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Adoption determinants and constraint of BRRI released Aman rice varieties: Evidence from Mymensingh District

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ABSTRACT

This study investigates the prospect and constraint of BRRI developed Aman rice varieties in Bangladesh. To address the objective 13 Upazila of Mymensingh district selected purposively. Farm-level data was collected through farmers' group discussions (FGD) with the key informants and face to face interviews for household surveys. A multistage random sampling technique was adopted in selecting the 780 respondents. Moreover, in total, twenty-six FGDs and interviews of experts were conducted to generate in-depth data and validation of data about the adaptation dynamics of rice varieties in the Aman season. Both the descriptive and inferential statistics were used to process the data. A censored Tobit model was used to measure the adoption intensity of BBRI released Aman varieties. The empirical findings of the study show that farmers adopted about 68 percent of BRRI varieties followed by indigenous (15.6%), other MVs (10.2%), Indian (5.5%), and hybrid (1.3%). Moreover, susceptibility biotic and abiotic stresses, longer growth duration, and unavailability of quality seed were the major reasons for decreasing adoption. But still now among the farmers, the popularity of BRRI varieties has higher. The model result reveals that family size, farm size, easy access to extension services, and better market demand along with higher yield potential, good appearance, higher price, and good taste to eat had a positive significant influence on the widespread adoption of BRRI cultivars in Mymensingh district. Therefore, in the process of varietal development, to develop and disseminate, researchers must consider the preferences of the rice value chain actors and the agro-climatic conditions of the regions. In this regard, due consideration should be given to increased yield potential, biotic, and abiotic stress-tolerant, short to medium growth duration, good market demand.

***Key Words**: Aman season, Adoption, BRRI varieties, Criteria & constraints and Tobit censored regression*

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I. Introduction

Bangladesh is a developing country, and the economy mainly dominated by the agriculture sector. While the share of Gross Domestic Product (GDP) in the manufacturing and service sector has gradually increased, agriculture remains the primary sector of the Bangladesh economy, accounts for 13.31 percent of national GDP and employing 40% of the population (Shiblee, 2011; BBS, 2019; and LFS, 2018). This sector's success has an enormous effect on the country's macroeconomic goals such as poverty alleviation, job creation, and food security. With increased productivity, incipient crop diversification (fruit and vegetables), and almost self-sufficiency in rice production, the people's main staple, this sector performs well (Hassan and Das, 2015).

As a predominantly deltaic country, around 57 percent area of it is cultivable. It has three different intersectional cropping seasons (*Boro*, *Aus*, and *Aman*) and rice is the single most leading crop grown in all these seasons, covering around 77 percent of the total cropped area (Huq et al., 2019). The production of rice almost tripled from 11 to around 35 million tons, putting the nation on the verge of achieving food grain self-sufficiency (Rahman and Al-Amin, 2016). The three rice growing seasons *Aus*, *Aman*, and *Boro* constitute about 8 percent, 39 percent, and 53 percent of the country's rice production, respectively (BBS, 2020). Such harvests almost provided the rice needed to feed 164.6 million people (BBS, 2019). This achievement was based on a significant intensification of farming: modern rice varieties (MVs) now account for 87.54 percent of the rice area harvested; and cropping intensity increased to 200 percent (Nasim et al., 2017 and BBS, 2020).

Though *Boro* and *Aman's* seasonal rice contribute together in the value chains, the share of *Aman* rice's value chain is important. Additionally, *Aman* season rice straw is very essential to fuel and cattle feed for farm households (Kabir et al., 2019). The agriculture sector is, however, extremely vulnerable to the impacts of climate change induced by global warming. The hydro-climatic factors affecting the agricultural sector in the country include rising temperatures, erratic precipitation, decreasing the length of winter, foggy conditions, rising sea level, increasing floods, and increased intensity of cyclones and storm surges (Mondal et al., 2012). Rahman et al. (2017) reported that, in developing countries like Bangladesh, unfavorable conditions could be exacerbated. A study shows that the rice production in *Aman* season may decrease by 0.036, 0.230 and 0.292 tons, by 1 mm increased in rainfall at vegetative, reproductive and ripening stages, respectively (Faroque et al., 2013). Another similar study showed that *Aman* rice production may decline by 2.94, 53.06, and 17.28 tons with an overall temperature rise of 1^0C at the vegetative, reproductive, and ripening stages, respectively (MoEF, 2011).

Therefore, it is now highly vulnerable to cultivate *Aman* rice in Bangladesh. Besides, this population of the country is supposed to be 215 million by 2050 and the nation would have to generate an extra 10.8 million tons of rice (Hussain, 2011). Therefore, supplying additional food from dwindling land and other scared resources to the ever-growing extra population of the country is a major challenge (Rahaman et al., 2018). The best choices may be to eliminate the hurdles to achieving the target are-increasing genetic potentiality, developing location-specific production technologies, minimizing yield gap, and reducing the adoption lag (Kabir et al., 2015). It should mention that public organizations, such as the Bangladesh Rice Research Institute (BRRI), the Bangladesh Institute of Nuclear Agriculture (BINA), and universities in Bangladesh are developing and disseminating modern high-yielding rice varieties, which made an outstanding contribution towards achieving rice self-sufficiency in Bangladesh.

