment and subsistence in rural regions of Bangladesh. However, rice yield in Bangladesh is declining due to the continued use of outdated cultivars sensitive to diseases, insects, and pests. One of the primary causes for poor cultivar replacement is a lack of exposure to new cultivars; as a result, old cultivars continue to be farmed on a larger scale.

Despite the availability of many varieties in widespread cultivation since 1994, BRRI dhan28 and a few old cultivars account for a significant portion of the land under rice cultivation during the winter dry season (*Boro*: November–June). Because farmers may not regard increasing productivity as a top goal, the newly produced varieties may or may not have met the farmers' final needs. They usually make trade-offs between several attributes to select the optimal variant. As a result, a diverse choice of superior rice varieties must be tested on-farm by involving farmers directly in a participatory way. Using that method, they can select a rice variety based on their preferences. This practical approach is essential to boost the acceptance rates and country-wide dissemination of new superior rice variety(s). Joshi and Witcombe [1] defined this approach as participatory varietal selection (PVS).

Many researchers have previously utilized the PVS approach to study, select, and distribute various varieties/genotypes on farmers' fields depending on the farmers' preferred traits and their perceptions and preferences for varietal specification [2–4]. Farmers' quick adoption of superior rice varieties demonstrates the strength of the PVS system and the effectiveness of a demand-based rice breeding program. Keeping the importance of work insight concerning farmer well-being, we conducted the current study utilizing the novel PVS approach. We asked farmers and extension workers to examine and select superior rice varieties from the five tested types depending on their discretion. Given the findings, this study describes the strategies for varietal testing for farmers to replace the old mega rice variety, BRRI dhan28.

2. Materials and Methods

2.1. Study Sites and Seasons

The present on-farm study was carried out at the Kadra and Arjuntola villages of Senbag (22.9833° N; 91.2333° E), Nurpur and Sharifpur village of Fulgazi (22.5338° N; 91.325° E), and Joypur village of Mirsarai (23.3214° N; 90.2418° E) sub-district under Noakhali, Feni, and Chattogram district of Bangladesh. The duration of the study was the dry winter season: November 2017–June 2018. The lowest minimum of about 15 °C and the highest maximum of 35 °C air temperatures were recorded at Fulgazi and Senbag during February and May, respectively. The maximum rainfall of 401 mm was observed in June at Mirsarai site (Figure 1). The nutrient content of the sandy-loam-textured medium fertile soil at all sites is presented in Table 1.

