MALAYSIAN JOURNAL OF AGRICULTURAL ECONOMICS

Original Research Article

Factors Influencing Farmers' Behavior Towards Adoption Intensity of The Modern Rice Varieties in Bangladesh

Mohammad Samiul Islam[1], Nitty Hirawaty Kamarulzaman[2]*, Mad Nasir Shamsudin[3], Nolila Mohd Nawi[4], Mohammad Jahangir Alam[5] and Humnath Bhandari[6]

[1,2,4]Department of Agribusiness and Bioresources Economics, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor. gs51403@student.upm.edu.my, nitty@upm.edu.my, nolila@upm.edu.my respectively

[3]Putra Business School, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia. mns@upm.edu.my

[5]Department of Agribusiness and Marketing, Bangladesh Agricultural University, Mymensingh, Bangladesh. Alambau2003@gmail.com

[6]Impact Evaluation, Policy and Foresight Unit, International Rice Research Institute, Dhaka, Bangladesh. h.bhandari@irri.org

*Corresponding author: Nitty Hirawaty Kamarulzaman, Department of Agribusiness and Bioresources Economics, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia; nitty@upm.edu.my

Abstract: The adoption of high-yielding agricultural technologies remains a promising strategy for achieving food security and poverty reduction in developing countries. With the innovation of green technology like seeds, fertilizers, and irrigation water, the productivity of land has increased significantly in Asian countries like Bangladesh. The high-yielding varieties of rice generate a yield gain of 15-20% over the conventional bred varieties in general. Yet, despite strenuous government efforts, farmers' adoption rates have remained low in Bangladesh compared to other Asian countries like India, China and Vietnam. Therefore, this study was carried out to determine the factors influencing the adoption of modern rice varieties in some selected areas of the Mymensingh district in Bangladesh. A structured questionnaire was used to collect data from 510 smallholder *Boro* rice farmers, and the collected data was analyzed using descriptive and Tobit regression analysis. The Tobit regression model was used to determine factors affecting the adoption intensity of modern rice varieties in the *Boro* season. The results of the descriptive analysis demonstrated that most respondents are between the ages of 31 and 39 and that younger farmers are adopting technology at a faster rate than their older counterparts. Tobit model results revealed that factors such as educational levels, farm size, extension contract, training, taste, yield capacity, credit access, seed access, and farmer-based organization membership significantly influence the adoption of modern rice cultivars in Mymensingh. However, factors like farmer age, distance from the extension office, and NPK fertilizer deficiency were found to be negative. Therefore, addressing these factors could facilitate the wider adoption of modern rice cultivars, enhancing productivity and sustainability in the region. These findings recommended that rice breeders should emphasize the farmers' preferences while developing varieties as well as providing training, formal credit, trusted seed dealers and membership access for spreading newly established modern rice cultivars.

Keywords: HYV rice; adoption; diffusion of innovation theory; Tobit model; Bangladesh

Received: 27th November 2023

Received in Revised Form: 3rd May 2024

Available Online: 30th May 2024

Published: 19th June 2024

Citation: Islam, M. S., Kamarulzaman, N. H, Shamsudin, M. N., *et al*.. Factors Influencing Farmers' Behavior Towards Adoption Intensity of The Modern Rice Varieties in Bangladesh. Malays J Agric Econ 2024; 31(1): a0000511. https://doi.org/10.36877/mjae.a0000511

1. Introduction

Increasing crop productivity through agricultural technology adoption can be a significant strategy for farmers to combat hunger and food insecurity (Chandio & Yuansheng, 2018). Additionally, improving family well-being is facilitated by encouraging the sustainable adoption of improved high-yielding variety (HYV) crops (Asfaw *et al*., 2012).

Crops classified as high-yielding varieties (HYV) can yield a substantial quantity of food while being resistant to diseases and pests. According to Bairagi *et al*. (2021), these seeds are of higher quality and a better choice for producing a wide range of crops in a healthy manner. Major crops like rice, maize, and wheat saw a steady increase in production between the 1930s and the late 1960s due to the development of HYV in cereals, which was facilitated by chemical fertilizers, new cultivation and irrigation techniques, and modern management techniques (Evenson *et al.*, 1996; Hossain, 1998).

Rice is the predominant and staple food of about 170 million people, which is closely intertwined with the economy of Bangladesh (Bangladesh Economic Review [BER], 2023). About 75% of the total cropped area and over 72% of the irrigated area is planted rice (Bangladesh Bureau of Statistics [BSS], 2022). In Bangladesh, there are three (3) overlapping rice production seasons: *Aus*, *Aman*, and *Boro* (Shelley *et al*., 2016). The share of rice produced in the *Boro* season 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.

Over the past forty years, Bangladesh has maintained satisfactory growth in rice production. Between 1975 and 1976, 14.18 million tonnes of rice (husked) were produced;

by 2021–2022, that amount had climbed to 38.4 million tonnes (BSS, 2022). Furthermore, between 1975–76 and 2021–22, the average rice yield grew from 1.05 to 5.20 tons per hectare at the same rate as rice production (BBS, 2022). Adopting green revolution technology, such as modern rice varieties (MVs), has transformed the once-dubbed “Bottomless Basket” nation into a “Full of Food Basket” (Al Mamun *et al*., 2021; Kabir *et al*., 2016).

Despite a notable increase in rice production, Bangladesh's average rice yield is substantially lower than the global average, despite being a developed nation (Rahman & Connor, 2022). The reduced yield is caused by a number of variables, including weather-related calamities including droughts, floods, and saline intrusion (Bairagi *et al*., 2021; Mottaleb *et al*., 2015). The use of traditional varieties (TV) of rice is also a significant factor in the lower yields (Rahman *et al*., 2020).