The Bangladesh Rice Research Institute (BRRI) has developed 102 varieties of HYV rice including 7 hybrids so far (BRRI, 2020). Out of 102 varieties, few mega varieties have been popularized and adopted in different seasons, contributing to the lion's share of rice production; but these varieties' yield performance is now under declining trends due to various biotic, a-biotic, and socio-economic constraints. Consequently, it is necessary to assess the causes of the adoption of modern *Aman* rice varieties along with their shortcomings released by BRRI. However, none of the studies was found to address the issues-especially in Bangladesh. Under such a situation, an in-depth study was designed to explore the adoption scenario of varieties and their criteria and constraints, reasons of declining adoption and factors facilitated the adoption of BRRI varieties at the field level with the following objectives- i. Identify the drivers and drawback of adoption of different BRRI released *Aman* rice

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varieties; and ii. Delineate the underlying causes and factors affecting the adoption of BRRI varieties at the farm level.

II. Materials and Methods

Study area

To address the objective, Mymensingh district was selected purposively. All of the Upazilas (13 Upazila) of Mymensing district also selected purposively and thereafter, two Unions from each Upazila were selected randomly for this survey.

Data

The survey has been conducted from April to July 2018. Both primary, as well as secondary data, were employed for the entire analyses of the study. Farm-level data was collected through farmers' group discussion (FGD) with the key informants and household survey. A multistage random sampling technique was adopted in selecting the respondents. Socio-demographic data of 780 sample farm households' farmers were collected to identify factors affecting adoption to the rice cultivars. Moreover, in total, twenty-six FGDs were conducted to generate in-depth data about the adaptation dynamics of rice varieties in the *Aman* season. Besides, an expert panel interview consisting of Sub-assistant Agriculture Officer (SAAO) and Upazila Agriculture Officer (UAO) was conducted to validate the data collected through farmers' group discussion. The selected farmers were interviewed using a pretested structured questionnaire. Both the descriptive and inferential statistics were used to process the data.

Econometric model

The observed adoption choice of agricultural technology (such as BRRI released rice varieties) considered as the findings of a complex set of preference judgments made by farmers. Let the utilities generated from growing BRRI seed technology (BRRI variety) and other rice seed technology (Other MVs) be denoted by U(M) and U(T), respectively. The i^{th} farmer's perception of the varietal-specific characteristics of BRRI seed technology and other rice technology be given by P_{im} and $P_{it,}$ respectively. Let the socio-cultural characteristics and access to information of farm household influencing the adoption decision to be noted by S_i and A_i, respectively.
For simplicity, let these relates be represented as

(1) $U_{Mi} = q(P_{im,} P_{it,} S_i, A_i)$
$U_{Ti} = w(P_{im,} P_{it,} S_i, A_i)$

The optimal proportion of land allocated to BRRI varieties can be derived by satisfying the usual first and second-order conditions needed to maximize the aggregate utility associated with growing different proportions of BRRI seed technology and other rice technology. In this model above, the perception variables are explicitly included in the utility function.

A Tobit model was used to estimate the intensity of adoption of BRRI developed rice varieties. The utility function specified in equation (1) forms the basis for deriving a Tobit model. The model represented below using an index function approach.

(2) $y_i = \beta X_i + \varepsilon_i$
(3) $y_i = 0 \quad \text{if } y_i^* \leq 0$
(4) $y_i = y_i^* \quad \text{if } y_i^* > 0$

where,

y_i a percent area of BRRI seed technology, is the observed choice;
y_i^* is an essential endogenous variable indexing adoption;
X_i represents the vector of socio-cultural, access to information of farm household, and the technology perceptions/ variety specific characteristics of the farmer;
β' is a vector of parameters to be anticipated, and ε_i is an error term.

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The Tobit model is also a broad class of models that has both discrete and continuous parts. It is an extension of the Probit model and it is one of the approaches to dealing with the problem of censored data (Johnston and Dinardo, 1997). The Tobit model can be used to measure not only the probability that a farmer will adopt BRRI varieties but also the intensity of the technology that has been adopted. The estimated coefficients can be further disaggregated to determine the effects of change in the i^{th} variable on the change in the probability of adopting BRRI varieties and the expected marginal effect of explanatory variables on the adoption level. Following (McDonald and Moffit, 1980), it can be shown as

(5) $E(yi) = \theta(z)\, E(y_i^{**})$

where,

$E(y_i^{**})$ is the anticipated value of y_i for the farmers who already have made the adoption decision, and θ is the cumulative normal distribution function at z, where z is $X\beta/\sigma$. The variance of the error term is given by σ^2.

Using the decomposition approach suggested by (McDonald and Moffit, 1980), the marginal effect on the area under BRRI seed technology adoption for those farmers who are already adapters can be estimated as:

(6) $\delta Ey^{**}/\delta X_i = \beta_i [1\text{-}z\, f(z)/\theta(z) - f(z)^2/(\theta(z))^2]$

Where,

f(z) represents the unit normal density.

