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Rice Variety Preferences in Bangladesh – What is the Role of Public Breeders?

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study compared preferred rice varieties by millers and farmers in Bangladesh, hypothesizing that public breeders would focus on public goods like disease resistance, whereas private breeders would focus on profits in the entire chain. Primary data were collected from 99 farmers and 68 millers, who are among the key stakeholders in the rice production system. A four-point rating scale was designed to assess the level of preference for different traits of the selected rice varieties. It was found that farmers who prioritize disease resistance prefer the public over privately bred Aman

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rice varieties. In general, they prefer rice varieties that are high yielding, have high market value and are of short duration while millers prefer rice verities considering the size and shape, color, and milling performance of the grains. Most significantly, millers prefer privately bred rice varieties if compared to farmers. It can be concluded that public rice breeders should take efforts to also consider the needs of intermediaries in the chain.

Keywords: Preference; rice variety; varietal traits; public breeders; private breeders.

1. INTRODUCTION

Most crops being grown on the world's arable land have been bred by private enterprises [1]. However, there are exceptions to this rule. For some crops, in particular perennial ones, the time lag between starting breeding and making a profit is too long to be attractive, so public breeders jump in [2,3]. Another exception is rice in South East Asia. Both international actors like IRRI and national research organizations are active in providing a major share of rice species used for production [4,5].

It has been suggested that public breeders should put more emphasis on the integration of public good aspects into their work as compared to private enterprises, so that varietal resistances, for example, should be more important traits than yield [6]. However, this has remained a normative framework so far. It is unclear to what extent the objectives of public breeders really differ from private enterprises' breeding objectives.

Different actors in the food value chain have different demands on the attributes of a variety. In the case of rice, for example, rice that grows well as is resistant to a large scale of diseases and insects is not necessarily well suited for milling. In the case of privately bred varieties, it can be assumed that the "invisible hand of the market" will lead to varieties being adapted to the needs of both farmers and millers. But does this also apply to the work of public breeders?

To shed light on these questions, this paper uses the case of the rice chain in Bangladesh. The structure of this chain, with particular respect to breeders, is sketched in Section 2. Rice production is influenced by the preferences of both producers and consumers [7], explicitly including the role of intermediates, in particular millers whose role in securing the supply in the rice chain increasingly gets attention [8,9]. While knowledge of farmers' preferences is an important factor to understand the successful adoption of improved rice varieties [10], the same will apply to the preference of millers. Section 2 then describes the method of how the strength and weaknesses of public and private breeders can be evaluated. Section 3 displays the results and discussion, and Section 4 concludes.

1.1 The Rice Chain in Bangladesh

Rice is not only the main food of half of the world's population [11], but also the staple food for Bangladesh and a strategic crop for ensuring food security [12]. Its contribution to Bangladeshi agricultural GDP is about 70% while its share of total national income is one-sixth [13]. Rice is produced in Bangladesh mainly in three seasons: Aus, aman, and boro. In Bangladesh, aus is the pre-monsoon season of rice cultivation and aman is the wet season. Aman is transplanted with shorter-duration varieties in shallow flooding depths and directly seeded as an upland crop from March to May in deep flooding depths. The plant then grows in floodwater from June to September and is harvested after the floodwater recedes from November to December. Boro rice is a dry-season irrigated rice. Boro was traditionally produced on very low-lying land (unsuitable for cultivating any crop during the monsoon season), transplanted in November following the receding flood water, and harvested in April– May [14].

Public breeders are very active to deliver new varieties to the market. They comprise two sorts of actors: The International Rice Research Institute (IRRI) is part of the UN-financed CGIAR institutes [15] and is most active in the release of rice varieties [16]. On the national level, both the Bangladesh Rice Research Institute (BRRI) [17] and the Bangladesh Institute for Nuclear Agriculture (BINA) [18] are also active to breed, mainly using inputs from the IRRI.

A new variety is often released to replace an old variety that has become susceptible to insects and diseases. It does not necessarily have to be a higher-yielding one [14]. Many factors influence a farmer's choice of rice variety. In addition to yield, farm size, tenure status, and education,

access to extension services and credit facilities have a major influence on the varietal preference of farmers [19]. Rice variety preferences are primarily influenced by factors such as yield, market value, pest resistance, adaptability to various types of soil, aromatic features, fertilizer use, etc. Also, farmers' choices of rice varieties depend on the grain quality preferences of consumers and other actors in the rice value chain such as millers, traders, wholesalers, and retailers. In the 2017–18 Boro (dry season), IRRI distributed tons of improved seeds of stress-tolerant rice varieties in Bangladesh and observed a prominent impact on farm income, food security and livelihoods of rice farmers [20]. A high level of farmers' perception was identified for rice straw utilization which also led to a positive effect on agriculture and the surrounding environment [21]. In addition, rice varietal traits such as high yield, disease resistance, drought tolerance, good cooking and eating grain quality, aroma, earliness to maturity and high market value were preferred by farmers [22]. So, different factors have considerable effects on farmers' perceptions of rice varieties.