As in other Asian countries, the development of HYV rice has been a major achievement of rice research in Bangladesh. A total of 139 modern HYVs rice have been generated by various rice research organizations in Bangladesh since 1961 in an effort to explore genetic yield potentials (Salam *et al*., 2018). The farmers, however, only use a small number of such varieties (Rahaman *et al*., 2020b; Kabir *et al*., 2021). In addition, adopting these varieties under an unfavourable environments like submergence and drought-prone areas of Bangladesh are very poor (Rahman *et al*., 2021).

Several research papers, including Hossain *et al*. (2013), Kabir *et al*. (2016), and Shew *et al*. (2019), have reported that farmers are adopting traditional varieties (TV) of rice rather than MVs due to the genetic benefits (i.e., increased productivity) of hybrids. Moreover, there is a substantial on-farm yield difference since HYV rice is still not fully adopted throughout the country (Kabir *et al*., 2016). Thus, this study was carried out to determine the factors influencing the adoption of modern rice verities in some selected areas of the Mymensingh district in Bangladesh. Through this study, the government, policymakers, researchers, breeders, and other extension agents will be utilizing the data to know the farmers’ adoption intention towards adopting MVs of rice cultivars.

2. Literature Review

2.1 Empirical Evidence

The empirical review of the literature on technology adoption in developing countries reveals that the various factors that influence technology adoption can be grouped into the following three broad categories (1) factors related to the characteristics of the farmers; (2) factors related to the characteristics and relative performance of the technology and (3) program and institutional factors (Teklewold *et al*., 2013; Melesse, 2018). Farmers' characteristics or sociodemographic factors include education level, experience, age, gender, wealth, farm size, plot characteristics, labour availability, resource endowment, and risk aversion (Islam *et al*., 2023; Rahaman *et al*., 2020b). The age of the household head is another variable in explaining farmers' technology adoption behaviour which plays an important role in influencing farmers' information access and shaping their ability to change the available information into action (Adam *et al*., 2021). Older farmers may have experience and resources that would allow them more possibilities for trying new technology. On the other hand, younger farmers are more likely to adopt new technology because they have had more schooling than the older generation (Ilesanmi & Afolabi, 2020).

Different agricultural technology adoption studies revealed conflicting results on the influence of age on adoption. Some of the findings confirmed that age negatively influences the adoption behaviour of farmers (Islam *et al*., 2023). On the other hand, other agricultural technology adoption studies by other researchers indicated that age positively affected adoption. Various studies confirm that it has a significant favourable influence on adopting technologies. For instance, Nazu *et al*. (2021) studied factors affecting the adoption of improved wheat management practices in Bangladesh. They have found that more educated farmers are likelier to adopt improved wheat management practices in the study area. This finding is consistent with Mariano *et al*. (2012) and Rahaman *et al*. (2020b), who showed that education is statistically significant and has a positive correlation with the intensity of wheat management practices adoption. These results also conform to previous studies (Ghimire *et al*., 2015).

Extension service is a very crucial institutional factor that differentiates adoption status among farmers (Islam, 2018). In the existing situation, much of agricultural technology delivery is undertaken by the extension system. Access to participate in training, demonstration, field day and other extension services therefore creates the platform for the acquisition of the relevant information that promotes technology adoption. Several studies have used different variables to measure farmers' access to extension services (Islam *et al*., 2023; Rahman *et al*., 2019). A study conducted by Rahaman *et al*. (2020b) shows that farmers who had more frequent contact with extension agents were more likely to adopt wheat technology as compared to farmers who had low frequent contact. A similar study conducted by Islam *et al*. (2023) also identified that the farther farmers live from agricultural extension offices (AEO), the less likely they are to adopt new technologies. Therefore, agricultural extension organizations supply useful information about new agricultural technologies. Access to such sources of information can be crucial in the adoption of improved varieties (Rahaman *et al*., 2020b; Rahman *et al*., 2021)).

Technology's characteristics include taste and preference, yield capacity, complexity and performance, availability of complementary inputs, relative profitability, investment recovery period, local adoption patterns, and susceptibility to environmental hazards (Rahaman *et al*., 2020b; Ghimire *et al*., 2015; Timu *et al*., 2014). Yield potential plays a crucial role in cultivating a specific variety (Hossain *et al*., 2006). The study by Rahaman *et al*. (2020a) found that yield variation due to local or old varieties is expected to influence rice cultivars' adoption positively. Similar results were reported by Ghimire *et al*. (2015), Ghimire & Suvedi (2018), and Timu *et al*. (2014).

Different authors confirmed that farmers who have access to credit services are more likely to adopt new agricultural technologies compared to those without such access. Rahaman *et al*. (2020b) confirm access to credit can increase the probability of adopting new agricultural technologies by offsetting the financial shortfall of the households. Similar finding indicates financial resources were necessary to finance the uptake of new technologies (Mottaleb *et al*., 2015; Islam *et al*., 2023). They indicated that households who had more access to formal and/or informal sources of credit significantly adopted technology. In addition, Danso-Abbeam *et al*. (2017) found that access to credit had a positive and significant relationship with the adoption of improved maize varieties among the farmers.