Model specification:

(7) $Y_i = \beta_0 + \beta_i X_i + \varepsilon_i$

where,

Y = intensity of adoption of BRRI seed technology
X_1 = Age (year) of the respondent
X_2 = Education (year of schooling) of the respondent
X_3 = Household size (number)
X_4 = Marginal farm size dummy (1= marginal farm, 0= otherwise)
X_5 = Small farm size dummy (1= small farm, 0= otherwise)
X_6 = Training dummy (1= received training, 0= otherwise)
X_7 = Distance to local market (Kilometer)
X_8 = Distance to Upazila Agriculture Office (UAO) (Kilometer)
X_9 = Price variation (Tk./kg)
X_{10} = Taste and preference dummy (1= good taste and preference, 0= Otherwise)
X_{11} = Varieties number
X_{12} = Yield variation (Kg/ha)
β_0 *and* β_i parameters to be estimated and ε_i is the error term

III. Results and Discussion

Socio-economic and demographic characteristics of farmers

Table 01 summarizes the socio-economic characteristics of *Aman* producing farmers of the study areas. The results showed that the majority of respondents were adults between 30 and 59 years of age (72.16 percent). However, 59.61 percent of farmers had a family size range of between 4 and 6; compared to a farm hiring situation, this assisted their rice production. Approximately 2.82 percent of respondents graduated while 25.38 percent of respondents did not receive any formal schooling. Findings have also shown that 70.64 percent of the respondents have small farms while 2.56 percent have large farms. Agriculture was the main source of livelihood around 73.20 percent of farm households in the Mymensingh district. Nearly half of the respondent farmers on average had about 21-40 years of farming experience. Farmers in the study area had been affiliates of different social and

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political organizations. Typically, they engaged as members of different social organizations, such as mosque committees, school boards, cooperative societies, field schools for farmers, professional associations, etc. The average distance from home to the nearby market, and Upazila Agriculture Office (UAO) was 4.5 and 5.6 kilometers, respectively.

Table 01. Socio-economic characteristics of the *Aman* producing farmers.

Particulars	Percentage
Age:	
<30 years	15.76
31-39 years	38.84
40-49 years	20.38
50 -59 years	12.94
60 years and above	12.05
Family size:	
1-3 person	16.28
4-6 person	59.61
7 and above person	24.10
Male	47.69
Female	52.30
Education:	
No formal education (0)	25.38
Primary education (i-v)	43.33
Secondary education (vi-x)	18.20
Higher secondary Education(xi-xii)	10.25
Graduate and above	2.82
Farm Size:	
Small	70.64
Medium	26.79
Large	2.56
Occupation:	
Farming as primary	73.20
Farming as secondary	26.79
Farming Experience:	
0-10 years	13.33
11-20 years	26.28
21-40 years	43.58
Above 40 years	16.79
Member of any social organization	2.75
The average distance from home to nearby market (km)	4.5
The average distance from home to UAO (km)	5.6

Note: Farm size has been classified by following the guidelines of (BBS, 2020) as small farm (0.05-2.49 acre), medium farm (2.50-7.49 acre), and large farm (7.50 to above). Data source: field survey 2018.

Performance of *Aman* varieties

Table 02 shows the adoption status of *Aman* rice varieties in the Mymensingh district. In the *Aman* season, the overall adoption of BRRI varieties was about 67.5 percent of the *Aman* area in Mymensingh district where BRRI dhna49 occupied 33 percent area followed by BR11 (10%) and BRRI dhan34 (4%), respectively. Moreover, the adoption of submergence tolerant varieties, BRRI dhan51, and BRRI dhan52 occupied 4-12 percent of areas in Fulbaria, Fulpur, Haluaghat, Gouripur, Sadar, and Tarakanda Upazilas. It was found that the adoption of BRRI varieties was substantially high (64-91%) in the most Upazilas except Dhobaura and Muktagacha. The adoption of local varieties in Dhobaura was about 39 percent of the total *Aman* area followed by BRRI varieties (30%), Indian varieties (13%), and hybrids (12%). Besides, the adoption of BRRI varieties was only 32 percent in Muktagacha, because of higher adoption of Indian variety (35% of total) in particular Madhobi (27%) as it performed (4.68 ton/ha) better than that of BRRI dhan49 (4.48 ton/ha). On the other hand, coverage of BRRI varieties was about 50 percent of the total *Aman* area in Haluaghat due to notable coverage of LVs (20%), other MVs (16%), and Indian varieties (11%) (Table 02).

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Although the adoption of BRRI varieties in Tarakanda Upazila was high (64% of total), the coverage of local varieties was significant (23.5%). Farmers preferred to grow LVs; like Borhafji (5.4%), Kumri (4.3%), Tulshimala (3%), Kalizira (2.8%), and Zirabalam (2.7%) varieties for their home consumption and festival dishes, besides these varieties has higher market demand and also environmental suitability for planting in low lying natural flash flood-prone areas. Similarly, coverage of BRRI varieties in Sadar Upazila of Mymensingh was 68% (Table 02).

Table 02. Adoption status of *Aman* rice varieties in Mymensingh.