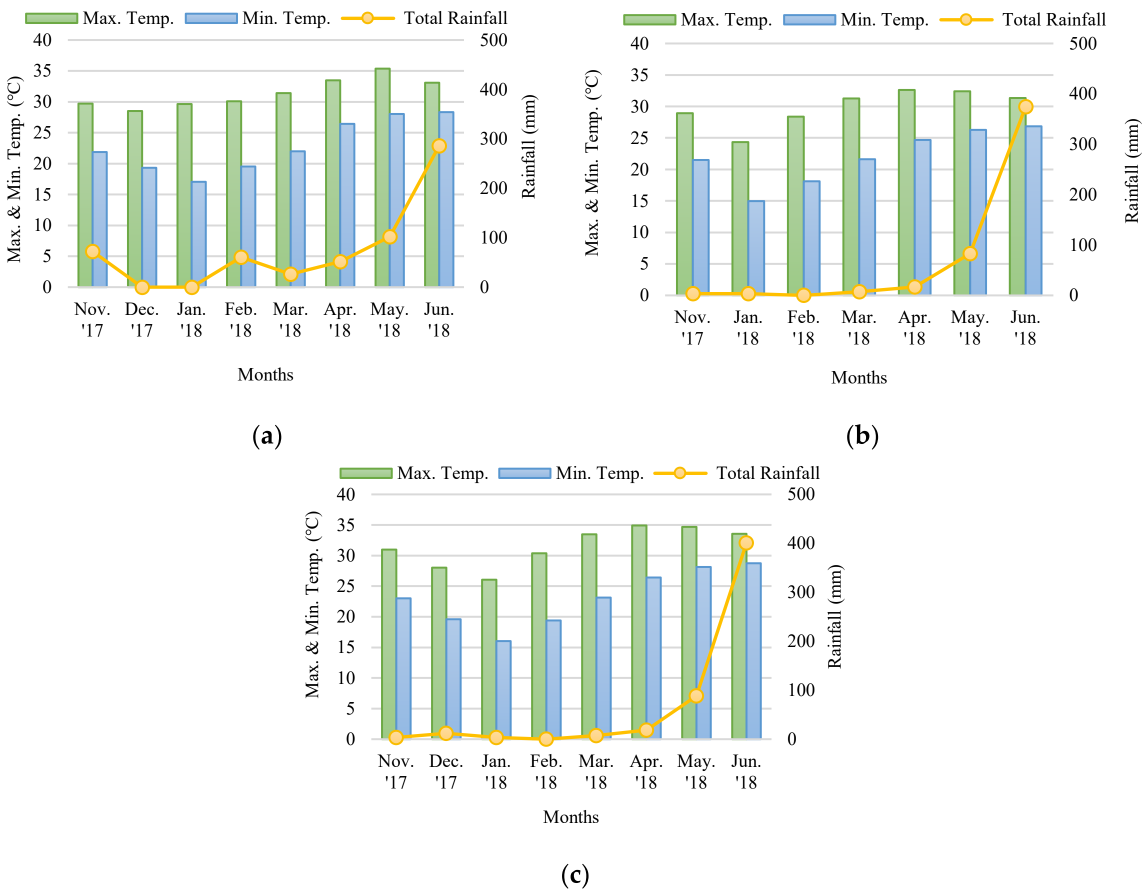

Figure 1. The climate of the study sites (**a**) Senbag, (**b**) Fulgazi, (**c**) Mirsarai during November 2017–June 2018.

Table 1. Nutrient analysis of soil at 0–15 cm depth.

Properties	Senbag	Fulgazi	Mirsarai
pH	7.28	7.21	7.40
Organic matter (%)	1.71	1.59	1.71
Total nitrogen (%)	0.08	0.12	0.15
Available phosphorus (ppm)	45.08	10.9	11.7
Available sulfur (ppm)	36.17	77.0	82.8
Exchangeable potassium (Cmol kg^{-1})	0.19	0.15	0.17

2.2. Treatment and Design

In this on-farm trial, four rice varieties, BRRI dhan58, BRRI dhan63, BRRI dhan67, and BRRI dhan74, were evaluated compared to the check variety BRRI dhan28. We selected three advanced and promising farmers from each of the five villages, hence, 15 farmers (13 males and two females) participated in this study. The design of the experiment was the randomized complete block design (RCBD) in a remotely replicated approach. Here, five villages represented five blocks and three farmers represented three replications in each block.

2.3. Crop Farming

The land was prepared operating a four-wheel tractor. Plowing and cross-plowing was performed three times to a depth of about 8–10 cm of the inundated soil. Before transplanting, the puddled soil was leveled thoroughly. We planted 30-day-old seedlings at 20 × 20 cm rice hill spacing, which can accommodate two to three rice seedlings per hill.

Fertilizer management was implemented following BRRI recommendations [5]. During the final land preparation, we applied triple super phosphate, muriate of potash, gypsum, and zinc sulphate at 150, 190, 75, and 8 kg ha^{-1}, respectively. Prilled urea at 400 kg ha^{-1} was broadcasted in three equal parts at 15, 40, and 60 days after transplanting. Irrigation was conducted when needed. All other cultural activities were performed per the guidelines of BRRI [5].

2.4. Data Transcription

Data on crop growth duration (days), including 50% flowering and 80% maturity dates and plant height (average of five plants) were transcribed. Paddy yield (t ha^{-1}) was recorded at 14% moisture content. Moreover, visual field scoring was performed intensively for the incidence (%) of diseases and insects, and lodging at the reproductive stage as in the Standard Evaluation System (SES) for rice [6]. The crop was harvested from each plots' central 5 m × 2 m area.

2.5. Data Analysis

The International Rice Research Institute, Los Baños, Philippines developed software *STAR* 2.0.1 (Statistical Tool for Agricultural Research) [7] and the *PBTools* 1.4 (Plant Breeding Tools) [8] were employed to undertake the variance analysis and G × E interactions, respectively, of the paddy yield parameters in different locations. Duncans' Multiple Range Test was used for all pair-wise mean comparisons of treatments at the $p \leq 0.05$ level of significance.

We conducted a combined Analysis of Variance with genotype as the fixed variable and environment as the random effect. The AMMI (Additive Main Effect and Multiplicative Interaction) approach proposed by Zobel et al. [9] was used to evaluate the main effects of variety (G) and location (E) and G × E interactions for grain yield in multi-environment data. The most stable variety was calculated based on the AMMI Stability Value (ASV) recommended by Purchase et al. [10] as Equation (1).

$$ASV = \sqrt{\frac{SSPC_1}{SSPC_2} \times \left(PC_1^2 + PC_2^2\right)} \quad (1)$$

Here, SS represents sum of squares, while PC_1 and PC_2 represents interaction principal component analysis axis I and II, respectively.

The yield stability index (YSI) [11] was used to identify the most stable genotypes based on the rank of ASV (rASV) and mean yield (rY) of the variety as Equation (2).

$$YSI = rASV + rY \tag{2}$$

3. Results

The Analysis of Variance (ANOVA) showed that days to 50% flowering (DTF) and 80% maturity (DTM), plant height (PH), and paddy yield (PY) varied significantly ($p < 0.05$) according to the tested varieties (G) at different locations (E). However, their interaction (G × E) had no significant effect on these parameters (Table 2).