In addition, several studies revealed the biophysical conditions like flood-tolerant zone, drought-tolerant zone, and fertilizer deficiency that affect the adoption intensity of modern rice farmers (Mariano *et al*., 2012; Mottaleb *et al*., 2015; Tiongco & Hossain, 2015; Verma *et al.*, 2021). Therefore, from the review, it can be concluded that sociodemographic characteristics, extension services, biophysical conditions, varietal-specific attributes and institutional factors are the key factors that influence the farmers' intention to adopt the modern rice cultivars (Islam *et al*., 2023; Rahaman *et al*. 2020b; Nazu *et al*., 2021; Mottaleb *et al*., 2015).

2.2 Theory Used in Technology Adoption

The study adopted Rogers's (2003) Theory of Diffusion of Innovation (DOI) to determine the factors affecting the adoption of modern HYV rice. It is one of the well-known theories of innovation that tries to explain how, why, and how quickly an innovation spreads through a population or social system (Rogers, 2003). Many researchers, including Emani *et al*. (2018) and Scott and McGuire (2017), claimed that the DOI theory thoroughly expanded our understanding of psychology and society to explain the steps involved in the adoption of innovation by the general public. The theory has been widely used to describe and explain the behaviour of organizations and individuals towards adopting innovations (Frambach & Schillewaert, 2002; Lim, 2009). The DOI model resembles the Technology Acceptance Model (TAM), which stresses the behavioural intention of the individual to adopt new technology resulting from psychological and social influences (Davis,1989).In this study variables such as sociodemographic characteristics, extension services, biophysical conditions, varietal-specific attributes, and institutional access from Rogers's (2003) theory of diffusion of innovation (DOI) were incorporated to determine the factors influencing the adoption of modern rice verities.

Figure 1 shows the conceptual framework that was established for the study. The framework was adopted from the theory of the Diffusion of Innovation (DOI) (Rogers, 1962). The DOI theory is one of the most established and most implemented theories of human behavioural research (Jamshidi *et al.*, 2015; Oliveira & Martins, 2011). The variables such as sociodemographic characteristics (decision-making unit), varietal specific attributes (relative advantage), extension services (trialability and observability), and institutional access (compatibility) were adopted from the DOI theory, while the biophysical conditions variables were adapted from the studies of Mariano *et al*. (2012) and Rahman *et al*. (2020b). The dependent variable of this study was the adoption intensity of the modern HYV rice and dependent variables namely sociodemographic characteristics, extension services, biophysical conditions, varietal-specific characteristics, and institutional access-related factors were used to determine factors influencing farmers' intention to adopt modern HYV rice.

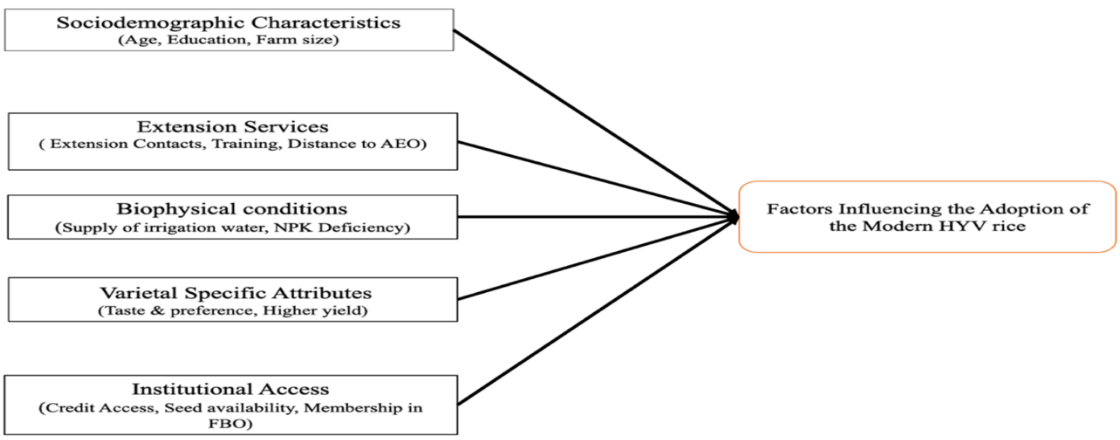

Figure 1. Conceptual framework of factors influencing adoption of modern HYV rice.
Source: Adapted from Rogers (2003), Mariano *et al*. (2012), Rahman *et al*. (2020b).

3. Materials and Methods

3.1 Study Area

The location of this study includes seven Upazilas of Mymensingh district under the Mymensingh Division of Bangladesh. Mymensingh district consists of twelve Upazilas such as Bhaluka, Dhubaura, Fulbaria, Gaffargaon, Gauripur, Haluaghat, Ishargonj, Mymensingh Sadar, Muktagacha, Nandail, Phulpur, and Trishal (BBS, 2013). Figure 2 shows the map of the Mymensingh district of Bangladesh. Among the twelve Upazalia, seven are selected for this study based on the production, area and farm holding of modern rice cultivars. They are Phulpur, Fulbaria, Nandail, Trishal, Haluaghat, Gaffarfaon and Mymensingh Sadar (Figure 2).

