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Drivers of Adoption of BRRI Cultivars in *Boro* Season Among Farm Households of Mymensingh District, Bangladesh

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ABSTRACT

Bangladesh has made tremendous strides in the development of modern rice varieties as well as boosting domestic rice production up. Therefore, this study aims to investigate the performance, identify the criteria and constraints, as well as find out the drivers influencing the adoption and intensity of adoption of BRRI developed modern rice cultivars in *Boro* season. A total of 780 randomly selected farmers were interviewed using a structured schedule from 13 upazilas of the Mymensingh district. Descriptive statistics used mainly to evaluate the socio-economic characteristics of farmers as well as the performance of BRRI varieties, and a censored Tobit regression model employed to figure out the drivers of BRRI variety adoption. The results showed that in the *Boro* season about 85% area of Mymensingh district was covered by BRRI varieties and yielded 5.93 t/ha on average. The outcome of the model indicates that variables such as farmers schooling, farm size, farming experience, training and extension service, demonstration, distance to the nearby market, higher yield capacity, number of cultivated varieties, higher price, and good taste were influential drivers of adopting BRRI variety during the *Boro* season. This finding recommends that breeders should emphasize the farmers' preferences while developing varieties, as well as providing training and field demonstration for spreading newly established BRRI rice varieties.

Introduction

The Government of Bangladesh is committed to achieving the United Nations (UN) Sustainable Development Goals (SDGs) by ensuring food security and sustainable development (MoA, 2019). Agriculture is playing a key role in meeting the food and nutrition needs of the people, ensuring food security, and providing employment to the rural population. The agricultural sector contributed around 13.64% to Gross Domestic Product (GDP) and more than 40% of employment (BBS, 2020).

Rice, the predominant and staple food crop for the 164.6 million people, which is closely intertwined with the economy and culture in Bangladesh (BBS, 2019). About 74.85% of the total cropped area and over 72% of the irrigated area is planted to rice (BBS, 2020). Therefore, rice plays a significant role in both supplying food and maintaining the food security of the large and rapidly increasing population (Talukder and Chile, 2014).

In Bangladesh rice has been cultivated in three overlapping seasons, namely *Aus*, *Aman,* and *Boro* (Mondal *et al*., 2019), and produced 36.39 million tons of rice (BBS, 2020). Nevertheless, the share of *Boro* rice in the value chains is relatively higher than that of the Aus and Aman rice (Kabir *et al*., 2019). Of the three rice types, *Boro* rice alone accounts for 60% of annual rice production and over 52% of Bangladesh's total food grain production (BBS, 2020), which also has a year-round effect on domestic market prices. About 99.2% of the land is planted with high yielding rice varieties during the *Boro* season, of which 67.04% is developed by the Bangladesh Rice Research Institute (BRRI).

Many studies have attempted to shed light on the financial profitability and efficiency of *Boro* rice production in Bangladesh. Sujan *et al*. (2017) showed that *Boro* rice cultivation in the Bogura district of Bangladesh is profitable and growers allocated most of their resources. The same results have also been

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reported by Rasha *et al*. (2018) for the Mymensingh district. Another study reported that the benefit-cost ratio for USG and traditional urea users on producing *Boro* rice in Rangpur was 1.5 and 1.3, respectively (Masum *et al*., 2018). Ali *et al*. (2019) tried to show the agro-economic performance of *Boro* rice and reported that *Boro* rice is profitable. Basak *et al*. (2010) reported on the effect of climate change on *Boro* rice production in Bangladesh and found a significant reduction in the yield of *Boro* rice due to climate change. Likewise, Karim *et al*. (1999) showed that 60% of moisture stress on top of other effects might cause a 32% decline in *Boro* yield. Nath *et al*. (2018) evaluated the growth and yield performance of BRRI dhan58. Ghosh (2016) estimated the adoption of BRRI dhan28 in the coastal region of Bangladesh. The adoption status in the whole country has been estimated by Hossain and Chamala (1994) and Hossain *et al*. (2006), which do not represent the present scenario of rice adoption in Bangladesh. The area coverage of BRRI varieties in the *Boro* season is 67.04% and the coverage in the Mymensingh district is 74% (BRRI, 2019).

To the best of the authors' knowledge, neither of the studies in Bangladesh's perspective covers all the cultivated *Boro* varieties adoption status in a specific area. Further, no empirical research in Bangladesh had considered identifying positive and negative traits of BRRI developed *Boro* cultivars as well as understanding the adoption determinants. The cultivars of BRRI are very popular with the farmers of Bangladesh. But in the *Boro* season, many varieties have been cultivated for a long time, and due to different biotic, abiotic, and socio-economic constraints caused the reduction of the yield performance of BBRI cultivars. Therefore, this study was taken to identify the drivers and drawbacks of different BRRI released *Boro* cultivars, and find out the causes and determinants of their adoption and its intensity in the Mymensingh district intensively.

