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Drivers of Adoption Intensity of BRRI Released Modern Aus Rice Varieties: Evidence from Smallholders Farmers in Jamalpur District of Bangladesh

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ABSTRACT: This study was conducted to determine factors influencing the intensity of BRRI cultivar adoption in the Aus season on farm households in the Jamalpur district. The data were collected through structured questionnaires from 200 randomly selected rice farmers from three upazilas in the Jamalpur district. The study employed descriptive statistics and Tobit-censored regression to determine the adoption and the intensity of the adoption. In addition, ten FGDs and expert panel interviews were conducted to verify the collected data. The results show that 88.04% of the area in Jamalpur district was cultivated with rice varieties developed by the Bangladesh Rice Research Institute (BRRI), with an average yield of 3.85 t/ha during the Aus season. The findings of the Tobit censored regression indicate that schooling, distance to the local market, distance to UAO, training, price variation, taste and preference, number of cultivated varieties, and yield variability were the significant factors of the intensity of BRRI variety adoption in the Aus season. The study's results suggested that breeders should also emphasise farmers' choices while developing varieties. In addition to developing new rice varieties, BRRI, the Department of Agricultural Extension (DAE), Bangladesh Agricultural Corporation (BADC), and other seed-producing organisations need to work together to provide the farmers with good-quality seeds of BRRI varieties, which will increase the country's total production and thus help to ensure food safety.

Keywords: Adoption Intensity, Aus Season, BRRI Varieties, Smallholder Farmers, Tobit Regression, Rice in Bangladesh

1. Introduction

Among the major challenges facing Bangladesh are sustainable food production and ensuring food security for all. A significant issue for Bangladesh has been and will continue to be food safety (Rahman et al., 2020; Chowdhury, 2009). The government of Bangladesh is working tirelessly to ensure food security for all. Despite steady progress towards industrialisation, agriculture remains the most crucial sector in Bangladesh (Islam et al., 2023). The agriculture sector is fully cooperating with the government of Bangladesh to achieve food self-sufficiency and food security (Islam et al., 2020a). The agriculture sector contributed 13.64% of the total Gross Domestic Product (GDP), employing 40% of the population and seems to have managed to feed around 164.6 million people in the country (BBS, 2019, 2018). Rice leads in all crops, contributing to 88.33% of the overall food grain output (BBS, 2019).

Rice is Bangladeshi's staple food as it is consumed at @367 gm/person/day by 99% of the population, supplying around 75% of the calories and 55% of the protein in the average daily diet (Rahman et al., 2016; BBS, 2016; Bhuiyan et al., 2002). Although a steady rice supply has significant consequences for food security, many see food security as associated with achieving self-sufficiency in rice production (Hossain et al., 2005). Rice has occupied about 74.85% of the total crop area and produced 36.39 million tons of rice (BBS, 2019). Rice is cultivated in Bangladesh in three overlapping seasons: Aus, Aman, and Boro (Shelley et al., 2016). Besides two other rice crops (Aman and Boro), Aus rice contributed to food production until the mid-1980s. Aus is usually grown in March-April and harvested in June-July. Aus rice accounts for nearly 9.59% of the overall cultivated area, covering 84.59% of modern varieties, producing 2.70 million tons of clean rice (BBS, 2019).

In several empirical studies, Islam et al. (2020a, 2020b) conducted research to estimate the economic analysis of vegetables like cauliflower in the study area. In addition, a study by Islam et al. (2020c) determines the productivity of the impacts of modern rice varieties in the study area. However, there needs to be more investigation into factors affecting the adoption of modern rice cultivars in the study area. For example, Uddin and Dhar (2018) noted that Aus rice started to lose value as farmers gradually moved to irrigated Boro rice cultivation, supported by its higher yields. The acreage dwindled below 1.5 million hectares during the Aus season, from 3.0 million hectares in the early 1980s, and rice output slumbered. Simultaneously, the Boro rice acreage and production went up many folds. Conversely, climate change could affect Bangladesh's Aus rice production. Research indicates that any period from seedling to reproductive stages Aus rice may be suffering from drought (Shelley et al., 2016). Khanom (2016) displayed evidence of decreased Aus yield in a warmer (by 40C) temperature scenario. Since the advent of modern technology and best management practices, farmers have altered cropping patterns and farming systems. Farmers have also modified their land use pattern under this farming circumstance and launched a mix of modern ventures and rice production (Islam et al., 2010). As a result, there has been a shift to Aus rice land and jute production (Afroz et al., 2012). BRRI indicates that one of the factors behind the decrease in the production of Aus rice is the non-availability of land as its seed sowing or transplanting cycle falls during March and April while Boro rice remains in the region (BRRI, 2012). Farmers do not get adequate time and land to produce paddy out of it.