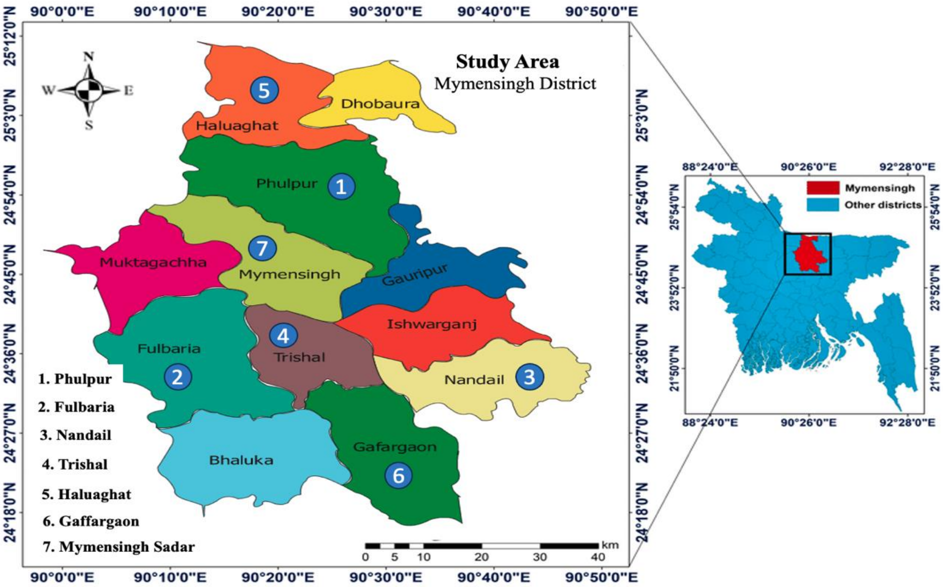

Figure 2. Study Area Map of Different Upazilas of Mymensingh District, Bangladesh.

3.2 Sampling Techniques and Sample Size

A multi-stage random sampling technique was used to select a representative sample of rice farmers. In the initial stage, Mymensingh district was selected in consultation with local agriculture officers. In the subsequent stage, six Upazilas—Phulpur, Fulbaria, Nandail, Trishal, Haluaghat, Gaffargaon, and Mymensingh Sadar—were chosen based on their HYV Boro rice production levels. In the third stage, the sample was distributed according to the percentage (%) of farm holdings. Seven Upazilas were chosen as the study area since they account for approximately 89% of the total HYV Boro rice production in the Mymensingh district, based on the most recent district statistics published in 2011 by the Bangladesh Bureau of Statistics (BBS). Due to the large sample size (Mymensingh district) and homogeneity of production in all areas in the Mymensingh district, a total of 511 respondents were selected as respondents for the study using the method proposed by Yamane (1967) represented in equation (1) below:

$$n = \frac{\mathrm{N}}{1 + \mathrm{N}(\mathrm{e})\hat{}2} \qquad (1)$$

Where, margin errors, e= 0.05, confidence level= 95%, population, N=404375, and sample size, *n*=510 farmers.

Table 1. Sample Size of Mymensingh District

Upazila	Area ('ooo') ha	Production ('ooo') MT	Farm Holding	% of farm Holdings	Sample size per Uoazila
Phulpur	43	179	85004	21%	107
Fulbaria	21	90	64500	16%	82
Nandail	22	88	57054	14%	72
Trishal	22	89	52717	13%	67
Haluaghat	21	81	43921	11%	56
Gaffargaon	21	82	44125	11%	56
Mymensingh Sadar	21	77	57054	14%	72
Total	**172**	**686**	**N=404375**	**100%**	**n=510**

Source: District Statistics 2011, Mymensingh, BBS

Hence a total of 510 sample farm households were selected to collect socio-demographic characteristics, extension services, biophysical conditions, varietal-specific characteristics, and institutional access-related data to identify factors affecting the adoption of the modern rice cultivars.

The adoption rate and intensity were calculated as a percentage of the total farmland allotted to modern rice cultivars. For non-adopters, this has a value of 0; for adopters, it has a value between 0 and 1 (where 1 means that 100% of the current variations were accepted). Adoption and adoption intensity were analysed on a discrete and continuous assessment scale.

The data collected were analysed using several statistical analyses such as descriptive, Chi-square, and Tobit regression analyses. Descriptive analysis is used to explain the socio-demographic profiles of the respondents. Chi-square analysis on the other hand was used to measure the associations between the independent variables with the dependent variables like adoption and intensity of modern rice adoption.

Tobit regression analysis was used to determine the factors influencing modern rice adoption. The Tobit model is the modified version of the Probit and Logit model, that addresses the issue of censored data (Johnston & Dinardo 1997). Following the work of Maddala (1983), the Tobit model can be derived by defining a new random variable y* that is a function of a vector of variables.

The equation for the model is constructed as:

$$y^* = X_i\beta_i + \varepsilon_i \tag{2}$$

Where y* is unobserved for values less than 0 and greater than 1 (called a latent variable) which represents an index for the adoption of modern rice cultivars; and X_i represents a vector of explanatory variables; β_i is a vector of unknown parameters; and εi is the error term. By representing Y_i (a particular agricultural technology adoption index) as the observed dependent variable, the two-limit Tobit model can be specified as:

$$Y_i = \begin{cases} 0 \ if \ Y_i^* \leq 0 & (3) \\ Y^* \ if \ 0 < Y_i^* < 1 & (4) \\ 1 \ if \ Y_i^* > 1 & (5) \end{cases}$$

Censored regression models (including the standard Tobit model) are usually estimated by the Maximum Likelihood (ML) method. The log-likelihood function is specified with an assumption that the error term ε follows a normal distribution with mean 0 and variance σ^2. The Tobit coefficients can be interpreted as coefficients of a linear regression model. Accordingly, factors that influence the use intensity of modern rice were identified using the Two-limit Tobit model.