Methodology

Study area

For this study, the sample obtained from the population of farmers of the 13 upazilas of Mymensingh district and subsequently, two unions from each upazila were selected randomly.

Data

The survey was conducted from April to July 2018. The data were obtained from both primary and secondary sources. In order to select the rice farmers for the interview, a list of the 240 farmers from each Upazila Agriculture Officer (UAO) was collected for sampling. From the collected list 60 farmers were selected randomly from each upazila. Hence, a total of 780 sample farm households were selected randomly to collect socio-demographic and farm-level data to identify factors affecting the adoption of the BBRI rice cultivars. Moreover, in total, 26 FGDs were conducted to generate in-depth data about the adaptation dynamics (such as variety-wise adoption rate, varietal traits, reasons behind adoption or dis-adoption, etc.) of rice varieties in *Boro* season. Besides, an expert panel interview consisting of Sub-assistant Agriculture Officer (SAAO) and UAO was conducted to validate the data collected through farmers' group discussions. The selected farmers were interviewed using a pre-tested structured questionnaire. The data were processed using both descriptive and inferential statistics.

Analytical framework and estimation method

Adoption can be defined as using innovation and continuing to use it (Rogers, 1962). Like Danso-Abbeam et al. (2017) this study also used a random utility framework in the analysis of the adoption intensity of BRRI cultivars in *Boro* season. We presumed that a rice farmer is a reasonable producer and thus would make a fair decision about production. Anticipating that rice farm households often want to cultivate BRRI cultivars; either other modern varieties (MVs) or a mixture of both. Farm households seek to increase gains from their options by contrasting the advantages they obtain from the different choices they have accessible.

Let the utilities derived from cultivating BRRI cultivars and other rice cultivars (Other MVs) be represented by U(M) and U(T), respectively. P_{im} and P_{it}, respectively, give the i^{th} farmer's perception of the varietal-specific characteristics of BRRI cultivars, and other rice cultivars. The socio-cultural and access to information of farm household affecting the adoption decision shall note 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 optimum proportion of land assigned to BRRI varieties can be obtained by meeting the normal conditions of first and second-order necessary to maximize the cumulative utility associated with growing different proportions of BRRI seed technology and other rice technology. The awareness variables were directly incorporated in the utility function in this above model.

A Tobit model was used to estimate the adoption and intensity of adoption of BRRI developed rice varieties. The utility function specified in equation (1) forms the basis for deriving a Tobit model. Following previous and recent studies (Baltas & Doyle, 2001 and Diiro *et al*.,

2015) the model represented below using an index function approach.

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

where y_i a % area of BRRI rice cultivars, is the observed choice; y_i^* is an underlying latent variable that indexes adoption; X_i is the vector of socio-cultural, access to information of farm household, and the technology perceptions of the farmer; β' is a vector of parameters to be estimated; and ε_i is an error term.

Specification of the Tobit model

Following, Danso-Abbeam *et al*. (2017), Awotide *et al*. (2016), and Taha (2007) this research also utilize the Tobit model established by Tobin (1958) to estimate the level of adoption measured as a proportion of the total farm household allocated to BRRI rice cultivation. The Tobit model is also a broad class model with discrete as well as continuous parts. It is an extension of the Probit model and is one approach to tackling the censored data problem (Johnston and Dinardo, 1997). The Tobit model applied for analyzing determinants of adoption and intensity of adoption of BRRI cultivars is shown below:

$$Y_i = \beta_0 + \beta_i X_i + \varepsilon_i$$

The Tobit model can be used to determine not just the likelihood of BRRI cultivars being adopted by a farmer but also the intensity of BRRI cultivars being used once adopted. It is possible to further disaggregate the predicted coefficients to evaluate the impact of the shift in the i^{th} variable on the change in the likelihood of adoption of BRRI varieties and the projected marginal effect of explanatory variables on the degree of adoption. Following Mcdonald and Moffit (1980), it can be shown as:

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

where $E(y_i^{**})$ is the expected value of y_i for those farmers who have already 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 Mcdonald and Moffit's (1980) approach of decomposition, the marginal effect on the area under the adoption of BRRI cultivars for those farmers who are already adapters can be estimated as:

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

where f(z) represents the unit normal density.