Conversely, the country's increasing population by 2050 must generate an additional 10.8 million tons of rice to fulfil food grain demand (Hussain, 2011). Sustaining the food security status and supplying additional food for the country's ever-growing population from dwindling land and other scared resources thus, presents a significant challenge (Rahaman et al., 2018). Therefore, governments are intervening in agriculture to achieve various economic and social goals and food security. Agricultural incentives are a common element in agricultural development to promote the adoption of new technologies and thus increase agriculture productivity (Ellis, 1992). This intervention can take several forms, such as price support programs, direct payments, and input support, to influence the costs and availability of agricultural inputs such as credit, fertilizers, seeds, irrigation water, etc. Input aid is the most common of all domestic support instruments in agriculture.

Bangladesh's government has, however, launched an incentive program with a Tk (Bangladeshi currency) cost. 336.2 million for small and marginal farmers seeking to rejuvenate the Aus rice cultivation. In contrast, a total of 231,363 small and marginal farmers were provided with seed and chemical fertilisers at no cost to grow local high-yielding variety (HYV) and NERICA (a stress-tolerant African variety) of Aus rice in 49 drought-prone districts

throughout the country [9]. The government of Bangladesh allocated 350 million Tk. for Aus seeds and fertilisers in 2020, while 360 million Tk was allocated for irrigation to increase the output. These required inputs have already been moved to different stations across the country, and the farmers are getting these inputs for the Aus rice cultivation.

Public organisations such as the BRRI, Bangladesh Institute of Nuclear Agriculture (BINA), and universities in Bangladesh have been researching, developing and disseminating modern high-yielding, short-duration rice varieties. BRRI has developed 102 HYV rice varieties, including 7 hybrids (BRRI, 2020). Out of 102 varieties, a few mega varieties have been popularised and adopted in various seasons, contributing to rice self-sufficiency. BRRI developed Aus rice verities covering about 70.28% of the total cultivated areas and produced clean rice of 2.0 million tons. In such a scenario, an in-depth study was undertaken to examine the adoption and yield status of Aus rice varieties, as well as criteria, constraints, and factors influencing the adoption of BRRI-developed Aus rice cultivars.

2. Methodology

2.1. Study Area and Sample Size

The study was conducted at 3 Upazilas in the Jamalpur district. All Upazilas were selected purposively, and two Unions from each Upazila were selected randomly for this survey. The survey was conducted from April to July 2022. A total of 200 farmers were randomly selected to identify factors affecting the BRRI-developed Aus rice cultivars' adoption decision. Farm-level data were collected with key informants and household surveys through a Farmers' Group Discussion (FGD). Besides, ten FGDs were performed to produce in-depth data on the adaptation dynamics of rice varieties during the Aus season. An expert panel interview consisting of the Sub-Assistant Agriculture Officer (SAAO) and Upazila Agriculture Officer (UAO) was held to verify the data gathered via the discussion group of farmers. Using a pre-tested standardised questionnaire, selected farmers were questioned. The data were analysed using both descriptive and inferential statistics. Descriptive statistics are used primarily to analyse the frequency, percentage, mean, and median of the farmers' socioeconomic attributes in the study area. The Tobit model was used to identify the factors behind the adoption of BRRI technology and to analyse the probability of farmers adopting technology and the intensity of adoption.

2.2. Econometric Model

The Logit and Probit models are the popular models used by different research to determine the impact of variables affecting the probability of a given technology being implemented. However, adoption experiments focused on dichotomous regression models have sought to clarify only the probability of adoption versus non-adoption rather than the adoption rate and intensity (Ilesanmi and Afolabi, 2020). Therefore, for specific problems such as fertiliser, a purely dichotomous variable is always inadequate to examine the adoption's extent and intensity (Feder et al., 1985). Meanwhile, Splett et al. (1994) established what became known as the Tobit or censored regression model for circumstances where dependent variable values greater than 0 are observed but are not observed (censored) at zero or lower values (Splett et al. (1994). The Tobit model is also a broad class of models with discrete and continuous parts. It is an extension of the Probit model and is one approach to tackling the censored data problem (Johnston and Dinardo, 1997).