Far less conclusive evidence exists on the preferences of rice millers. Millers' preferences for procurement of rice varieties were assessed in Tamil Nadu and reported that 'fineness' and 'high milling return' were the major deciding parameters for procurement by rice millers [23]. Rice millers prefer varieties with high milling and head rice out-turn, whereas consumers consider physicochemical qualities [24]. Paddy needs to be processed after harvesting for consumption. Before milling rice, all the processes including cleaning, parboiling, soaking, steaming, and drying of paddy are needed. These processes have important implications for the nutrient content of milled rice. When it comes to 'excellent rice quality', 39% of millers consider it should be clean, 35% feel it should not be broken, and 26% think it should have slender grain. 79% of millers polish rice once to ensure good quality, which is the minimum requirement to make rice eatable [25]. However, 21% of millers polish rice more than once to make the grains whiter and thinner. Bangladesh's per capita income has improved rapidly in recent decades. As a result of rising income levels, more people are now interested in processed rice since it looks glossy, takes less time to cook, is free of stones and dead rice, and has a longer shelf life. To meet the demand of the people, new automatic rice mills are being set up at a mounting rate. Thus, rice millers need to take significant steps to keep up with the consumers' demand. While the channels of communication between IRRI and farmers are well established [26], IRRI and other public breeders may be less attached to the needs of millers.

To understand the millers' and farmers' overall lifestyles and the reasons behind their preference for different rice varieties, a survey of rice growers and millers was carried out. The objective of the study was to identify and compare the salient features of various rice varieties preferred by the millers and farmers. With regard to the research questions formulated above, the following three hypotheses are formulated:

H_1: Bangladeshi farmers prioritizing public good attributes like disease resistance will rather prefer publicly bred varieties, whereas

H_2: Bangladeshi farmers prioritizing market value will rather prefer privately bred varieties.

H_3: Millers, as compared to farmers, will rather prefer privately bred varieties.

2. METHODOLOGY

The study was conducted in four geographical regions viz. northeast, northwest, central, and coastal regions of Bangladesh. With the help of the International Rice Research Institute (IRRI), eleven districts such as Barishal, Bogura, Faridpur, Gaibandha, Moulvibazar, Satkhira, Sunamganj, Sherpur, Dinajpur, Jhenaidah, and Bhola were selected as the regions of the study. IRRI has been playing an active role in the above-mentioned areas for the awareness and promotion of promising rice varieties.

A list of rice millers and farmers was collected from IRRI, Bangladesh, and 68 rice millers and 99 farmers were selected unbiasedly from 340 millers and 495 farmers, respectively for primary data collection. A proportionate stratified random sampling technique was followed for the selection of the respondents. To collect reliable and valid information from the respondents, a semi-structured interview schedule was prepared meticulously keeping the objectives of the study in mind. The schedule contained both open and closed-form questions. It was pre-tested under field situations and necessary corrections and modifications were made accordingly. Data were collected through face-to-face interviews with

farmers and millers by a team of researchers. Qualitative data were converted to quantitative form using suitable scoring. Data were presented either in graphical or tabular forms.

To understand the socio-demographic conditions of both respondent millers and farmers, the actual age of the respondents was recorded and categorized [27].

The level of knowledge in rice cultivation was measured by asking twelve questions, each assigned score of two. A respondent obtained a full score against each question for the right answer, 0 (zero) for the wrong answer and a partial score for a partially correct answer. The opinion of millers and farmers was used to calculate preference percentage based on four levels of agreement (never considered, less preferred, moderately preferred, and highly preferred) against a list of selected factors, and the *Chi*-square test was used to test the association between levels of preferences of different traits.

Table 1 describes the variables used for our analysis in order to test the three hypotheses. The dependent variables were constructed by calculating the share of publicly bred varieties preferred by the farmer and miller. This index was explained in two steps. In the first step, the subsample of farmers was used to examine how the preference for a typical private good (market value) and a typical public good (disease resistance) would influence the preference for either privately or publicly bred varieties. In the second step, the sociodemographic characteristics of respondents, including their role as either farmers or millers, were used to explain the preference for either publicly or privately bred varieties. In this case, we found it important to include control variables like knowledge and age that were skipped for the analysis of the subsample due to the sample size. The shares were explained by using the ordinary least square method, the software was Stata 17.