Table 2. ANOVA of response variables at 0.05% level of significance.

Source	DF [1]	DTF			DTM			PH			PY		
		SS	MS	*p*-Value	SS	MS	*p*-Value	SS	MS	*p*-Value	SS	MS	*p*-Value
Replication	2	52.9	26.4	0.98	8.9	4.4	0.14	4.1	2.1	0.59	3.8	1.9	0.12
Variety (G)	4	950.7	237.7	0.00	891.8	222.9	0.00	2524.0	631.0	0.00	34.5	8.6	0.00
Location (E)	4	177.0	44.3	0.00	21.9	5.5	0.03	53.1	13.3	0.01	4.7	1.2	0.00
G × E	16	64.18	4.01	0.24	18.1	1.1	0.89	69.9	4.37	0.35	2.2	0.1	0.89
Error	48	149.09	3.10		95.8	1.9		185.2			12.0	0.3	
Total	74	1393.9			1036.5			2836.4			57.5		

[1] DF: degrees of freedom, SS: sum of squares, MS: mean square, DTF: days to 50% flowering, DT: days to 80% maturity, PH: plant height, PY: paddy yield.

3.1. Days to 50% Flowering (DTF) and 80% Maturity (DTM)

The G × E effect revealed that DTF ranged from 98 to 117 days with a mean of 107 days, but the varieties needed 103–110 days at most locations (Figure 2). On the other hand, DTM required 135–150 days with a mean of 143 days to reach 80% maturity; however, at the majority of locations, varieties required 141–146 days to be mature (Figure 2).

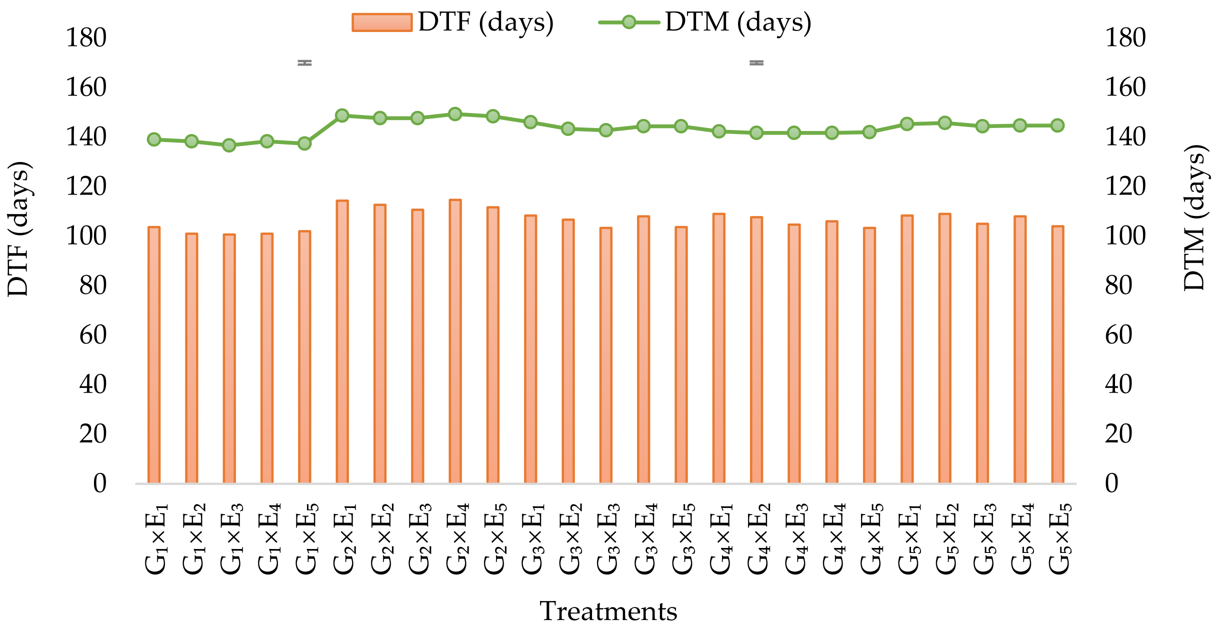

Figure 2. G × E interaction on the days to 50% flowering (DTF) and 80% maturity (DTM) of rice varieties.

Data revealed that the variety BRRI dhan28 took the shortest time of 102 and 138 days to reach DTF and DTM, respectively. On the other hand, BRRI dhan58 needed the longest time of 113 DTF and 148 DTM. Compared to BRRI dhan28, BRRI dhan63 was four and six days late to flower and mature, respectively. BRRI dhan67 was four days late and BRRI dhan74 was five and seven days late to flower and mature, respectively (Figure 3).