2.3. Model Specification

The Tobit model applied for analysing factors affecting the adoption of BRRI rice varieties is shown below:

$$Y_i^* = \beta X_i + \mu_i, \quad i=1, 2... n.$$

Where,

Y_i=the observed dependent variable (index of adoption of BRRI rice varieties)

Y_i^*=the latent variable

X_i=vector of factors affecting adoption and intensity of BRRI rice varieties

β_i=vector of unknown parameters

μ_i=residuals that are independently and normally distributed with mean zero and a common variance ($\sigma 2$).

The Tobit model shown above is also called a censored regression model because it is possible to view the problem as one where the observation of Y* at or below zero is censored (Johnston and Dinardo, 1997).

2.4. Definition of Variables

In this study, the dependent variable is the adoption and intensity of the BRRI rice varieties. The explanatory variables were taken from those considered to influence the adoption and intensity of BRRI rice varieties.

Table 1. Definition of the Variable

Variables	Description	Expected sign
Dependent variable		
Adoption and intensity of adoption of the BRRI rice Varieties	0 for non-adopters and varied between 0 and 1 for adopters (where 1 mean 100% of BRRI varieties were adopted)	
Explanatory variables		
Socio-demographic variables:		
Farmer age	Year	+
Education	Year of schooling	+
Household size	Number	+
Farm size	Acre	+

Access to information		
Training facilities	Dummy (1=received training, 0=otherwise)	+
Local Market distance	Kilometre	-
Distance to AEO	Kilometre	-
Price Variation	Taka/kg	+
Varietal specific characteristics		
Taste and preference	Dummy (1=good taste and preference, 0=Otherwise)	+
Total Varieties cultivated	Number	+
Yield variation	Kg/ha	+

3. Results and Discussion

3.1. Socio-economic Features

Table 2 summarises the socio-economic and demographic information of the sampled respondents in the study area. The table shows that most of the respondents belong to the age group 31 to 39. The age of farmers plays a crucial position in farming and management practices. Mostly younger farmers are embracing emerging technology more rapidly than their older peers. The average family size was 5.40, of which 55.34% were male. It was observed that 45.05% of respondents had primary education, while 20.47% had no formal education. Results also show that 75.45% of the respondents had a small farm size, and around 75% of their primary occupation was farming in the study area. On average, 48.07% of farmers' farming experience ranged from 21 to 40 years. The average distance from home to the nearby market and Upazila Agriculture Office (UAO) was 3.53 and 5.65 kilometres. Around 15.67% of respondents have also been members of various social organizations.

Table 2. Socio-demographic characteristics of the sample farmers in the study area.

Particulars	Percentage (%)
Age	
<30 years	13.38
31-39 years	40.55
41-50 years	20.22
51-60 years	12.10
61 years and above	13.75
Family size	
1-3 person	16.27
4-6 persons	60.12
7 and above persons	23.61
Male	55.34
Female	44.66
Education	
No formal education (0)	20.47
Primary education (i-v)	45.05
Secondary education (vi-x)	21.21
Higher secondary education (xi-xii)	12.14

Graduate and above	1.13
Farm classification	
Small (0.05-2.19 acre)	75.45
Medium (2.50-7.49 acre)	21.56
Large (7.50 to above acre)	2.99
Occupation	
Farming as primary	75.56
Farming as secondary	24.44
Farming experience	
0-10 years	12.45
11-20 years	23.34
21-40 years	48.07
41 years and above	16.14
The average distance from home to nearby market (km)	3.53
The average distance from home to UAO (km)	5.65
Member of any social organization (%)	15.67

3.2. Factors Affecting Adoption of BRRI Varieties

The outcome of the censored regression in Table 3 showed that, as predicted, several variables influence the likelihood of adoption. For the estimation, the model has included factors presumed to facilitate setting the adoption decisions of alternative rice varieties. The variables were socio-cultural factors, information access, and varietal-specific features. Also checked were multicollinearity and heteroscedasticity for the estimation of the best parameters. Multicollinearity does not affect the estimation of the best parameters at all. Heteroscedasticity was detected in the dataset, and the 'Robust' command on STATA was used to stamp out that problem. The F value also implied the degree of fitness of the model, and the present model shows a higher level of significance overall.