Table 1. Variables of the study

Variable	Meaning	Measurement	Mean	Minimum	Maximum
Dependent variables					
Share aman	Preference shares of public varieties for Aman rice	Number of public varieties divided by the number of total varieties	0.817	0	1
Share boro	Preference shares of public varieties for Boro rice	Number of public varieties divided by the number of total varieties	0.906	0	1
Independent variables for farmers only					
Disease resistant	Importance of insect resistance	Rank within 15 attributes, 1 for highest, 15 for lowest preference	7.63	2	15
Market value	Importance of market value	Rank within 15 attributes, 1 for highest, 15 for lowest preference	3.65	1	15
Independent variables					
Miller	Respondents' profession	0 = farmer 1 = miller	0.414	0	1
Knowledge	Respondents' level of knowledge	$Score$	14.9	1	25
Age	Respondents' age	Years	43.4	19	80
Gender	Respondents' gender	1= male; 2= female	1.17	1	2
Own land	Owned farmland	Ares	391	7	8000

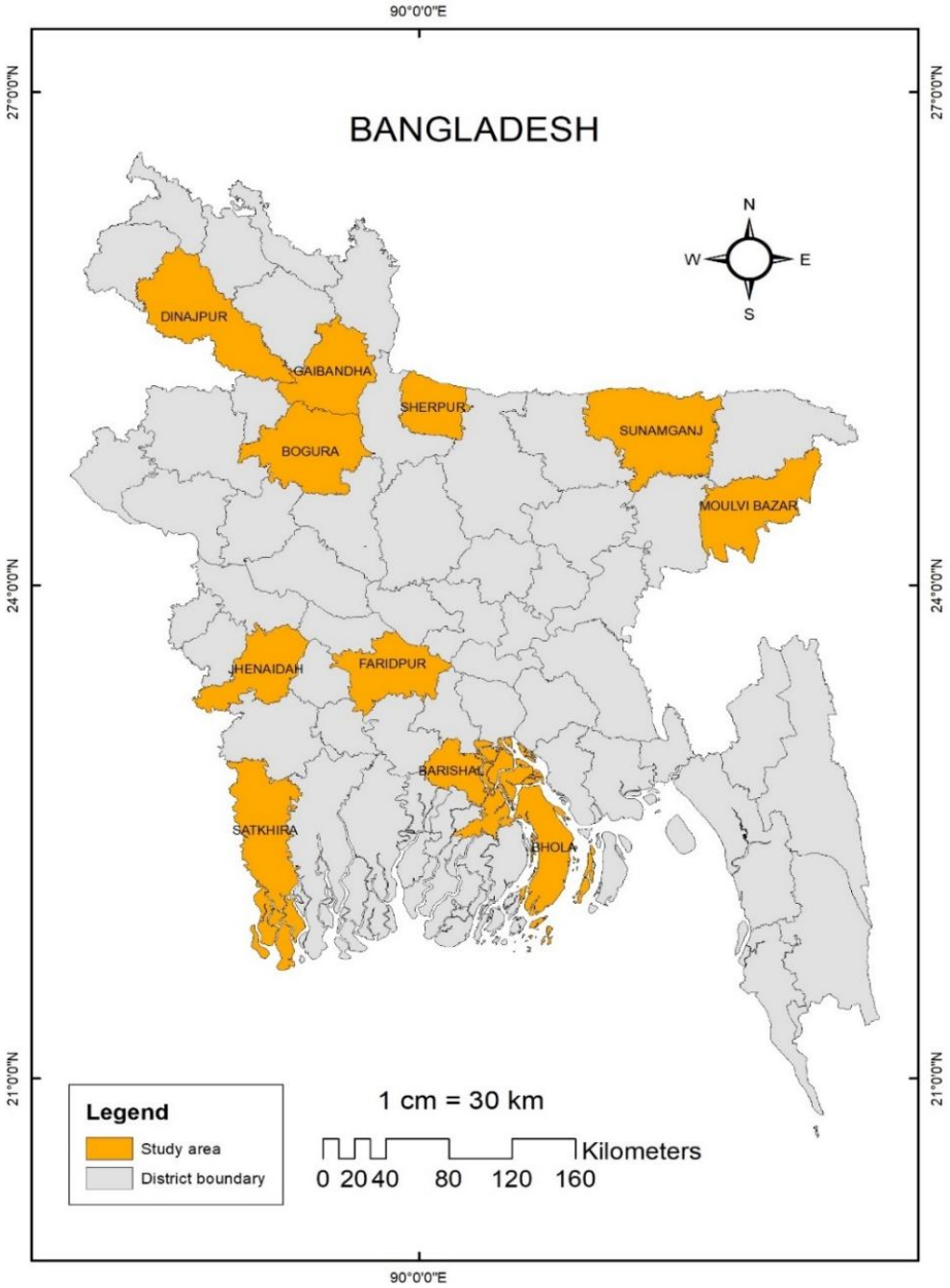

Fig. 1. A map of the study area

3. RESULTS AND DISCUSSION

3.1 Descriptive Findings

In aman season, millers from all around Bangladesh mostly preferred to mill BRRI dhan51, and BINA dhan11, while specific rice varieties were favourites in distinct parts of the country. Millers' inclination to publicly bred rice varieties was dominant in all the regions but private breeders' varieties were demandable in north-western Bangladesh (Fig. 2).