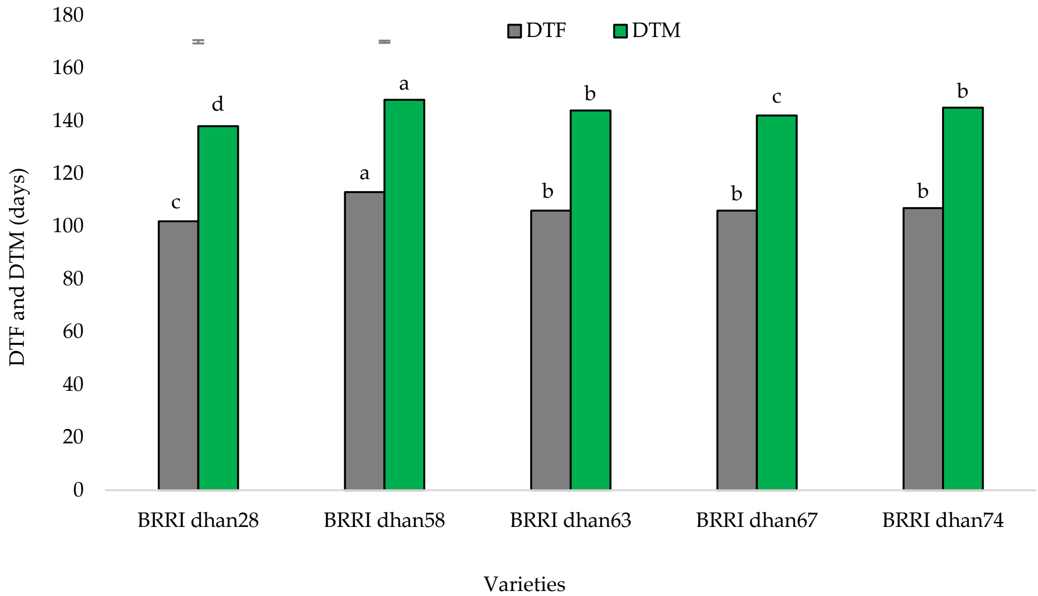

Figure 3. Effect of rice varieties on the days to 50% flowering (DTF) and 80% maturity (DTM). The means with similar letters do not differ significantly at $p \leq 0.05$.

At the Kadra (E1) and Sharifpur (E4) locations, varieties took the longest, 109 and 144 days, respectively, to blossom and mature. Compared to these sites, Arjuntola was two days ahead for both DTF and DTM, and Nurpur and Joypur were four and five days and three and two days earlier for DTF and DTM, respectively (Table 3).

Table 3. Effect of location (environment) on the yield attributes and yield of rice varieties.

Locations	DTF [1]	DTM	PH	PY
Kadra	109 ^{a}	144 ^{a}	100 ^{b}	6.17 ^{bc}
Arjuntola	107 ^{b}	142 ^{b}	104 ^{a}	6.09 ^{bc}
Nurpur	105 ^{c}	141 ^{b}	99 ^{b}	5.98 ^{c}
Sharifpur	109 ^{a}	144 ^{a}	100 ^{b}	6.38 ^{ab}
Joypur	104 ^{c}	142 ^{b}	99 ^{b}	6.69 ^{a}
CV (%)	1.65	0.98	1.97	8.00
StdErr	0.64	0.52	0.72	0.18
LSD	1.29	1.04	1.44	0.37
StdDev	4.34	3.74	6.19	0.88

[1] DTF: days to 50% flowering, DTM: days to 80% maturity, PH: plant height, PY: paddy yield, CV: coefficient of variance, StdErr: standard error, LSD: least significant variance at 5% level, StdDev: standard deviation. The means with similar letters do not differ significantly at $p \leq 0.05$.

3.2. Plant Height (PH)

According to the G $\times$ E interaction, PH varied from 86–110 cm but mostly from 92–110 cm, with a mean of 100 cm tall, while the varieties at most of the sites attained a height of 99–104 cm (Figure 4). BRRI dhan58 was the tallest plant at 107 cm, while BRRI dhan63 was the shortest plant (89 cm). BRRI dhan28, 67, and 74 had statistically identical heights of 101, 102, and 100 cm, respectively (Figure 5). The Arjuntola site produced the tallest plant of 102.4 cm, while at the rest of the sites the plant height was about 100 cm (Table 3).