3.3 Multiple Regression Analysis

Multiple regression tests were used to analyse the contribution of independent variables to dependent variables and study the level of contribution of independent variables in depth. Tobit regression analysis was used to determine how the farmers' adoption intention could be explained by respondents' sociodemographics, extension services, biophysical conditions, varietal-specific characteristics, and institutional access-related factors. Thirteen predictors Tobit regression model was proposed to explain the variation of the adoption intensity. The multiple regression equation can be expressed as follows:

$$Y = bo + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} \tag{6}$$

$$+ b_{11}X_{11} + b_{12}X_{12} + b_{13}X_{13} + \varepsilon.$$

Where:
Y= adoption and intensity of adoption
X_1 = Age
X_2 = Education level
X_3 = Farm size
X_4 = FBO membership
X_5 = Extension contracts
X_6 = Distance to Agriculture Extension office (AEO)
X_7 = Training
X_8 = Irrigation water supply
X_9 = NPK deficiency
X_{10} = Taste and preference
X_{11} = Higher yield capacity
X_{12} = Credit Access
X_{13} = Seed Access
bo = constant
ε = error

The independent variables are used to explain the variation in the dependent variable. The variables used in this study were selected from previous studies and based on their implications from economic theory.

4. Results and Discussions

Table 2 shows a summary of the socio-demographic information of *Boro* rice sampled farmers in the Mymensingh district.

As shown by the statistics in Table 2, most respondents fall within the age range of 31 to 39. A significant factor in farming and management strategies is the age of the farmers. Younger farmers are adopting technology more quickly than their older counterparts. With a mean family size of 5.30, 60.34% were male. 38.01% of respondents had completed elementary school, compared to 29.51% who had never attended a formal educational setting. According to the results, approximately 75.35% of the respondents' primary occupation in the research area was farming, while 70.25% of the respondents owned small farms. The average farming experience ranged from 21 to 40 years for 47.13% of farmers. The average distance was 4.86 kilometres from one's residence to the Upazila Agricultural Office (UAO). Generally, 17.45% of those surveyed had also participated in different social groups as members.

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

Variables	Group	Frequency	Percentage (%)
Gender	Male	306	**60.34**
	Female	204	39.66
	Total	510	100
Age	<30 years	78	15.32
	31-39 years	205	**40.23**
	41-50 years	107	21.12
	51-60 years	52	10.1
	61 Years and above	68	13.23
	Total	510	100
Family Size	1-3 person	74	14.45
	4-6 person	326	**64.10**
	7 and above	110	21.45
	Total	510	100
Education Level	No formal education(0)	150	29.51
	Primary education (i-v)	195	**38.01**
	Secondary Education (vi-x)	83	16.22
	Higher secondary education (xi-xii)	72	14.12
	Gradate and above	10	2.14
	Total	510	100
Farm Size	Small (0.05-2.19 acre)	358	**70.25**
	Medium (2.5-7.49 acre)	140	27.53
	Large (7.5 to above)	12	2.22
	Total	510	100
Occupation	Agriculture as Primary	385	**75.35**
	Agriculture as Secondary	125	24.65
	Total	510	100
Farming Experience	0-10 years	92	18.1
	11-20 years	125	24.67
	21-40 years	240	**47.13**
	Above 41 years	51	10.10
	Total	510	100
The average distance from home to UAO (km)		510	4.86
Member of any social organization		510	**17.45**

4.2 Factors Influencing the Adoption of Modern HYV Rice Varieties

The estimated results from the Tobit regression models are displayed in Table 3. The Tobit model includes factors that were thought to help with figuring out whether alternative rice varieties would be accepted. Multicollinearity and heteroskedasticity do not affect choosing the appropriate parameters, allowing the diagnosis of the data set to be checked off. Once heteroscedasticity in the data set was identified, Stata's "Robust" command was used to resolve the problem. The F value always represents the model's goodness level of fitness, and the current model exhibits a higher level of overall significance. Additionally, the model explicitly stated both the upper and lower limits.

The findings of the Tobit regression model provided in Table 3 indicate that twelve out of the thirteen variables employed in the model were crucial for interpreting the variation in the intensity of modern rice cultivar adoption. The age of the farmers was negative and statistically significant. The result suggests that younger farmers are more likely to adopt new rice varieties than their older peers. The result suggests that younger farmers are more likely to adopt new rice varieties than their older peers. Younger farmers preferred to take risks, particularly in choosing new farm technology (Hoque *et al*., 2022; Rahaman *et al*., 2020b; Chandio & Yuansheng, 2018; Karidjo *et al*., 2018; Mutuku *et al*., 2017).

Results showed that education is statistically significant and correlates positively with the adoption intensity of modern *Boro* rice cultivars. Farmers with a relatively high educational level thus intensify the adoption of modern rice cultivars compared to their counterparts with inferior educational levels, presumably because they can understand and evaluate new rice technologies and quickly process more knowledge than others. This result conforms to previous studies (Hoque *et al*., 2022; Ilesanmi & Afolabi, 2020; Kumar *et al*., 2020; Rahaman *et al*., 2020b; Ghimire *et al*., 2015).