The overall preference of millers for aman rice varieties was higher for the public breeders and only 3 to 7 percent looked for private breeders. The regional information on aman varieties compared that around 60 percent of millers in north-west Bangladesh milled BRRI dhan49 and Sharna 5, while BINA dhan11 (51%) and Pazam

(39%) were the most popular aman varieties in north-east Bangladesh. In addition, BRRI dhan49 was a popular aman season rice variety in Bangladesh because of its high yield and medium slenderness [28]. Millers from the north-western region preferred to mill a wide range of privately bred rice varieties which might be because of the higher market share of private companies in that region. However, Pazam and Tulshimala were considered favourites only in the north-eastern side of Bangladesh whereas public breeds viz. BRRI dhan49, BRRI dhan75, and BINA dhan17 were among the least popular varieties in that region.

In coastal areas of Bangladesh, BRRI dhan49 and BRRI dhan51 were the two public breeds which occupied three-fourths of the millers' choice of rice varieties, which were well above the millers' overall around Bangladesh. As most of the government rice breeding organizations are situated in central Bangladesh, millers in the central region only showed interest in public breeds. This means that demand for public and private breeds could be driven by the market share, which obviously differs between different regions (Fig. 2).

It is obvious from the graph in Fig. 3 that the farmers' preference for aman rice in Bangladesh is mainly focused on public breeders because farmers have a long trustworthy relationship with government organizations and they supply good quality seeds at cheaper prices. On the contrary, rice seeds from private breeders are comparatively superior in terms of yield but the cost of private rice seeds is more than twice that of the public breeders.

Overall farmers' preference for public breed aman rice varieties fluctuated for different varieties. Most of the promising new varieties were more widespread in northeast and central Bangladesh. BINA dhan11 was found to be the widely preferred variety for all the regions of Bangladesh, but, farmer's choice of BRRI dhan51 and BRRI dhan52 might get influenced by the special trait of submergence tolerance in all the regions except central, as flooding, water logging is not a common scenario in that part of Bangladesh. Special traits of varieties developed by public breeders viz., BINA dhan17 has a drought-tolerant feature, BRRI dhan75 has aromatic grain, and BRRI dhan87 has a slender grain size which instigates farmers' choice of rice varieties. In addition, these varieties were highly popular (above 50%) among the farmers in the central region [29] especially the Faridpur district due to their yield superiority (Fig. 3).

In the north-western part, almost half of the farmers preferred BRRI dhan51 and all the other rice varieties were available to the farmers. Lastly, between 34 to 39 percent of the farmers of the southern coastal region preferred BRRI dhan52 as a submergence-tolerant, and BINA dhan11 as a saline-tolerant rice variety [30], which is reasonable because saline water intrusion and flooding are more common in coastal areas (Fig. 3).

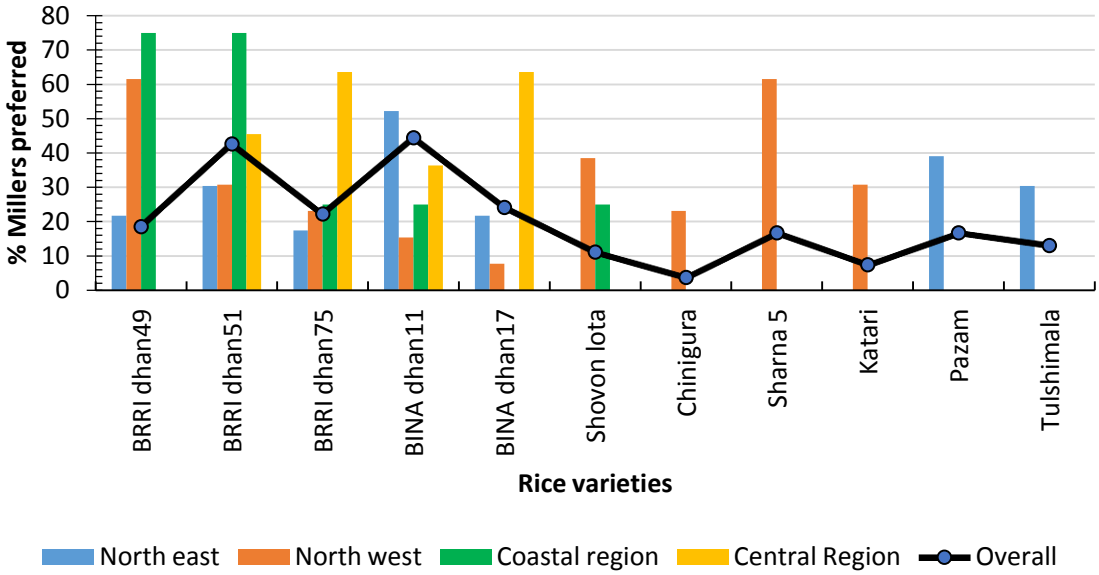

Fig. 2. Comparison of millers' preference for aman rice varieties in four regions of Bangladesh