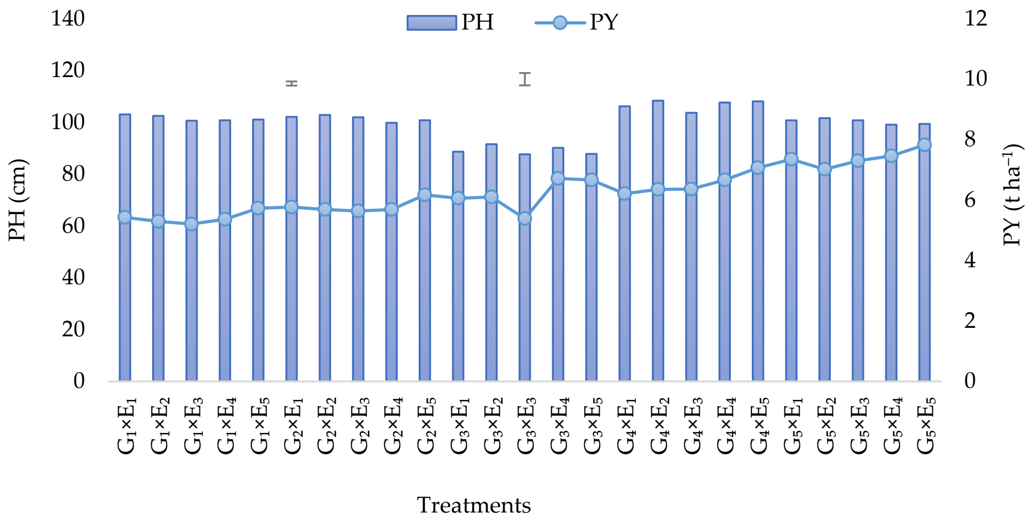

Figure 4. G × E interaction on the plant height (PH) and paddy yield (PY) of rice varieties.

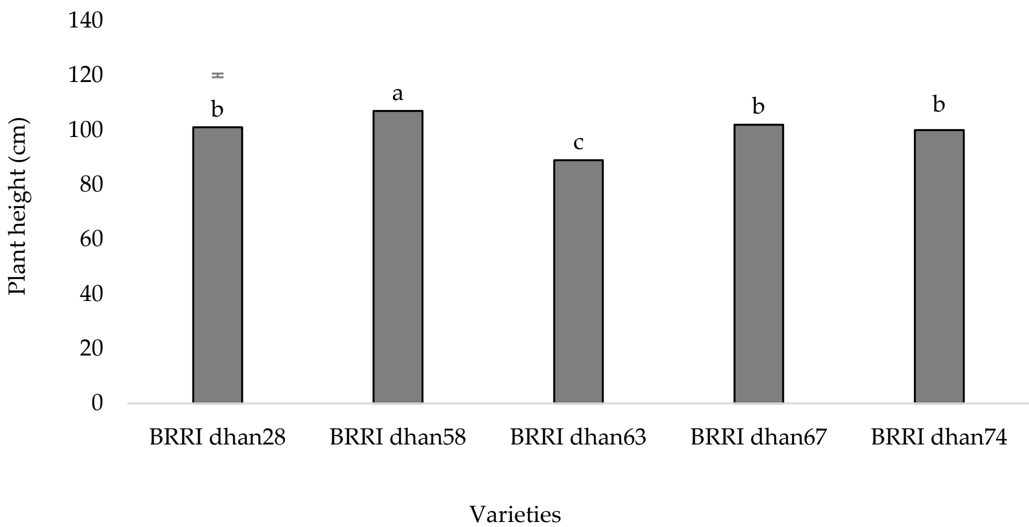

Figure 5. Effect of rice varieties on the plant height. The means with similar letters do not differ significantly at $p \leq 0.05$.

3.3. Paddy Yield

The tested rice varieties showed a yield potential of 4.34–8.30 t ha^{-1} across the study sites, with a mean yield of 6.26 t ha^{-1}. The range of yield potential of the varieties at most sites was 5.45–6.86 t ha^{-1} (Figure 4). According to the analysis, BRRI dhan74 had the highest yield (7.39 t ha^{-1}), followed by BRRI dhan67 (6.53 t ha^{-1}) and BRRI dhan63 (6.19 t ha^{-1}), while BRRI dhan58 was ranked fourth (5.79 t ha^{-1}). With a yield of 5.41 t ha^{-1}, BRRI dhan28 had the lowest yield potential (Figure 6). Compared to BRRI dhan28, BRRI dhan74, 67, 63, and 58 demonstrated yield advantages of 7, 15, 21, and 37%, respectively.

The yield stability index (YSI) based on the AMMI stability value (ASV) data presented in Table 4 revealed that BRRI dhan67 was the most stable variety with the lowest YSI value of 3, followed by BRRI dhan74, which had a YSI of 4. In comparison, BRRI dhan28, 58, and 63 were identified as unstable variants based on YSI values of 7, 8, and 8, respectively. YSI value enables selection for yield and stability performance concurrently; on this basis, genotypes with the lowest YSI reflect the most stable genotypes with high performance [11]. Moreover, the output of the Finlay–Wilkinson model of stability (Table 5) also confirmed that BRRI dhan67 was the most stable variety, having a probability 0.024 less than that of the 5% level, and the slope (b = 1.22) was higher than 1 [12]. BRRI dhan74 was less stable than BRRI dhan67, as the probability and slope value inclined.