Table 3. Estimation of Tobit Regression Model for Determinants of Adoption of Modern *Boro* Rice Cultivars in The Mymensingh District (*n*=510)

Explanatory Variables	Adoption intensity of HYV rice cultivars Coefficient	Robust Std. Err.	t-statistics	P>|t|	Expected sign
Sociodemographic characteristics:					
Age (year)	-0.0027 **	0.015	-1.78	0.076	-
Education (year of schooling)	0.026 ***	0.007	3.70	0.000	+
Farm size (acre)	0.045***	0.015	2.92	0.004	+
Extension services:					
Extension Contact (Dummy)	0.053**	0.023	2.26	0.024	+
Training (Dummy)	0.144***	0.032	4.56	0.000	+
Distance to UAO (km)	-0.062***	0.016	-3.92	0.000	-
Biophysical conditions:					
Supply of Irrigation water (Dummy)	0.032^{NS}	0.024	1.35	0.177	+
NPK-deficiency (Dummy)	-0.063**	0.024	-2.57	0.010	-

Explanatory Variables	Adoption intensity of HYV rice cultivars				
	Coefficient	Robust Std. Err.	t-statistics	P>|t|	Expected sign
Varietal-specific attributes:					
Taste & preference (Dummy)	0.120**	0.062	1.94	0.053	+
Higher Yield Capacity (Dummy)	0.115***	0.030	3.80	0.000	+
Institutional access:					
Credit Access (Dummy)	0.089***	0.027	3.30	0.001	+
Seed Access (Dummy)	0.073**	0.0312	2.37	0.018	+
Member of FBO (Dummy)	0.055**	0.024	2.29	0.022	+
Constant	0.236**	0.1241	1.91	0.057	
Log pseudo-likelihood value	-48.574				
Sigma	0.1965608				
Prob > F	0.0000				
Pseudo R^2	0.8911				
VIF	1.82				

Note: *, **, and * imply statistical significance at 10%, 5% and 1 % levels, respectively. NS means not significant.**

The results show that the likelihood and intensity of adoption of modern rice cultivars were directly linked to the size of the farm holdings. The positive and significant sign-on effect of farm size indicates that as farm size increased, farmers were more likely to adopt and intensify modern rice cultivars. These results are consistent with the empirical studies of Pello *et al*. (2021), Groher *et al*. (2020), Rahaman *et al*. (2020b), Ghimire *et al*. (2018), and Danso-Abbeam *et al*. (2017).

The extension contact is a significant consideration for adopting modern *Boro* rice cultivars. In this study, the coefficient of extension contact was positive and significant. It suggests that if farmers in the Mymensingh district had more significant extension interactions with the extension agents, they were more likely to adopt new *Boro* cultivars. This outcome is in line with the findings of Hoque *et al*. (2022), Massresha *et al*. (2021), Pello *et al*. (2021), Rahaman *et al*. (2020b), Chandio & Yuansheng (2018), Mutuku *et al*. (2017), and Ghimire *et al*. (2015).

Moreover, the training helped the farmers adopt modern rice, as evidenced by the significant and positive coefficient of training attendance. This may be explained by the fact that trained farmers have a greater understanding of the benefits of the modern rice cultivar and associated production techniques, increasing the adoption rate of modern rice cultivars. This finding is supported by Hossain *et al*., 2021; Liu *et al*. (2018); Martey and Kuwornu (2021); Rahaman *et al*. (2020b); Takam-Fongang *et al*. (2019); Zakaria *et al*. (2020) results.

The results show that the distance of the Upazila Agriculture Extension Office (AEO) had a negative and significant correlation with the adoption intensity of improved *Boro* rice cultivars in the study area. The result indicates that reducing the distance to the AEO significantly and positively impacted farmers' choices of modern rice cultivars. That is because a lesser distance minimizes the transaction cost of obtaining varied information and training facilities. These results concur with those of Awotide *et al*., (2016), Asfaw *et al*. (2012), Gebre *et al*. (2019) and Rahaman *et al*. (2020b).

The coefficient of biophysical conditions like NPK deficiency was negative and significant in the model. The result indicates that the farmers were discouraged from adopting modern *Boro* rice cultivars due to nutrient deficiencies in their cultivating land. This finding is consistent with the studies of Alauddin & Sarkar (2014), Komatsu *et al*. (2022), Mariano *et al*. (2012), and Mutuku *et al*. (2017). Additionally, positive and significant taste and preference coefficients show that the preference to adopt more modern *Boro* rice cultivars is greatly affected by the taste and quality of the rice. The results support those from Okello and Okello (2021), Rahaman *et al*. (2020a, 2020b) and Timu *et al*. (2014). The model demonstrated that yield variation was statistically influenced by considerably increasing the area coverage of the improved *Boro* rice varieties in the farmer's field.

Finally, it was mentioned that any rice variety's potential for a larger yield might encourage growers to expand their planting areas. The results of Bannor *et al*. (2020), Ghimire *et al*. (2015) and Rahaman *et al*. (2020b) agree with this research. The results indicated that the farmers' access to credit significantly and positively influenced the adoption of modern *Boro* rice cultivars. Access to credit is expected to increase the probability of adoption because credit enables farmers to purchase necessary inputs, like seeds, fertilizers, labour, fuel, etc., that are required to produce rice. This result of the study is consistent with the findings of Donkor *et al*. (2018), Hagos *et al*. (2018), Haque (2019), and Mutuku *et al*. (2017), Ruzzante *et al*. (2021), and Ullah *et al*. (2020).

The availability of seeds positively and significantly impacted the adoption intensity of modern *Boro* rice cultivars. The presence of government-approved registered seed dealers influences the farmers' intention to adopt modern *Boro* rice cultivars. The result is consistent with the empirical studies by Bannor *et al*. (2020), Danso-Abbeam *et al*. (2017), Singh *et al*.

(2018) and Zeleke *et al*. (2021). Besides, membership in farmer-based organisations (FBOs) influenced the adoption intensity of modern *Boro* rice in the Mymensingh district positively and significantly. Membership status in the FBO increases the probability of a farmer adopting an improved agricultural technology compared to a non-member. Farmers obtain much information regarding production and marketing through a farmer-to-farmer network. The finding is consistent with Massresha *et al*. (2021), Zakaria *et al*. (2020), Danso-Abbeam *et al*. (2017).