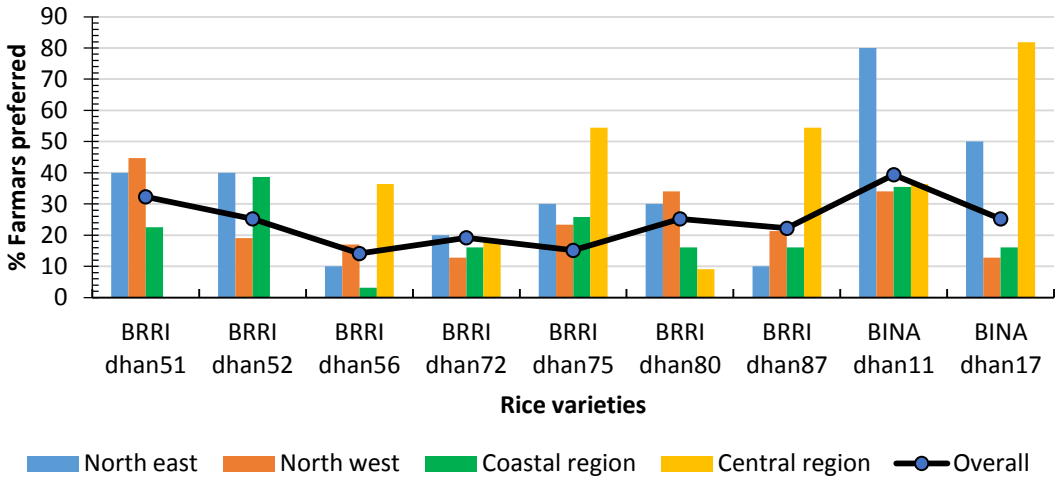

Fig. 3. Comparison of farmers' preference for aman rice varieties in four regions of Bangladesh

Rice varieties for the dry season such as; BRRI dhan58, BRRI dhan74 and BRRI dhan88 were well known in all the regions, while BRRI dhan28 and BRRI dhan29 were the most in Bangladesh except for coastal areas. Despite knowing the promising modern rice variety BRRI dhan92 has similar characteristics as BRRI dhan29, millers are not much open to milling the variety because BRRI dhan29 has helped millers to gain more profits since it was launched in the markets (Fig. 4).

All the public breed rice varieties mentioned in Fig. 4 were available in the north-eastern and north-western regions of Bangladesh, but the millers' preference for BRRI dhan28 and BRRI dhan29 were highest for all the regions except for coastal areas. The level of preference of coastal millers was well above the average rate of preference for boro rice varieties. The most (75.0%) preferred rice varieties for millers were BRRI dhan58 and BRRI dhan89 in the coastal areas, while half of them chose to mill BRRI dhan81 and BRRI dhan88 (Fig. 4). The popularity of high-yielding varieties is increasing in the coastal region due to fewer saline water intrusions over the last few years.

It is obvious in Fig. 5 that BRRI dhan28 and BRRI dhan29 are the two mega rice varieties for the boro season cultivated all around the country as these varieties have proven their improved ability to perform in versatile environments over the years.

Public breeds viz., BRRI dhan88, BRRI dhan84, and BRRI dhan58 got promising interest from the farmers in both of the northern regions, but Katari (29.79%) was the only popular private breed that was cultivated in the northwest of Bangladesh for its drought tolerance ability as this region has a history of drought problems. In the coastal region, BRRI dhan74 (38.7%) had a better adoption rate as it is a saline-tolerant rice variety, but in recent years, farmers didn't face any saline water intrusion into their farmlands that's why other high-yielding varieties are providing good yield performance in the coastal districts of Bangladesh.

Rice farmers and millers often prefer cultivating rice types that exhibit distinctive characteristics. They want the new promising rice varieties to be better than the conventional rice varieties, or else they are reluctant to incur the risk of trying new varieties. It is difficult to develop awareness among them because they do not have the necessary education or information, and have a tendency to cling to more conventional or proven technologies or practices. That's why we need to know the varietal trait preference of millers and farmers to serve them the desired rice varieties.

Information presented in Table 2 shows there are fifteen different characteristics of rice varieties that influence millers' decisions on varietal choice. Most of the millers who responded (61.3%) thought that the size and shape of rice grains was the most important trait of a rice variety, and the calculated *Chi*-square value (51.68**) for the trait shows that the millers' opinions were very different (Table 2).

'Market demand' is another important trait and millers have ranked it as the second most important trait for a rice variety. Most of the respondents (66.1%) had strong positive opinions about this trait, while 11.3% considered it moderately important. The *Chi*-square value (59.16**) shows that they had different opinions.