Factors that positively and significantly influence the adoption of BRRI varieties include education marginal and small farm size, training, distance to the local market, price variation, taste, number of varieties cultivated, and yield variation. Results showed that an increase in the education of farmers raises the probability of adoption of BRRI varieties. The result reveals that the more educated the farmer, the more likely would be to adopt BRRI varieties, presumably because he can process more knowledge easily than others. This result is consistent with earlier literature by Langyintuo and Mungoma (2008), Kassie et al. (2011), Asfaw et al. (2012) and Ghimire et al. (2015). The positive and significant sign-on farm size indicated that the probability of farmers adopting and intensifying the BRRI varieties increased as farm size increased. Such findings are compatible with Danso-Abbeam et al.(2017),Mariano et al. (2012), Ghimire et al. (2015) and Islam et al.(2019).

Table 3. Tobit model for determinants of adoption of BRRI Aus varieties in Jamalpur district, (n=200)

Variables	Tobit Coefficient $^{\#)}$	Marginal effect (dy/dx)
Socio-demographic variables		
Age	0.630^{NS} (0.78)	0.62

Education	1.76* (1.69)	1.65*
Household size	0.14^{NS} (0.34)	0.012^{NS}
Farm size	32.34** (2.56)	28.23**
Access to information		
Training	1.451**(2.11)	1.00**
Distance to local market	-2.67* (-1.76)	-1.56*
Distance to UAO	-0.671*(-0.51)	-0.54*
Price variation	7.561** (2.13)	5.231**
Varietal specific characteristics		
Taste and preference	10.561*** (3.56)	6.341***
Number of varieties	2.342* (1.77)	2.011*
Yield variation	13.342*** (2.76)	8.567***
Constant	97.561	
Log pseudo-likelihood	-88.751	
Sigma	104.325	
Prob >F	0.000***	
Pseudo R^2	0.351	

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

Training helps farmers to gain realistic know-how for new technology and technical information. Participation in the training has significantly and positively affected the adoption of BRRI rice cultivars. The finding conforms with the results of Teshome et al. (2019) and Takam-Fongang et al.(2019). However, reducing the gap between the UAO and the local market had a major and optimistic impact on BRRI variety choices. That is because the transaction cost of obtaining varietal information and marketing their goods to the local market is minimized by a lesser distance. These findings agree with Mondo et al. (2019) results. Paddy price is always a more significant factor in farm revenue and is extensively responsible for adopting BRRI varieties.

Additionally, positive and significant coefficients indicate that the adoption decision of more BRRI varieties highly depends on the quality of rice and its good taste. The results are similar to Timu et al.(2014)'s and Otieno et al.(2011). The number of verities coefficients was positive and statistically significant, meaning more varieties give farmers more options. This suggests that more BRRI varieties should increase the coverage of the area to them. The model exposed that yield variation was positive and influenced statistically to significantly increase the area coverage of BRRI varieties in the field of the farmer. Similar results were reported by Ghimire et al. (2015) and Timu et al. (2014). Finally, it was commented that the possibility of a higher yield of any variety of rice might easily inspire the farmers to increase the variety’s area coverage.

4. Conclusion and Recommendation

Adopting modern varieties for cultivation is vital to meet the food demand of the growing population. The availability of quality seeds and region-specific cultivars will also enhance the rice growers' adoption decisions. This research examined the factors that affect the adoption and intensity of the adoption of Aus cultivars of BRRI. Tobit censored regression econometric model was implemented for the study, and the empirical findings revealed that schooling, farm size, training, distance to UAO, price variation, yield variation, taste and preference, and distance to the local market significantly and positively affected BRRI cultivars' decision to adopt, while age, household size had no significant impact on the decision to adopt.

The policy implication of this study is that breeders should also concentrate on non-yield traits such as taste and fine grain and hold cooked rice for more extended periods to develop new Aus varieties since they are very important in explaining the high adoption of BRRI varieties. Secondly, the availability of quality seeds of recently introduced BRRI cultivars should be ensured for farmers. Thus, this requires enormous cooperation between BRRI, DAE, BADC, and other seed producers to deliver the required quality seed to the farmers.

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Ethics Approval and Consent to Participate

All survey participants obtained explicit oral informed consent before the survey enumeration and recorded it as the opening question after reminding survey participants regarding the intent of the research. When permission was refused, the enumeration of the sample was cancelled.

Consent for Publication

Every author accepts and consents to publish the manuscript.

Conflict of Interest Statement

All the authors do not have any possible conflicts of interest.

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