5. Conclusions

In Bangladesh, rice contributes a significant portion of the country's dietary intake of calories and protein. Production of rice has achieved almost a self-sufficiency threshold level, but each year a significant amount of rice needs to be imported to meet the domestic demands. The supply of rice is vulnerable to indifferent natural shocks like floods, drought, cyclones and salinity intrusion. In addition to these, access to certified and modern rice seeds is another important hindrance to the lower productivity in rice production. So, to feed the growing population of Bangladesh, it is necessary to increase rice production in the country by adopting improved rice cultivars. Therefore, this study analysed the factors that influence the adoption intensity of modern rice varieties by smallholder farmers in the Mymensingh district in Bangladesh. The results of the descriptive analysis demonstrated that most respondents are between the ages of 31 and 39 and that younger farmers are adopting technology at a faster rate than their older counterparts. For the study, the Tobit econometric model was applied, and the empirical results revealed that factors such as education level, farm size, extension contact, and training facilities were significant and positively associated with the farmers' intention to adopt modern rice. Furthermore, taste and preference, yield capacity, credit access, seed access, and membership in social organizations were also significant and positive factors influencing farmers' intention behaviour to adopt the modern rice cultivars whereas age, distance from agricultural extension offices, and fertilizer deficiency had significantly negative effect on adoption of modern rice cultivars.

Based on the findings, this study recommended that the rice breeder and extension workers consider these findings to develop new varieties and disseminate them to the farmers swiftly. In addition, it is necessary to strengthen farmers' training centres to enable them to properly demonstrate available modern rice and at the same time to capacitate farmers on technology utilization by offering training. The policy consequence of this study is that breeders should also concentrate on features such as the taste of premium grain quality and higher yield in their efforts to develop new *Boro* rice cultivars as they are very significant in describing the high adoption. Intensifying extension programs in rural areas would encourage newly developed modern cultivars to be adopted by farmers. Moreover, the study recommended that the farmers should stay informed about the latest rice varieties and join farmer field schools or similar programs that offer hands-on training and demonstration of modern rice techniques. This study also recommended that financial sources of credit like Bangladesh Agricultural Bank (BKB), Commercial Banks, and Microfinance institutions should provide timely and easy access to agricultural credit facilities to the farmers. Moreover, there is need for a friendly cooperation among different rice research and extension organizations such as the Bangladesh Rice Research Institute (BRRI), Bangladesh Institute of Nuclear Agriculture (BINA), the Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (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.

This study revealed many interesting results, nevertheless, it has many limitations that must be considered. Firstly, the limitation was related to the sample and location of the study. Although in the present study, the sample size was reasonably large, it merely covered a few Upazila under the Mymensingh District of Bangladesh. This condition probably affected the generalisation of the findings. For further research, an investigation avenue could be expanded to other districts of Bangladesh, where rice was produced as a major crop. Secondly, the study was limited in determining the factors affecting the adoption of modern rice varieties during the *Boro* season. Still, a further investigation could be conducted on the other two rice growing seasons (*Aus* and *Aman*) in Bangladesh.

Acknowledgements: The authors express their gratitude to the International Rice Research Institute for funding this research under the Lee Foundation Rice Scholarship Program under agreement No. A-2012-285/8R-633-13396. The authors are very grateful to the farmers, Upazila agriculture officer (UAO), and Sub-assistant Agriculture Officer (SAAO) for providing the required data for this research.

Conflict of Interests: The authors declare that there is no conflict of interest regarding the publication of this paper.

References

Al Mamun, M. A., Nihad, S. A. I., Sarkar, M. A. R., *et al.* (2021). Growth and trend analysis of area, production and yield of rice: A scenario of rice security in Bangladesh. *PLoS ONE*, *16*(12), e0261128. https://doi.org/10.1371/journal.pone.0261128

Adam, L., Jin, J., Khan, A., *et al*. (2021). A study of the adoption of technology in agriculture: Evidence from the Indonesian paddy-rice Farmer. *Cutting-Edge Research in Agricultural Sciences*, *12*, 105–124.

Alauddin, M., & Sarker, M. A. R. (2014). Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. *Ecological Economics*, *106*, 204–213.

Asfaw, S., Shiferaw, B., Simtowe, F., *et al.* (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, *37*(3), 283–295.

Awotide, B.A., Karimov, A.A., & Diagne, A. (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. *Agricultural and Food Economics*, *4*(3), 1–24. https://doi:10.1186/s40100-016-0047-8

Bairagi, S., Bhandari, H., Das, S. K., *et al*. (2021). Flood-tolerant rice improves climate resilience, profitability, and household consumption in Bangladesh. *Food Policy*, *105*, 102183. https://doi.org/10.1016/j.foodpol.2021.102183

Bannor, R. K., Kumar, G. A. K., Oppong-Kyeremeh, H., *et al*. (2020). Adoption and impact of modern rice varieties on poverty in Eastern India. *Rice Science*, *27*(1), 56–66.

Bangladesh Bureau of Statistics. (2013). *District Statistics 2011*, *Mymensingh*. Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Retrieved from https://www.bbs.gov.bd

Bangladesh Bureau of Statistics. (2022*). Preliminary Report on Agricultural Census of Bangladesh*. Dhaka: Ministry of Planning, Government of the People's Republic of Bangladesh. Retrieved from https://www.bbs.gov.bd

Bangladesh Economic Review. (2023). Economic Adviser's Wing, Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh. Dhaka. p.17–99.

Chandio, A. A. & Yuansheng, J. I. A. N. G. (2018). Determinants of adoption of improved rice varieties in Northern Sindh, Pakistan. *Rice Science*, *25*(2), 103–110.