The milling percent of the rice grain is another varietal trait that can draw millers' attention. The majority (41.9%) of the millers considered good milling percentage as a highly preferred trait, while 40.3 percent had a moderate preference, and the *Chi*-square value (25.88**) shows that the millers' opinions were isolated (Table 2). So, we can assume that size and shape, market demand, and milling percentage are the three most important qualities of a rice variety that millers take into account when milling different types of rice.

The 'profitability' of the variety was ranked fourth among the varietal traits and the *Chi*-square value 17.09** means the trait's importance varies in millers' opinion (Table 2). 'Rice colour' is another important factor that influences how people like varietal traits. More than half (41.9%) of the millers who answered the survey said they liked it a lot. Another 25.8 percent said they liked it a little bit, and 19.4 percent said they didn't like it at all. The calculated *Chi*-square value (11.55**) shows that the respondents' opinions are significantly different. The final appearance of the milled rice was ranked sixth among all the other important rice varieties and 38.7 percent of the millers highly preferred that trait.

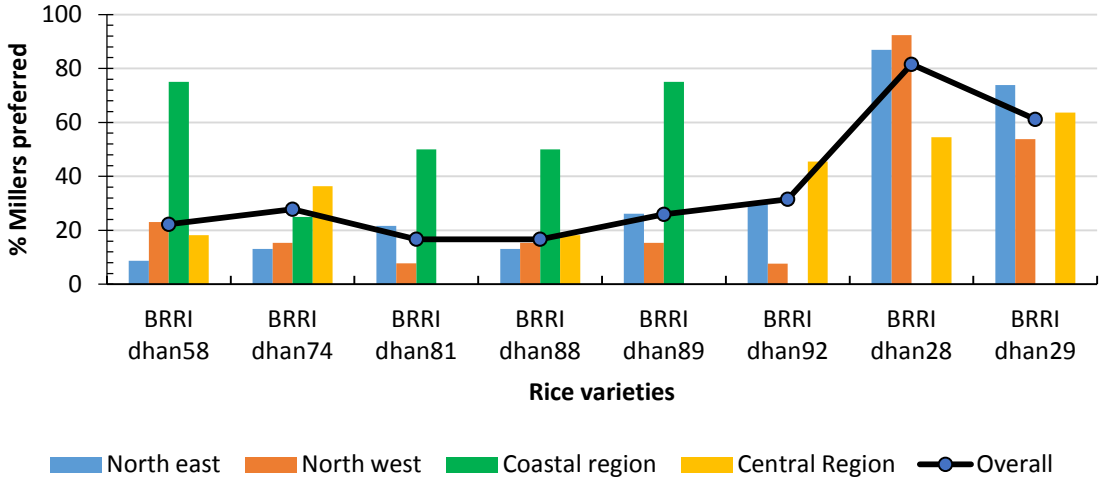

Fig. 4. Region-wise boro rice varieties preference of millers in Bangladesh

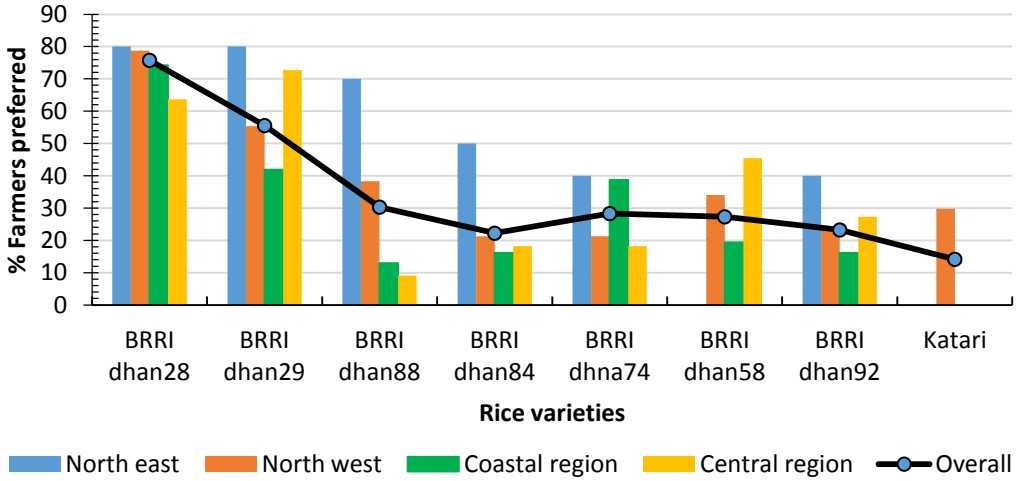

Fig. 5. Region-wise boro rice varieties preference of farmers in Bangladesh

Table 2. Distribution of respondent millers according to their trait preference of rice varieties and ranking