Varieties	Upazila													Mymensingh
	1	2	3	4	5	6	7	8	9	10	11	12	13	
BR11	4.1	6.4	4.7	13.4	7.7	4.7	38.7	8.9	8.3	5.7	9.1	4.3	20.9	10.3
BR22	0.0	3.8	0.0	10.1	0.0	0.0	1.4	0.9	2.2	9.0	0.0	17.0	0.0	3.4
BR23	0.0	0.8	0.0	7.0	0.2	0.0	1.2	0.9	0.0	4.0	0.0	0.0	0.0	1.1
BRRI dhan32	4.9	2.1	1.0	3.7	3.3	6.3	1.0	0.0	5.3	5.0	1.9	4.3	0.9	3.1
BRRI dhan34	1.6	5.2	10.6	0.6	11.8	1.7	0.9	5.4	0.0	5.0	12.4	1.7	0.0	4.4
BRRI dhan40	0.0	2.8	1.0	0.0	2.0	1.9	0.0	0.0	0.7	7.5	3.0	0.0	0.5	1.6
BRRI dhan41	0.1	3.8	3.8	0.2	2.9	1.4	0.2	0.0	1.8	4.0	2.7	0.0	0.7	1.7
BRRI dhan49	8.5	37.2	14.3	33.4	46.0	26.6	41.1	13.3	71.4	10.1	20.6	51.0	46.2	32.8
BRRI dhan51	6.1	3.0	9.4	0.6	0.5	2.7	0.5	1.0	0.9	6.0	4.2	0.9	1.8	2.8
BRRI dhan52	4.5	4.3	12.6	0.7	4.7	4.2	0.3	0.9	0.6	10.1	7.5	0.9	1.6	4.1
Other BRRI varieties	0.0	3.0	7.3	4.7	1.1	1.40	1.3	0.7	0.5	1.8	2.4	1.7	0.9	2.0
BRRI Varieties	29.8	72.2	64.6	74.3	80.2	51.0	86.6	32.0	91.7	68.3	63.8	81.5	73.6	67.5
Dhanigold	12.0	0.0	0.2	0.0	0.6	1.3	0.1	1.1	0.0	1.8	1.4	0.0	0.0	1.1
Other Hybrids	0.2	0.0	0.1	0.0	0.0	0.3	0.2	0.4	0.1	0.2	1.1	0.0	0.0	0.2
All Hybrid	**12.2**	**0.0**	**0.3**	**0.0**	**0.6**	**1.6**	**0.3**	**1.5**	**0.1**	**2.0**	**2.5**	**0.0**	**0.0**	**1.3**
Madabi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.9	0.0	0.0	0.0	0.0	0.0	2.1
Ranjit	0.2	3.7	0.0	0.0	0.0	4.3	0.0	4.7	0.0	0.0	0.0	0.0	0.0	1.1
Swarna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.8	0.4	0.0	8.7	1.0
S. Musuri	4.5	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Indian	13.1	3.7	0.0	0.0	0.0	10.7	0.0	35.4	0.0	0.8	0.4	0.0	8.7	5.5
Bina dhan7	3.3	2.8	6.5	4.0	1.0	3.9	1.0	1.7	1.9	3.5	1.0	1.7	3.9	2.8
Binadhan10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Binadhan11	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Binadhan9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Guti IRRI	0.0	0.0	0.0	0.0	0.6	0.0	6.9	0.0	0.9	0.0	0.0	0.0	0.0	0.6
Hori dhan	0.4	6.3	0.0	0.0	6.5	0.2	0.0	23.6	0.0	0.0	3.6	0.0	0.0	3.1
Pajam	2.6	0.3	9.9	0.0	4.0	12.5	1.6	1.4	0.7	0.0	5.1	1.7	1.1	3.5
Other MVs	6.3	9.4	18.5	4.0	12.1	16.5	9.5	26.8	3.5	4.5	9.7	3.4	5.0	10.2
MVs	61.4	85.3	83.4	78.2	92.9	79.9	96.4	95.7	95.3	75.5	76.5	84.9	87.2	84.4
Balam	0.0	0.0	0.0	10.2	0.2	0.0	0.0	0.0	0.0	5.0	0.0	0.0	1.1	1.3
Borhafji	0.0	0.0	2.9	0.0	4.0	0.0	0.6	0.0	1.0	6.0	5.4	4.5	0.0	1.9
Chinisail	14.0	0.0	5.9	0.0	0.0	3.4	0.0	0.2	0.0	0.0	1.4	0.3	0.0	1.7
Fulgazi	0.7	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Kalizira	2.8	1.1	0.5	1.1	0.6	2.3	1.9	0.7	0.4	5.0	2.8	0.3	0.9	1.5
Kumri	0.0	2.3	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.5	4.3	0.3	0.9	0.7
Tulshimala	11.0	0.0	6.8	0.0	0.2	8.2	0.4	0.3	0.0	0.0	3.2	0.0	0.0	2.3
Zirabalam	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.5
Other LVs	4.8	11.3	0.5	10.5	1.9	1.6	0.7	2.9	3.3	8	3.7	9.7	9.9	5.1
LVs	38.6	14.7	16.6	21.8	7.1	20.1	3.6	4.3	4.7	24.5	23.5	15.1	12.8	15.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: 1) Dhobaura; 2) Fulbaria; 3) Fulpur; 4) Goforgaon; 5) Gouripur; 6) Haluaghat; 7) Ishargonj; 8) Muktagacha; 9) Nandail; 10) Sadar; 11) Tarakanda; 12) Trishal; 13) Valuka. Other BRRI varieties (BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan64, BRRI dhan67, BRRI dhan71, and BRRI dhan72). Source: Analyzed and prepared by authors based on the data from DAE, 2018

Adoption of Indian varieties was the highest in Muktagacha (35%) followed by Dhobaura (14%) in Mymensingh, whereas overall adoption of this variety in this district was only 5% due to coverage of the rest of the Upazila was almost zero. Adoption of LVs was about 16% of total T. *Aman* area of the District, but adoption of LVs in some Upazila namely Haluaghat (20%), Sadar (24%) and Tarakanda (24%) was very high, while adoption of LVs in Gouripur (7%), Ishargonj (3%), Muktagacha (4%) and Nandail (5%) is very low. Adoption of newly released varieties such as BRRI dhan56, BRRI dhan57,

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BRRI dhan62, BRRI dhan71and BRRI dhan72 are mainly confined to trial plots and only a few farmers adopted these varieties due to unavailability of seed at the local markets (Table 02).