Description of the Variables

For this research, the dependent variable is the adoption of BRRI cultivars and their intensity. That is zero (0) for non-adopters and varied between 0 and 1 for adopters (where 1 mean 100% of BRRI varieties were adopted). The explanatory variables were taken those variables which were thought to influence the adoption and intensity of BRRI rice varieties. Previous studies (Ghimire *et al*., 2015 and Danso-Abbeam *et al*., 2017) reported that farm technology including the use of modern varieties adoption is explained by farmers' socioeconomic characteristics, varietal-specific characteristics and institutional factors. To explain the factors influencing adoption of BRRI cultivars and their intensity considered farmers' age, education, household size, farm size, farming experience, extension service, training received, attended in the field demonstration program, distance to the local market, distance to Upazila Agricultural Office (UAO), price difference, taste and preference, total varieties cultivates and yield difference as explanatory variables.

Table 1. Summary of the variables used in the model

Variables	Definition	Expected sign
Farmers' age	Year	+
Education	Year of schooling	+
Household size	Number	+
Farm size	Operated area in hectares	+
Farming experience	Year	+
Training received	Dummy (1= received training, 0= otherwise)	+
Extension Service	Dummy (1= received extension service, 0= otherwise)	+
Demonstration field	Dummy (1= if farmers had demonstration field or visited demonstration field, 0= otherwise)	+
Distance to local market	Kilometer	-
Distance to UAO	Kilometer	-
Price variation	Tk./kg	+
Taste and preference	Dummy (1= good taste and preference, 0= Otherwise)	+
Total Varieties cultivated	Number	+
Yield variation	Kg/ha	+

Results and Discussion

Socio-economic characteristics of the respondents

Table 2 portrays the socio-economic features of *Boro* rice producing farmers in Mymensingh district. Findings showed that the majority of rice producers (55.89%) in Mymensingh district between the age of 31 and 49 years old.

Table 2. Socio-economic features of the sampled farmers

Particulars	Percentage
Age	
<30 years	16.79
31-39 years	33.33
40-49 years	22.56
50 -59 years	13.58
60 years and above	13.71
Family size	
1-3 person	15.12
4-6 person	61.41
7 and above person	23.46
Male	54.35
Female	45.65
Education	
No formal education (0)	26.41
Primary education (i-v)	41.28
Secondary education (vi-x)	18.07
Higher secondary Education(xi-xii)	12.94
Graduate and above	1.28
Farm classification	
Small	68.71
Medium	28.46
Large	2.82
Occupation	
Farming as primary	78.84
Farming as secondary	21.15
Farming experiences	
0-10 years	15.25
11-20 years	25.25
21-40 years	45.00
Above 50 years	14.48
Member of any social organization	18.36
The average distance from home to nearby market (km)	4.16
The average distance from home to UAO (km)	5.20

Note: The 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.

However, the majority of farmers (61.41%) had a family size ranges between 4 to 6, where 54.35% male and 44.65% female members. Their education level was quite low, with just around 1.28% graduating and beyond (26.41% of illiterates and 41.28% of primary education). Results also revealed that 68.71% of the surveyed respondents have small farms and just 2.82% of the respondents have large farms. Agriculture was their primary economic activity (78.84%) with a significant portion (59.48%) getting experience of more than 20 years in rice farming. Approximately 18.36% of farmers in the studied area were members of different social and political organizations. The average distance between home to the local market, and Upazila Agriculture Office (UAO), respectively, were 4.6 and 5.20 kilometers.

Performance of BRRI Boro rice varieties

The adoption percentage of rice varieties adopted by farmers in *Boro* season, adoption of modern varieties (MVs) was almost 100%, of which coverage of BRRI released varieties was 85%. BRRI dhan28 and BRRI dhan29 were dominant varieties, covered about 77% areas in Mymensingh district. The coverage of recently released BRRI varieties was lower compared to old varieties. Though the overall adoption of hybrids in Mymensingh district was 14.46% of the total area in Dhobaura (55%) and Haluaghat (31%), it was significantly higher. In *Boro* season, among all BRRI cultivars, BRRIdhan29 was the top yielder (6.13 ton/ha) followed by BRRI dhan58 (6.09 ton/ha) and BRRI dhan50 (5.73 ton/ha). The average yield of the hybrid was 7.18 ton/ha. The overall yield of modern varieties was about 6.57 ton/ha.