Sl. No	Preferential traits	Level of preference (% respondents)				Mean	Rank	*Chi*-square value
		NC*	LP	MP	HP			
i.	Size and shape	3.2	8.1	27.4	61.3	2.47	1st	51.68**
ii.	Market demand	3.2	19.4	11.3	66.1	2.40	2nd	59.16**
iii.	Milling percent	8.1	9.7	40.3	41.9	2.16	3rd	25.88**
iv.	Profit	9.7	14.5	35.5	40.0	2.06	4th	17.09**
v.	Rice colour	12.9	19.4	25.8	41.9	1.97	5th	11.55**
vi.	Final appearance	12.9	21.0	27.4	38.7	1.92	6th	8.83*
vii.	Breakage	12.9	25.8	37.1	24.2	1.73	7th	7.29(NS)
viii.	Availability	14.5	32.3	24.2	29.0	1.68	8th	4.45(NS)
ix.	Drying	24.2	19.4	32.3	24.2	1.56	9th	2.12(NS)
x.	Aroma	21.0	22.6	38.5	17.7	1.53	10th	6.51(NS)
xi.	Boiling	24.2	27.4	21.0	27.4	1.51	11th	0.71(NS)
xii.	Storability of rice grain	21.0	45.2	14.5	19.4	1.32	12th	14.00**
xiii.	Bran percent	29.0	35.5	16.1	19.4	1.26	13th	5.87(NS)
xiv.	Storability of milled rice	35.5	17.7	33.9	12.9	1.24	14th	9.61*
xv.	Husk percent	27.4	43.5	16.1	13.0	1.15	15th	14.25**

Note: NC=Never Considered, LP=Less Preferred, MP=Moderately Preferred, HP=Highly Preferred, NS= Not Significant, **= Significant at 1% level and *= Significant at 5% level*

Table 3. Distribution of respondent farmers according to their trait preference of rice varieties and ranking

Sl. No	Preferential traits	Level of preference (% respondents)				Mean	Rank	*Chi*-square value
		NC*	LP	MP	HP			
i.	High yield	3.0	2.0	5.1	89.9	2.82	1st	222.58**
ii.	Market value	5.1	6.1	11.1	77.8	2.62	2nd	147.91**
iii.	Duration	6.1	5.1	21.2	67.7	2.51	3rd	102.66**
iv.	Shape and size	6.1	8.1	33.3	52.5	2.32	4th	58.29**
v.	Insect resistant	6.1	7.1	55.6	31.3	2.12	5th	65.48**
vi.	Lodging resistant	10.1	7.1	54.5	28.3	2.01	6th	56.51**
vii.	More tiller	10.1	12.1	46.5	31.3	1.99	7th	35.18**
viii.	Disease resistant	11.1	9.1	50.5	29.3	1.98	8th	44.15**
ix.	Edibility	8.1	29.3	28.3	34.3	1.89	9th	15.95**
x.	Nutritional quality	7.1	34.3	38.4	20.2	1.72	10th	24.19**
xi.	Submergence	8.1	38.4	30.3	23.2	1.69	11th	19.67**
xii.	Straw quality	10.1	36.4	37.4	16.2	1.59	12th	23.06**
xiii.	Weed resistant	9.1	41.4	36.4	13.1	1.53	13th	31.38**
xiv.	Drought	11.1	45.5	23.2	20.2	1.52	14th	25.24**
xv.	Aroma	6.1	52.5	26.3	15.2	1.5	15th	48.11**

Note: NC=Never Considered, LP=Less Preferred, MP=Moderately Preferred, HP=Highly Preferred, NS= Not Significant, **= Significant at 1% level and *= Significant at 5% level*

Millers' preference for several varietal traits such as breakage of grains, availability, aroma, drying, boiling, and bran percent had shown an insignificant association among the levels of preferences. The difference among the levels of preference for storing raw paddy and husk percent of the grain was found highly significant (1% level), while the majority (45.2 and 43.5%, respectively) of the millers' least preferred features were these two traits (Table 2).

An overview of Table 3 reveals that farmers' preferences vary to the traits of rice varieties. Most of the farmers who answered the survey (89.9%) thought 'high yield' was the most important trait for a rice variety. Another 5.1 percent thought it was important, but not as much. The few farmers who didn't think it was important either never thought about it or the least preferred it. So, 'high yield' has become a key trait for a rice variety for its wider adoption. The *Chi*-square value (222.58**) shows that the

farmers have very different ideas about the yield of rice. Also, the lack of accessibility to high-yielding rice varieties caused the increased costs of rice in the value chain, resulting from the conversion of low paddy quality to high rice quality [31].

The second most preferred trait is the 'market value' of the rice grain, which according to two-thirds (77.8%) of the sample farmers was important when choosing a variety. The value of *Chi*-square (147.91**) is very high and indicates that farmers have very different opinions on market value too. Traits like high yield, market value, etc. are the main reasons why certain varieties are very predominant.