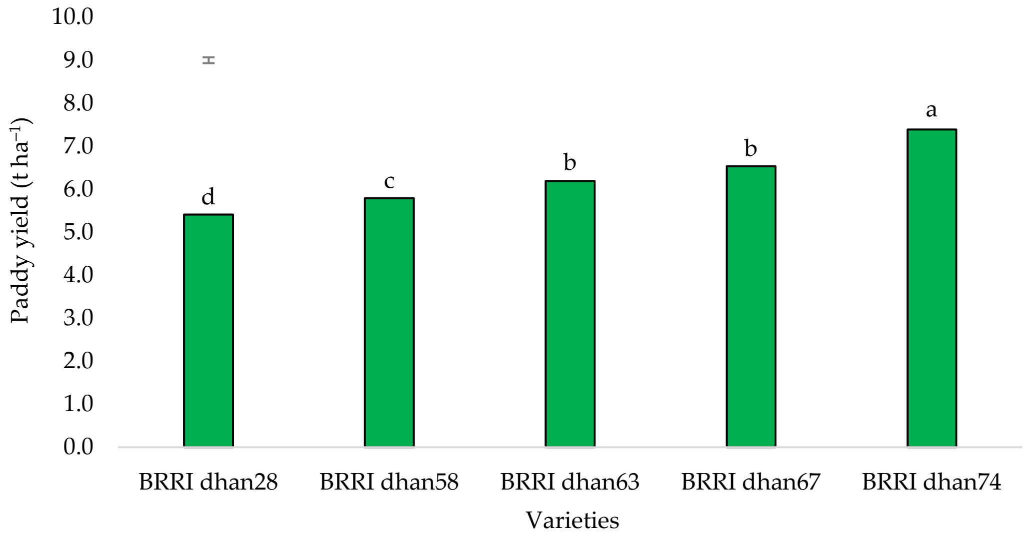

Figure 6. Effect of rice varieties on the paddy yield. The means with similar letters do not differ significantly at $p \leq 0.05$.

Table 4. AMMI stability value (ASV) and yield stability index (YSI) of the rice varieties.

Variety	ASV	rASV [1]	Y	rY	YSI (= rASV + rY)
BRRI dhan28	0.54	2	5.40	5	7
BRRI dhan58	0.64	4	5.78	4	8
BRRI dhan63	1.74	5	6.18	3	8
BRRI dhan67	0.44	1	6.53	2	3
BRRI dhan74	0.55	3	7.38	1	4

[1] rASV: ranking of ASV, Y: paddy yield, rY: ranking of paddy yield.

Table 5. Finlay–Wilkinson model values show the stability of rice varieties.

Variety	Slope (b)	*p*-Value	SE [1]	t. Value	MSReg	MSDev
BRRI dhan28	0.64	0.026	0.15	4.29	0.13	0.007
BRRI dhan58	0.67	0.055	0.22	3.07	0.14	0.015
BRRI dhan63	1.64	0.065	0.57	2.85	0.86	0.106
BRRI dhan67	1.22	0.024	0.27	4.12	0.40	0.023
BRRI dhan74	0.91	0.052	0.28	3.13	0.26	0.026

[1] SE: standard error, MSReg: mean square for regression, MSDev: mean square for standard deviation.

3.4. Diseases, Insects, and Lodging Incidence

Data presented in Table 6 reveal that the leaf blast (spindle-shaped lesions with gray center on leaves) disease was observed in the field, which was mainly caused by *Pyricularia oryzae* Sacc. fungi. The average damage scores of the five locations as per the SES values for this disease were 7 for BRRI dhan28 and 6 for BRRI dhan58, 63, and 74, while BRRI dhan67 was scored 1. Moreover, the bacterial leaf blight disease (wavy yellow marginal necrosis of leaves) caused by *Xanthomonas oryzae* Ishiyama. bacteria was found in the field. The severity scores of this disease were 3 for BRRI dhan63 and 67 and 5 for BRRI dhan58 and 74, but 7 for BRRI dhan28.

We observed "dead heart" symptoms at the vegetative and "white head" symptoms at the reproductive phase in the field caused by the rice yellow stem borer (*Scirpophaga incertulas* Walker) insect. As per the SES recommendation (Table 6), the infestation score for this insect was 5 for BRRI dhan28 and 3 for BRRI dhan58, 63, and 74. On the other hand, score 1 was recorded in BRRI dhan67. Furthermore, the infestation of rice bugs (*Leptocorisa acuta* Thunberg) insect was also found during the milking stage of the paddy. Field scoring based on the percent of chaffy rice for this insect was 7 for BRRI dhan28 and 58, 5 for BRRI dhan74, 3 for BRRI dhan63, and 1 for BRRI dhan67.