Criteria and constraints of adoption of popular Boro rice varieties

In Mymensingh district farmers adopted BRRI dhan28 due to its good yield potential, shorter growth duration, less irrigation requirement, and matured before monsoon, which eases threshing and drying of grain and straw. Besides, higher milling outturn, medium slender grain, good eating quality and ensured good market price are the key drivers of higher adoption. Moreover, cattle like the straw of this variety much as feed. However, due to the severe infestation of neck blast, some of the respondents suspected that the adoption of this variety may decrease substantially. Furthermore, adulteration even in the Bangladesh Agricultural Development Corporation (BADC) supplied seed, lower yield potentiality than newly released varieties, and lodging proneness in case of rain at maturity stage are also critical constrains of BRRI dhan28. So, the farmers are eagerly looking for a suitable variety as replacement of BRRI dhan28.

Higher yield potentiality, medium bold grain, good tasted to eat and higher market demand, less infestation of neck blast including other pests, no shattering, and lodging problems are the major reasons for continuous cultivation of BRRI dhan29. Longer growth duration; for which there are higher chances to affect this crop by extreme weather events and matured during the monsoon that hampered harvest and post-harvest activities which increase post-harvest losses**.** Delayed flowering of BRRI dhan58 can avoid neck blast infestation and escape adverse consequences of extreme weather events, requires less urea, lodging resistance, profuse tillering capacity, suitable for low laying area, test good to eat, etc. are the major drivers of adoption. However, the variety is sensitive to cold and several grains of top of the panicle remain unfilled. The application of higher doses of urea delay flowering and reduce yield as well. Respondents expected that adoption of this variety may rapidly increase if seed is guaranteed as per demand.

Reasons for low adoption of some BRRI varieties

Despite some positive traits such as strong stem, no shattering, good eating quality, and good yield, farmers about to stop cultivating BR14 as its long awn disturbs during harvesting and post-harvest operations. Despite the potentiality to give higher yield and less prone to sterility, farmers are about to stop cultivating BR26 as the cooked rice of the variety becomes soft and decomposed within a short while. Good yield potential, slender grain, good taste to eat, higher market price are the criteria of cultivating BRRI dhan50; however, adoption of the variety is low mainly due to lack of seed as well as higher shattering rate in the field, low milling out turn and unsuitability of milling in the non-rubber hauler mills. BRRI dhan68 gave lower yield at trial plots than that of existing varieties even under the farmers' practice. Cooked rice of BRRI dhan69 becomes soft after a short while is the main reason for less adoption of the variety despite having some important positive traits such as higher yield potential, medium-fine grain, and no lodging problem even in heavy and strong wind.

Factors influencing intensity of BRRI cultivars adoption in Boro season

Table 3 shows the estimated outcomes from the Tobit censored regression models. Censored regression (Tobit model) included the determinants, which were assumed to assist in determining the acceptance choices of alternate rice varieties. To check off the diagnosis of the dataset, multicollinearity and heteroscedasticity do not impact determining the right parameters at all. F value always pointed out the degree of model fitness and the present model displays a higher level of overall significance.

The findings of the Tobit censored regression model provided in Table 3 indicate that eleven out of the fourteen variables used in the model (Tobit) were important in understanding the variability in the intensity of BRRI cultivars adoption. Most of the model's variables had expected signs only except age. Age sign was negative and statistically insignificant. The finding is nuanced with other existing findings that older citizens are more reluctant about new rice varieties being adopted. While younger farmers favored risk-taking, particularly in choosing a new farm technology (Chandioand Yuansheng, 2018).

Results showed education is statistically significant and has a positive correlation with the intensity of BRRI cultivars adoption. Farmers with a relatively high educational level thus intensify the adoption of modernBRRI cultivars compared to their counterparts with a low educational level, presumably because their ability to understand and evaluate new rice technologies and also can easily process more knowledge than others. This result conforms to previous studies (Ghimire *et al*., 2015 and Kassie *et al*., 2011).

The results show that the likelihood and intensity of adoption of BRRI rice varieties were directly linked to the size of the farm holdings. The positive and significant sign-on farm size indicates that the likelihood of farmers adopting and intensifying modern BRRI varieties as the farm size grew. These results are consistent with Ghimire *et al*. (2015) and Danso-Abbeam *et al*. (2017). The estimated farming experience coefficient was positive and significant, which means that further farming knowledge would enable farmers to continue to implement modern BBRI rice cultivars because they can determine the benefits of modern agricultural technologies. Adedoyin *et al*. (2016) and Chandio and Yuansheng (2018) documented similar results. Training attendance had a significant and beneficial impact on the adoption of modern BRRI rice varieties. This may be explained by the fact that farmers who have training gain better knowledge on the advantages of the BRRI cultivars and related production practices which enhance the intensity of modern BRRI cultivars adoption. The result is compliance with Negasa *et al*. (1997) and Teshome *et al*. (2019) findings.