'Duration or life span' is one of the most important traits of a rice variety, as agreed by 67.7 percent of the farmers who answered the survey, and another 21.2 percent considered the trait moderately important. For more than half the respondents (52.5%) the 'size and shape' of rice grain was a very important trait. The *Chi*-square value (58.29**) is high enough to indicate a difference in opinion on this trait. Other traits, like 'submergence tolerance,' 'straw quality,' 'weed resistance,' 'drought tolerance,' and 'aroma,' are less important when farmers choose rice varieties. Submergence tolerance and drought tolerance, on the other hand, are most important to farmers in areas that face flooding and drought issues, respectively. When compared to the other traits, the *Chi*-square values (19.67**, 23.06**, 31.38**, 25.24**, and 48.11**) are lower. However, the values are significant at a 1% level of significance, which shows that farmers had different points of view on these sets of traits as well (Table 3).

Different studies on traits of rice varieties corroborate the findings of this study. They found high yield as the most preferred trait of a rice variety and "market value", "life duration", "shape and size", and "insect resist" were ranked second, third, fourth and fifth respectively preferred traits [19,22].

3.2 Multivariate Analysis

Table 4 displays the results of the analysis of farmers' preferences. It shows that for Aman rice, Hypothesis 1 cannot be rejected. Farmers who prioritize disease resistance, tend to prefer Aman rice from public breeders. For Boro rice, the sign is the same, but far away from a significant effect. Public rice breeders also found traits such as; high yield, better grain qualities, and tolerance to major biotic and abiotic stresses are the most urgent breeding objectives [32].

Hypothesis 2 has to be rejected. It cannot significantly be shown that farmers prioritizing the market value they get from their rice variety prefer privately bred varieties. Although hybrid rice varieties, which are mostly privately bred in Bangladesh offer significant yield improvements over varietal rice, adoption by farmers remains low and unstable [33].

Table 4. Results of the sub-sample analysis of farmers

	Share aman (n=96)	Share boro (n=93)
Disease resistant	-0.0133* (-2.05)	-0.0005 (-0.10)
Market value	0.0122 (1.60)	0.0007 (0.12)
R^2	0.05	0.00

*Note: *, **, *** and ˚denote p<0.05, p<0.01, p<0.001 and p<0.1, respectively. t-values are placed in parentheses*

Table 5. Result of the regressions of the total sample

	Share aman (n=164)	Share boro (n=107)
Miller	-0.237*** (-4.37)	-0.219*** (-3.69)
Knowledge	0.005 (0.91)	0.002 (0.40)
Age	-0.002 (-0.86)	0.001 (0.68)
Gender	-1.117˚(-1.70)	0.010 (0.22)
Own land	0.000 (-0.32)	0.000 (0.24)
R^2	0.15	0.13

*Note: *, **, *** and ˚denote p<0.05, p<0.01, p<0.001 and p<0.1, respectively. t-values are placed in parentheses*

However, in Table 5 it clearly can be indicated that Hypothesis 3 cannot be rejected. While the control variables hardly play any significant role, it is obvious that farmers are more strongly drawn to publicly bred varieties than millers are.

4. CONCLUSION AND RECOMMENDATION

Millers and farmers from all around Bangladesh liked to cultivate the mega varieties viz., BRRI dhan28 and BRRI dhan29 for the dry season (Boro). In northeast Bangladesh farmers' mostly preferred BINA dhan11 and BINA dhan17, while in addition to these varieties, millers also preferred private breeds viz., Pazam and Tulshimala as aman rice varieties. In the northwest, BRRI dhan49 and Sharna 5 were preferred by millers, and BRRI dhan51 was a favourite among Farmers, whereas in the central region, BINA-invented varieties such as; BINA dhan11 and BINA dhan17 were popular among both millers and framers. Moreover, in coastal areas, BRRI dhan49 and BRRI dhan51 were the priority for millers, while farmers' favourite aman varieties were BRRI dhan51 and BRRI dhan52. However, farmers prefer rice varieties with 'higher yield,' 'higher market value,' and 'shorter crop duration,' while millers consider 'size and shape of the rice grain,' 'market demand' and 'milling performance'.

The study found that farmers and millers had varied preferences in rice varieties, mostly because public research stations are targeting their efforts towards the need of farmers rather than millers. This is not only something that researchers have to bear in mind throughout the genesis, development, and expansion of new rice varieties. It is also something that should remind public breeders to be more strongly linked to the needs of the entire chain rather than to farmers. Therefore, the conventional, less robust rice types need to be replaced with new, potentially superior rice strains. Farmers and millers should have access to different types of rice with desirable characteristics. Our theoretical consideration that public breeders would be more oriented toward public goods like resistance, whereas private breeders would focus on private amenities like market value could only partly be confirmed.

CONSENT AND ETHICAL APPROVAL

The researchers maintained all ethical standards. Prior to each interview, the researchers described the purpose and confidentiality of the data to respondents, and then their verbal consent to provide information voluntarily was taken. The questionnaire content and procedure were properly reviewed by the research team.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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