Table 03. Yield of *Aman* rice varieties in Mymensingh district.

Varieties	Upazila													Mymensingh
	1	2	3	4	5	6	7	8	9	10	11	12	13	
BR11	3.88	4.84	4.33	4.31	4.20	4.18	4.13	4.63	4.07	4.19	4.38	4.25	4.33	4.28
BR14	-	-	-	-	-	-	-	-	-	-	3.11	-	-	3.11
BR22	2.99	4.40	-	4.28	-	2.99	4.07	4.18	4.03	4.27	-	4.06	-	3.92
BR23	2.99	4.39	-	4.27	3.57	2.99	3.99	4.35	-	4.22	-	-	-	3.84
BRRI dhan32	3.73	4.63	4.18	3.28	3.80	3.96	4.05	-	4.11	4.37	3.98	3.79	3.88	3.98
BRRI dhan34	3.28	3.51	4.19	4.01	3.72	3.28	3.73	3.58	3.88	3.84	3.48	3.13	-	3.61
BRRI dhan40	2.99	4.33	4.33	-	3.88	3.51	-	-	3.76	4.26	4.18	-	4.18	3.89
BRRI dhan41	2.99	4.66	4.18	3.99	4.03	3.58	4.07	-	4.03	4.57	4.58	-	4.03	4.02
BRRI dhan49	4.18	4.91	4.03	4.33	4.40	4.33	4.25	4.67	4.25	4.86	4.70	4.36	4.78	4.46
BRRI dhan51	4.18	4.63	4.48	4.03	3.73	3.96	4.64	4.33	4.06	3.84	4.58	4.39	4.48	4.23
BRRI dhan52	4.48	4.63	4.40	4.34	4.18	4.33	4.83	4.48	3.97	4.28	4.48	4.66	4.63	4.43
Other BRRI varieties	-	4.67	4.18	4.30	3.58	4.33	3.99	-	-	4.20	4.41	-	-	4.19
BRRI Varieties	3.57	4.37	4.24	4.12	3.85	3.82	4.14	4.39	4.00	4.21	4.14	3.98	4.31	4.08
Balam	-	-	-	2.64	1.54	-	-	-	-	2.57	-	-	2.39	2.29
Borhafji	-	-	2.79	-	2.69	-	2.69	-	2.39	2.72	2.49	2.66	-	2.63
Chinisail	2.09	-	2.51	-	-	1.64	-	3.13	-	-	1.99	2.09	-	2.24
Fulgazi	2.09	-	-	-	-	2.54	-	-	-	-	-	-	-	2.31
Kalizira	1.98	2.47	2.84	1.79	1.49	1.49	2.27	2.33	2.42	2.30	2.19	2.09	2.09	2.13
Kumri	-	3.28	-	-	2.70	-	-	2.69	-	3.12	2.69	2.69	2.69	2.84
Tulshimala	1.95	-	2.46	-	1.80	1.94	2.24	3.12	-	-	2.39	-	-	2.27
Zirabalam	2.24	-	-	-	-	-	-	-	-	-	2.59	-	-	2.41
Other LVs	2.31	3.07	2.84	2.54	2.53	1.94	2.66	2.72	2.46	2.37	2.32	2.11	2.69	2.53
LVs	2.16	2.98	2.69	2.47	2.26	1.90	2.47	2.80	2.40	2.51	2.35	2.41	2.57	2.45
Dhanigold	4.78	-	5.22	-	5.15	5.07	5.83	4.85		6.04	5.17	-	-	5.27
Other Hybrids	4.76	-	5.22	-		5.45	4.94	4.90	5.22	5.30	5.32	-	-	5.12
Hybrid	4.76	-	5.22	-	5.15	5.32	5.24	4.88	5.22	5.55	5.28	-	-	5.17
Madabi	-	-	-	-	-	-	-	4.68	-	-	-	-	-	4.78
Parijat	2.09	-	-	-	-	-	-	-	-		-	-	-	2.09
Ranjit	3.28	4.40	-	-	-	2.91	-	4.63	-	-	-	-	-	3.63
Swarna	-	-		-	-	-	-	4.03	-	2.55	2.20	-	4.78	3.39
Swarna Musuri	3.73	-	-	-	-	3.36	-	-	-	-	-	-	-	3.55
Indian	3.03	4.40	-	-	-	3.13	-	4.48	-	2.55	2.20	-	4.78	3.50
Binadhan-7	3.36	-	-	-	-	-	-	-	-	-	-	-	-	3.36
Binadhan-10	-	-		-	-	-	-	-	-	3.65	-	-	-	3.65
Binadhan-11	-	-	4.18	-	-	-	4.05	-	-	-	-	-	-	4.12
Binadhan-7	-	4.10	4.03	3.99	3.51	3.32	3.88	4.10	4.06	4.31	3.80	3.88	4.48	3.91
Binadhan-9	-	-	-	-	-	-	-	-	-	3.75	-	-	-	3.75
Guti IRRI	-	-	-	-	3.58	-	4.78	-	3.81	-	-	-	-	4.05
Hori dhan	3.73	4.63	-	-	3.95	3.73	-	4.40	-	-	3.98	-	-	4.07
Pajam	2.99	3.88	4.33	-	4.10	3.36	4.11	3.88	3.88	-	3.06	3.21	4.18	3.70
Other MVs	3.36	4.20	4.18	3.99	3.78	3.42	4.20	4.13	3.91	3.93	3.61	3.55	4.33	3.87
MVs	3.70	4.35	4.33	4.11	3.90	3.81	4.31	4.44	4.06	4.27	4.19	3.90	4.36	4.12
Average	3.26	4.02	3.99	3.49	3.39	3.48	3.90	3.97	3.61	3.72	3.61	3.28	3.61	3.65