Table 6. SES scoring of diseases and insects, and lodging percentage of varieties (average of 15 farmers).

Varieties	Leaf Blast	Leaf Blight	Rice Yellow Stem Borer	Rice Bug	Lodging (%)
BRRI dhan28	7	7	5	7	45
BRRI dhan58	6	5	3	7	40
BRRI dhan63	6	3	3	3	0
BRRI dhan67	1	3	1	1	0
BRRI dhan74	6	5	3	5	0

For blast, 1: small brown spots of pinpoint size, 6: blast on 11–25% of leaf blades, 7: blast on 26–50% of leaf blades; for blight, 3: 6–12% of leaf blade infected, 5: 13–25% of leaf blade infected, 7: 26–50% of leaf blade infected; for borer, 1: 1–10% dead heart, 3: 11–20% dead heart, 5: 21–30% dead heart; for bug, 1: <3% injured grains, 3: 4–7% injured grains, 5: 8–15% injured grains, 7: 12–25% injured grains.

Among the tested varieties, about 45% of lodging was recorded in BRRI dhan28, whereas the lodging percentage of BRRI dhan58 was about 40%. The remaining varieties were found to be lodging tolerant (Table 6).

3.5. Reaction of Farmers and Extension Workers

Based on the overall performance of each variety, participating farmers and extension personnel scored 7 for BRRI dhan28, 5 for BRRI dhan58, and 3 for BRRI dhan63 and 74. On the other hand, BRRI dhan67 performed the best, and earned a score of 1 (Table 7). Although BRRI dhan74 was the highest yielder among the tested rice varieties, they preferred BRRI dhan67 for its medium and slender grain, shorter growth duration, resistance to cold and lodging, less disease, and fewer insect outbreaks. Some neighboring farmers were motivated to cultivate BRRI dhan67 and 63 in the next season by collecting seeds preserved (5 kg) by the participating farmers. They also opined to grow BRRI dhan74 in case of the unavailability of the seeds of BRRI dhan67 and 63 for commercial purposes, but not for their own consumption due to its bold grains, which might not be palatable to eat as per their opinion.

Table 7. Farmers' preference scores for different rice varieties.

Variety	Score [1]	Reason
BRRI dhan28	7	Higher rate of leaf blast, bacterial leaf blight (BLB), rice yellow stem borer (RYSB), and rice bug and lodging, poor yield
BRRI dhan58	5	Longer growth duration, lodging, RYSB attack
BRRI dhan63	3	Smallest plant not ideal for straw for cattle feed Rosette morphology, leaf blast and rice bug attack
BRRI dhan67	1	Shorter growth duration, resistance to lodging, less disease and insect infestation, medium and slender grain
BRRI dhan74	3	Bold grain is not palatable to eat, rice bug attack

[1] 1: Excellent, 3: Good, 5: Fair, 7: Poor [6].

4. Discussion

4.1. Days to 50% Flowering (DTF) and 80% Maturity (DTM)

The DTF and DTM refer to a cultivars' genetic potential [13], which means cultivars with a long duration take longer to flower than cultivars with a short duration. Additionally, temperature change affects the time of flowering days. Stressed plants exhibit a shift in their physiological order of growth performance, resulting in a different time to flower and mature [14]. These two parameters are considered for genotype evaluation and varietal release processes. Additionally, DTM is a very important component of a cropping system, as the early maturing crop determines the early evacuation of land for subsequent harvests and avoiding insect pest assault. Natural disasters such as flash floods, cold, and heat stresses may be avoided by producing early maturing rice, and vice versa. Although a cultivars' lifetime is determined by its genetic composition [15,16], agronomic management and edaphic and climatic conditions affect the length of flowering and maturity [17]. The results of this study confirmed the previous results of variation in DTF and DTM amongst rice genotypes [3,18]. Karmakar et al. [19] also found comparable findings for genotype-specific changes in DTF and DTM of rice varieties.

4.2. Plant Height

Rice breeders, agronomists, and physiologists emphasized plant height because grain production and plant height are inextricably linked in the formation of new plant types [20]. Since farmers utilize rice straw as cattle feed, plant height is a proxy for straw yield, a more commercial commodity; they prefer cultivars that provide a bigger yield and more straw. Farmers' optimum plant height should be more than 100 cm [21]. Chhogyel et al. [22] also said that the optimal plant height for rice would be between 105 and 115 cm tall. Five of the test types grew to a height of around 89–107 cm in the present experiment, making them appropriate for farmers and qualifying them for additional testing, examination, and appraisal as a donor for future rice variety creation and/or enhancement through molecular rice breeding. The findings of this research corroborate the earlier findings of Das et al. [23] and Khatun et al. [24], who observed varying plant heights among rice varieties. Rasheed et al. [25] observed similar results for genotype-specific plant height differences in rice.