The agricultural extension service is a very significant consideration for the adoption of modern BRRI rice varieties. Results show that the coefficient was positive and significant. It indicates that farmers were more likely to adopt new BRRI cultivars in Mymensingh district if they get further extension services. This result is consistent with the findings of Ghimire *et al*. (2015), and Chandio and Yuansheng (2018). Furthermore, significant and positive coefficient of demonstration fields indicates that farmers involved in demonstration farms or on-farm trials were more likely to allocate a larger proportion of their farmland to modern BRRI cultivars. Besides demonstrating, farmers become aware of the attributes of modern BRRI rice cultivars and obtain enough knowledge to make adoption decisions. These results complement those of Danso-Abbeam *et al*. (2017) and Mmbando and Baiyegunhi (2016).

Decreasing distance to the local market, however, had a significant and positive influence on the choice of BRRI varieties. That is because the purchase cost of obtaining varietal details and marketing their goods to the local market is minimized by a lesser distance. Paddy price was always a bigger factor in farm revenue. So, the positive and significant results of price variation extensively responsible for the adoption of BRRI cultivars.

Table 3. Estimation of Tobit model for determinants of adoption of BRRI varieties in Mymensingh district (n=780)

Variables	Tobit Coefficient	Calculated t statistics	Marginal effect (dy/dx)
Age	-0.009^{NS}	–0.021	-0.005
Education	0.421*	1.94	0.258*
Household size	0.576^{NS}	0.93	0.106^{NS}
Farm size	0.596*	1.98	0.028*
Farming experience	0.039*	1.95	0.013*
Training	0.789***	3.02	0.352**
Extension service	0.252***	2.87	0.089
Demonstration field	1.561**	2.31	0.161
Distance to local market	-1.311*	–1.87	-0.131*
Distance to UAO	-0.029^{NS}	–0.81	-0. 010^{NS}
Price variation	1.013***	3.61	0.821**
Taste and preference	0.512*	1.91	0.381*
Varieties number	0.525*	1.85	0.212*
Yield variation	1.132***	2.73	0.862***
Constant	5.71	1.21	-
Log-likelihood	-71.51		
Sigma	58.92		
Prob > chi^2	0.000		
Pseudo R^2	0.502		

Note: *, ** and *** imply statistical significance at 10%, 5%, and 1% levels, respectively.

Furthermore, positive and significant coefficients indicate that the decision to adopt more BRRI varieties is highly dependent on rice quality and good taste. The findings are compliant with those reported by Timu *et al*. (2014) and by Otieno *et al*. (2011). The coefficients of the number of verities were positive and statistically significant, meaning that more varieties are giving farmers more choice. This indicates farmers will adopt more BRRI cultivars which will increase the area coverage of BRRI varieties. Rice yield, however, is primarily for domestic consumption or market, yield potential plays a crucial role in cultivating a specific variety (Langyintuo and Mungoma, 2008). Furthermore, yield variation is expected to positively influence the adoption of BRRI cultivars. Similar results were reported by Ghimire *et al*. (2015) and Timu *et al*. (2014).

Conclusion and Recommendation

Boro season is the most important rice-growing season in Bangladesh. During this season, most of the lands in Bangladesh are cultivated with modern high yielding rice varieties. The majority of the farmers in Mymensingh cultivated modern varieties of BRRI due to higher yield, profitability, and 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 such as education, farm size, farming experience, training, extension service, the field of demonstration, distance to the local market, higher yield potential, good appearance, higher price, and good taste for eating had significant and positive influences on the adoption of BRRI *Boro* cultivars in Mymensingh. The rice breeder and extension workers may consider these findings to develop new varieties and disseminate to the farmers swiftly.

The policy consequence of this study is that breeders should also concentrate on features such as higher yield as well as taste, fine grain, hold cooked rice for longer periods, biotic and abiotic stress-resistant in their efforts to develop new *Boro* cultivars as they are very significant in describing the high adoption of BRRI varieties. Intensifying extension programs in rural areas would encourage BRRI cultivars to be adopted. The further focus should be given to conducting on-farm trials with the farmers to improve their technological and managerial abilities, therefore enhancing the adoption of BRRI cultivars. It, therefore, needs tremendous cooperation between BRRI, Department of Agricultural Extension (DAE), BADC, and other seed producers to provide quality seed to the farmers to ensure maximum adoption and yield of the improved rice varieties for achieving the SDG's target of sustaining food security in Bangladesh.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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