Note: 1) Dhobaura; 2) Fulbaria; 3) Fulpur; 4) Goforgaon; 5) Gouripur; 6) Haluaghat; 7) Ishargonj; 8) Muktagacha; 9) Nandail; 10) Sadar; 11) Tarakanda; 12) Trishal; 13) Valuka. Other BRRI varieties (BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan64, BRRI dhan67, BRRI dhan71, and BRRI dhan72). Source: Analyzed and prepared by authors based on the data from DAE, 2018

Table 03 presents the yields of cultivated *Aman* varieties in Mymensingh district. Among the BRRI varieties, BRRI dhan49 was the top yielder (4.48 ton/ha), followed by BRRI dhan52 (4.43 ton/ha), BRRI dhan51 (4.24 t/ha) and BR11 (4.31 ton/ha) in *Aman* season, while average yield of hybrid (5.17 ton/ha) was higher than that of BRRI dha49. Although, the average productivity of Indian variety was 3.85 ton/ha, the performance of Indian variety; namely, Madhobi (4.68 ton/ha) in Muktagacha was better than that of most dominant variety BRRI dhan49 (4.48 ton/ha). The average yield of BRRI

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varieties (4.16 ton/ha) was mostly consistent with the average productivity of modern varieties (4.14 ton/ha) in this season. It can be noted that performance of recently released varieties, for instance, BRRI dhan62 (3.79 ton/ha), BRRI dhan71 (4.46 ton/ha) and BRRI dhan72 (4.43 ton/ha) at the farmer's field was not so impressive compared to currently adopted BRRI dhan49 (4.48 ton/ha), dhan52 (4.43 ton/ha), BRRI dhan51 (4.24 t/ha) and BR11 (4.31 ton/ha) varieties (Table 03).

Criteria and constraints of major BRRI released *Aman* varieties

Table 04 presents the criteria and constraints of the adoption of major *Aman* rice varieties in Mymensingh. Major drivers of adopting BRRI dhan49 in Mymensingh are better yield performance, medium slender grain, good taste to eat, higher market demand as well as shorter growth duration compared to BR11, which is suitable for three crops cropping patterns. Besides, farmers get liquid cash from selling quality straw of BRRI dhan49 which is harvested a bit earlier. However, the infestation of false smut (although, most cases scale of occurrence remains below the economic threshold level), susceptibility to leaf folder, brown planthopper, caterpillar and even neck blast diseases are the widespread concerns and bottlenecks of further dissemination of this variety. Besides, some extent susceptibility to lodging, lack of availability of seed at the local market, higher attack of birds due to early maturity issues hindered the adoption of this variety. Furthermore, few farmers also opined that BINA dhan7 is more suitable for three crops pattern than BRRI dhan49 due to shorter growth duration.

Table 04. Criteria and constraints of currently adopted major *Aman* varieties in Mymensingh.

Variety name	Positive traits	Respondents (%)	Negative traits	Respondents (%)
BRRI dhan49	Better yield potential	70	Infestation of false smut	100
	High market demand and better price	100	Longer growth duration	80
	Shorter growth duration which is suitable for three crops pattern	100	Susceptible to leaf folder, BPH, and neck blast.	70
	Higher price of straw	100	Lack of seed at local market	60
	Medium slender grain and a good test to eat	100	Somewhat lodging susceptible	60
	Potential to give good harvest despite moisture stress at the maturity stage	100	Longer growth duration	100
	Suitable for late planting in low lying and flood-affected areas	100	Lack of availability of seed	100
BR22	No lodging despite cultivating in the low laying area	70	Low demand for bold grain rice at the market	75
	Medium bold grain and tested good to eat	80	Susceptible to brown planthopper	50
	Less susceptible to pest and insect	60	Higher infestation to caterpillar under foggy weather	50
	Higher straw yield	50		
BRRI dhan34	Higher yield potential than local aromatic varieties	100	Susceptible to blast disease	80
	Suitable for making tasty scented dishes			
	Higher demand and price of rice grain	100		
	Straw is more preferred to cattle	100		
	Suitable for late planting	100		
BRRI dhan51	Highly suitable for low lying and flood-prone areas	100	Lack of availability of seeds	80
	Higher yield potential	80	Susceptible to sheath blight	50
	Medium bold grain and tested good to eat	60		

Source: Prepared by authors based on the field survey 2018

Good yield potential, medium slender grain, and better market demand, less susceptible to pest and insect, no lodging despite cultivating in the low laying area, the higher tillering ability even in the field

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with stagnant water, good yield despite moisture stress at maturity stage are the key considerations of continuous cultivation of BR22**.** However, lack of availability of seed, high susceptibility to brown planthopper, and higher infestation of caterpillar in case of foggy weather and longer growth duration are the main causes of low adoption of the variety at farmers' fields. Highly suitable in natural flash flood conditions, medium slender grain, good taste, and better market demand are the key criteria of the adoption of BRRI dhan51. Moreover, susceptible to stem borer, rice hispa, neck blast, brown planthopper, and also lack of availability of seed are the factors responsible for lower adoption of this variety. Higher yield potentiality than local aromatic rice, good taste, better market price; consequently, higher profitability as well as higher demand for straw which is preferred by cattle are the key criteria of adoption of BRRI dhan34. The drawbacks of this variety are susceptibility to neck blast, stem borer, and high brown planthopper attack (Table 04).