4.3. Paddy Yield

Yield is the most critical final feature when evaluating and screening rice varieties. Breeders, agronomists, physiologists, and researchers all aim to increase or optimize grain yield. Rice varieties with high yield potential and other fundamental characteristics offer a foundation for large-scale adaptation [26], as yield varies according to the varieties' genetic makeup [27]. Tahir et al. [28] showed large differences in rice grain yield owing to variance in many yield-contributing variables and concluded that these parameters were influenced by genotypic variation across genotypes. Significant changes in other metrics were also seen amongst the genotypes examined. There was also considerable diversity in grain yield across the twelve coarse rice genotypes [29]. In addition, this variance in grain yield could also be explained by environmental factors [30].

Rice varieties have excellent agronomic characteristics such as plant height, maturity time, and tillering ability [31], as well as disease and insect pest resistance [32], and are capable of producing greater yields under optimal management approaches [33]. The genotypes have the genetic potential to generate more efficient tillers per hill and a greater number of robust grains per panicle, which are thought to contribute to the increased grain production of rice [34,35].

Although we did not record the number of grain-producing tillers per hill, the length of panicles, the number of grains per panicle, and the weight of 1000 grains in this study but the previous reports indicate that the longer panicle has the capability of producing a greater number of effective tillers and a greater number of grains [36,37]. This may have contributed to BRRI dhan74 and 67 producing a better grain yield than the other varieties examined in this research. On the other hand, poor tillering, fewer grains per panicle, and a low seed weight may explain why BRRI dhan28 yielded so poorly in our study. Hargrove and Coffman [38] suggested that IR 8, a semidwarf better-yielding rice variety, was the paradigm for all current kinds farmed today. IR8 produced 9.4 t ha^{-1} grain yields under optimal management and was the first higher-yielding rice variety to alter the global food situation. Thus, current breeding and varietal development aim to produce greater-yielding cultivars. The assessments should be repeated annually in farmers' fields to determine which popular old rice types should be replaced.

4.4. Diseases, Insects, and Lodging Incidence

The level of disease and insect damage, as well as yield loss, may be impacted by a number of variables, including varietal genetic makeup for pest resistance, pest population density, crop development stage, and growing circumstances [39]. For example, Rubia Sanchez et al. [40] observed fewer attacks of stem borers in shorter-panicle-producing varieties than in the longer-panicle-producing types. Furthermore, climatic circumstances significantly affect the creation, development, and severity of disease and other pests, resulting in extensive genotype–environment interactions [41].

Rice disease and insect damage may be reduced by cultivating resistant cultivars, which is a primary strategy in integrated pest control [42]. Genetic resistance to diseases and insects is a plants' heritable property that protects from insect and disease damage. Rice breeding aims to develop resistance to many diseases and insects, significantly reducing pesticide use and harm to rice. Rice breeders, agronomists, pathologists, and entomologists collaborate to screen and develop breeding materials for disease and insect resistance, with breeders developing, agronomists growing and managing field trials, and pathologists and entomologists inoculating and evaluating the breeding lines' resistances.

The visual lodging percentage varied according to the variety in this study. The higher lodging index of rice was ascribed to the taller plant height and the poor breaking strength with shorter internodes. Moreover, the longer extended basal internodes contributed to the plants' increased height and lodging index [43]. Additionally, the same author claimed that the weight of the canopy impacts a plants' lodging sensitivity. Thus, plant height is not a key element in determining lodging hazards [44]. For example, Okuno et al. [45] discovered decreased stem stiffness in semidwarf rice genotypes when the culm diameter and thickness were reduced. Ma et al. [46] investigated the optimal internode length in rice that would maximize lodging resistance. On the other hand, robust rooting ability with stronger soil anchorage makes the rice resistant to lodging [47]. Thus, the weak culm with the dense canopy and poor rooting ability may have contributed to the variation in lodging incidence across the studys' rice varieties.

5. Conclusions

BRRI dhan67 was found to be an excellent variety based on its overall performance, yield stability, growth length, pest resistance, phenotypic acceptability, and, most importantly, farmer choice. Farmers should be involved in selecting the best varieties by testing them on their farms. This would be both effective and efficient. Ultimately, farmers are the ones who will use a new variety, so the decision of the farmers should be considered when evaluating a variety. This is because the farmers' willingness to grow a new variety is what determines whether the variety will become popular. Finally, it is suggested that BRRI dhan67 may be appropriate to replace the countrys' current mega variety, BRRI dhan28. Moreover, BRRI dhan74 may also be cultivated in case of the unavailability of the seeds of BRRI dhan67. Even though this was a single-season study, the promising results made it clear that more participatory varietal replacement trials should be conducted across the country to find the best new variety(s) to replace the old one. The farmers could be motivated to cultivate BRRI dhan67 by conducting field demonstration trials in different agroecological zones across the country.

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