Reasons for low adoption/decreasing adoption

Table 05 presents reasons for the low adoption of newly BRRI released varieties and the dis-adoption of old varieties in the Mymensingh region. Farmers reported that major reasons for a substantial decrease of adoption of BR11 are susceptible to sheath blight, leaf blight, and ufra diseases as well as brown planthopper, gall midge, and stem borer, etc. Moreover, poor yield performance (due to incomplete emerge of panicle) in late transplanting and cold stress the case while farmers are unable to transplant on time due to shifted delay of rainfall is also an important driver of decreasing the adoption of BR11. In addition, a smaller number of effective tillers and low demand for grain at the market because of bold grain has also affected the adoption of BR11. However, farmers have been continuing cultivation of the variety as the variety gives higher yield than that of available other varieties under good seasonal conditions (no biotic and abiotic stress) and better agronomic and pest management practices. Besides, tillering ability in anaerobic conditions, good eating quality and availability of household seeds and lack of access to seeds of newly release BRRI varieties are also the important factors of continuous cultivation of both the biotic and abiotic susceptible variety, for instance, BR11.

Farmers grow BR10 due to higher yield potential, a greater number of tillers per hill, though the productivity of this variety frequently affected by cold and drought due to longer growth duration as well as the attack of birds and rats. Similarly, tolerance to natural flash floods, a higher number of effective tillers, suitability to late planting in low lying, and flood-affected areas are the reasons for the adoption of BRRI dhan52. Farmers reported that susceptibility to BLB, blast, and BPH along with longer growth duration; lower market price, and lack of availability of seed is the key to low adoption of the variety (Table 05).

Table 05. Reasons for low adoption or decreasing trend of *Aman* varieties in Mymensingh.

Varieties	Reasons for low or decreasing adoption	Respondents (%)	Positive traits of the variety	Respondents (%)
BR10	Long duration, affected by cold and drought as well as birds and rats	100	Potential to give better yield under a favorable environment	55
	Susceptible to pest and diseases	80		
BR11	Highly susceptible to SB, LB, and Ufra as well as BPH, gall midge, and stem borer.	100	Better yield performance under a favorable environment and better management	80
	Lower yield in late transplanting	80		
	Number of effective tillers is relatively lower	70	Good taste to eat	70
	Low demand and market price	70		
	Infestation of caterpillar is high	30		
BRRI dhan52	Tolerance to natural flash floods	70	Longer growth duration	100
	Higher number of effective tillers	60	Susceptible to BLB, blast, and BPH	70
	Suitability for low lying and flood prone areas	50	Low market price	70
	Good yield potential	40	Lack of availability of seed	60

Source: Prepared by authors based on the field survey 2018

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Most of the farmers in the FGDs said that they have no experience of cultivating of the newly released BRRI varieties such as BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan64, BRRI dhan67, BRRI dhan71, and BRRI dhan72 mainly because of lack of availability of seeds at the local level. Farmers grow BR10 due to higher yield potential and a greater number of tillers per hills, but the productivity of this variety is frequently affected by cold and drought due to longer growth duration as well as the attack of birds and rats are the major causes of decreased adoption of the variety. Similarly, tolerance to natural flash floods, a higher number of effective tiller, suitability to late planting in the low laying and flood-affected areas, and good yield potential are the major reasons for adoption BRRI dhan52. Farmers reported that susceptibility to BLB, blast, and BPH along with longer growth duration, low price at the market, and lack of availability of seed were the key to low adoption of the variety (Table 05).

Determinants of adoption of BRRI varieties

The determinants, that were presumed to assist setting the adoption choices of alternative rice varieties, were included in censored regression (Tobit model) in Table 06. The variables picked were socio-cultural factors, information availability, and varietal specific characteristics. Multicollinearity does not affect the estimation of the best parameters at all to check off the dataset diagnosis. Heteroscedasticity was detected in the dataset, however, and Stata's 'Robust' command was imposed to stamp that problem out. The F value always indicated the degree of fitness of the model and the present model shows a higher level of overall significance. Moreover, both the upper limit and lower limit were declared in the model.

Table 06. Estimated results of the intensity of BRRI seed technology adoption using censored regression (Tobit) model.

Variables	Tobit Coefficient#)	Marginal effect dy/dx	Expected sign
Socio-demographic variables:			
Age (year)	-0.068^{NS} ; (-0.20)	-0.057^{NS} ; (-0.20)	+
Education (year of schooling)	0.942^{NS} ; (0.80)	0.795^{NS} ; (0.80)	+
Household size (no.)	1.381* ; (1.68)	1.165* ; (1.67)	+
Marginal farm size dummy	48.918*** ; (2.99)	46.932*** ; (2.90)	+
Small farm size dummy	31.781*** ; (4.26)	27.606*** ; (4.34)	+
Access to information:			
Training dummy (1= training received)	2.221^{NS} ; (0.30)	1.873^{NS} ; (0.30)	+
Distance to local market (km)	-6.753* ; (-1.91)	-5.697* ; (-1.90)	-
Distance to UAO (km)	-0.393^{NS} ; (-0.43)	-0.332^{NS} ; (-0.43)	-
Price variation (Tk/kg)	17.621* ; (1.74)	14.867* ; (1.75)	+
Varietal specific characteristics:			
Taste and preference dummy (1= good)	39.296*** ; (3.84)	30.344*** (4.47)	+
Varieties number	11.352* ; (1.73)	9.578* ; (1.69)	+
Yield variation (kg/ha)	19.743*** ; (2.97)	16.658*** ; (2.98)	+
Constant	109.154*** ; (2.97)		
Log pseudo-likelihood value	-446.157		
Sigma	382.269		
Prob > F	8.07***		
Pseudo R^2	0.081		
Sample (N)	780		

Note: #) means robust standard errors are calculated t statistics in parentheses and *, ** and *** imply statistical significance at 10%, 5%, and 1% levels, respectively.

Results show only the exception of age, most of the variables of the model had expected signs. The sign of age was negative with statistically insignificant. The result is nuanced with many existing studies that aged people are more reluctant toward the adoption of new rice varieties. Younger farmers preferred to take the risk, particularly in the choice of new farm technology. Besides, assuming farm size has a heterogeneous effect on making a variety of choices at the farm level. To single out such an effect, farm size categorized into three groups using dummy variables (marginal farm (<=49 decimal), small farm (>50 and <=249 decimal), and medium together with the large farm (>250 decimal)). In the model, both marginal and small farm size (operated area) had a significant effect on the adoption of

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BRRI varieties. In heuristic approach, medium and large farm seemingly has a scale effect on varietal choice implying that with the increase of farm size, the devotion of plot number toward BRRI varieties would considerably decrease. The reason might be that larger farms choose more yielders like hybrid rice or Indian varieties and high-value rice like aromatic variety for high profitability (Table 06).

The model identified that the number of family members had a significant effect on the selection of BRRI varieties. However, decreasing distance to the Upazila agriculture office (UAO) and the local market had a significant and positive influence on choices of BRRI varieties. This is because lesser distance reduces the transaction cost of getting varietal information and selling their products to the local market.

Paddy price is always a stronger determinant of farm profit and highly responsible to adopt BRRI varieties. Besides, the adoption of more BRRI varieties is greatly subject to quality rice and good taste. More varieties give the farmers a bigger number of choice options meaning that a greater number of BRRI varieties will increase the area coverage to them. Model exposed that, yield variation was positive and statistically influence toward increasing the area coverage of BRRI varieties in the farmer's field significantly. Finally, it was commented that the prospect for higher yield of any rice variety could easily motivate the growers to increase area coverage of that variety (Table 06).

IV. Conclusion

Bangladesh is presently facing several challenges, including food security, nutritional scarcity, environmental degradation, natural resource depletion, and changing climate. These are the challenges that are expected to increase over the coming decades. Food production has to increase and ideally be more environmentally efficient, that is, successful strategies have to be encouraged and adopted. Bangladesh Rice Research Institute (BRRI) dedicated solely to developing high yielding modern rice varieties to tackle the challenge of crop production in changing environments to achieve food self-sufficiency. Following this BRRI has developed 46 high yielding *Aman* rice varieties including 2 hybrids. Therefore, in this study we identify the criteria and constraints of BRRI released Aman cultivars and determine the factors of adopting BRRI released *Aman* cultivars in Mymensingh district of Bangladesh. In Mymensingh district, most of the farmers in *Aman* season cultivated modern varieties of which around 68 percent BRRI developed rice varieties. BRRI dhna49 was the most popular variety among the farmers followed by BR11 and BRRI dhan34 in the study area. Also, BRRI varieties gave higher average yield than other varieties. Although, BRRI varieties have some negative traits which caused decreasing adoption in the *Aman* season in Mymensingh district however farmers are still cultivating BRRI varieties at the highest level.

Farmers considered the drivers that profoundly influenced the adoption decisions were the yield performance of a variety along with profitability, the ability to tolerance in biotic and abiotic stresses, easily available of good quality seeds, the better quality of milled and cooked rice and ensured market demand. Socio-demographic factors like family size and income, farm size, easy access to extension services, and better market demand along with higher yield potential, good appearance, higher price, and good taste to eat had a significant and positive influence to adopt BRRI *Aman* varieties in Mymensingh district. Though some newly released varieties could not satisfy farmers' expectations; furthermore, the seed of those varieties which performed a bit better in the local demonstrations was not also sufficient. However, the seed of the prospective BRRI rice cultivars neither is currently available at the farm level nor the DAE has enough ability to make the seed available to meet the demand for local farmers. Therefore, Bangladesh Agricultural Development Corporation (BADC) as well as other private sector seed traders could produce only those most dominant and popular varieties which had widespread acceptance to the growers. Besides, BADC and other private seed traders were not much updated about the demand of location-specific particular popular variety for different seasons. So, for the dissemination of BRRI released *Aman* varieties, need coordination among BRRI, DAE, BADC, and other seed producing companies to deliver expected rice variety to the farmers.

Competing interest

The authors declare having no conflicting interests

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