Danso-Abbeam, G., Bosiako, J. A. Ehiakpor, D. S., *et al.* (2017). Adoption of improved maize variety among farm households in the northern region of Ghana. Cogent Economics & Finance, 5(1), 1416896.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319–340.

Donkor, E., Owusu, V., Owusu-Sekyere, E., *et al*. (2018). The adoption of farm innovations among rice producers in Northern Ghana: Implications for sustainable rice supply. *Agriculture*, *8*(8), 121.

Emani, S., Peters, E., Desai, S., *et al.* (2018). Perceptions of adopters versus non-adopters of a patient portal: an application of diffusion of innovation theory. *BMJ health & care informatics*, *25*(3).

Evenson, R. E., Herdt, R. W., & Hossain, M. (Eds.). (1996). *Rice research in Asia: Progress and priorities*. IRRI.

Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption: A multi-level framework of determinants and opportunities for future research. *Journal of Business Research*, *55*(2), 163–176.

Gebre, G. G., Isoda, H., Amekawa, Y., *et al.* (2019). Gender differences in the adoption of agricultural technology: The case of improved maize varieties in southern Ethiopia. *Women's Studies International Forum*, *76*, 102264.

Ghimire, R. & Suvedi, M. (2018). Farmers' adoption of improved rice varieties in Cambodia. *Journal of ISSAAS (International Society for Southeast Asian Agricultural Sciences)*, *24*(1), 41–57.

Ghimire, R., Wen-Chi, H.U.A.N.G. Shrestha, R. B. (2015). Factors affecting the adoption of improved rice varieties among rural farm households in Central Nepal. *Rice Science*, *22*(1), 35–43. https://doi.org/10.1016/j.rsci.2015.05.006.

Groher, T., Heitkämper, K., & Umstätter, C. (2020). Digital technology adoption in livestock production with a special focus on ruminant farming. *Animal*, *14*(11), 2404–2413.

Hagos, H., Ndemo, E., & Yosuf, J. (2018). Factors affecting adoption of upland rice in Tselemti district, Northern Ethiopia. *Agriculture & Food Security*, *7*(1), 1–9.

Hoque, M. N., Saha, S. M., Imran, S., *et al.* (2022). Farmers' agrochemicals usage and willingness to adopt organic inputs: Watermelon farming in Bangladesh. *Environmental Challenges*, *7*, 100451.

Hossain, M. (1998). Rice research, technological progress, and the impact on the rural economy: The Bangladesh Case. In P. L. Pingali & M. Hossain (Ed.), *Impact of rice research* (pp. 311–342). International Rice Research Institute (IRRI).

Hossain, M. S., Islam, A. K. M. S., Kabir, M. J., *et al.* (2021). Role of Training in Transferring Rice Production Technologies to Farm Level. *Bangladesh Rice Journal*, *25*(1), 111–120.

Hossain, A., & da Silva, J. A. T. (2013). Wheat and rice, the epicenter of food security in Bangladesh. *Songklanakarin Journal of Science and Technology*, *35*(3), 261–274.

Hossain, M., Bose, M. L., & Mustafi, B. A. A. (2006). Adoption and productivity impact of modern rice varieties in Bangladesh. *Developing Economies*, *44*(2), 149–166. https://doi.org/10.1111/j.1746-1049.2006.00011.x

Ilesanmi, J. O., & Afolabi, J. A. (2020). Determinants of adoption of improved cocoa technologies in Ekiti state, Nigeria. *International Journal of Agricultural Economics*, *5*(2), 36.

Islam, M. S., Huda, S. N., Begum, A., *et al.* (2023). Drivers of adoption intensity of BRRI released modern *Aus* rice varieties: Evidence from smallholders farmers in Jamalpur district of Bangladesh. ICRRD *Quality Index Research Journal*, *4*(1), 191–201. https://doi.org/10.53272/icrrd.v4i1.8.

Islam, A. (2018). Impact of improved rice varieties adoption on farmers' well-being (livelihood) in rural Bangladesh. *Bangladesh Journal of Agricultural Economics*, *38*(1). https://doi.org/10.22004/ag.econ.283710

Jamshidi, D., Hussin, N. & Lai Wan, H. (2015). Islamic banking services adoption as a new banking restructure: examining its adoption from the perspective of DOI theory and trust in Malaysia. *Humanomics*, *31*(2), 214–223.

Johnston, J., & DiNardo, J. (1997). *Econometric methods* (4th ed). New York.

Kabir, M. S., Paul, D. N. R., Hossain, M. I., *et al.* (2016). estimating area and production of rice under different crop-cut methods in Bangladesh. *Bangladesh Rice Journal*, *20*(1). https://doi.org/10.3329/brj.v20i1.30624

Kabir, M. J., Islam, M. A., Rahman, M. C., *et al*. (2019). Diffusion of wet season (T. Aman) rice cultivars under changed environment in northwest Bangladesh. *Bangladesh Rice Journal*, *23*(1), 81–106.

Kabir, M. S., Salam, M., Islam, A., *et al*. (2021). Doubling rice productivity in Bangladesh: A way to achieving SDG 2 and moving forward. *Bangladesh Rice Journal*, *24*(2), 1–47. https://doi.org/10.3329/brj.v24i2.53447

Karidjo, B. Y., Wang, Z., Boubacar, Y., *et al.* (2018). Factors influencing farmers' adoption of soil and water control technology (SWCT) in Keita valley, a semi-arid area of Niger. *Sustainability*, *10*(2), 288.

Komatsu, S., Saito, K., & Sakurai, T. (2022). Changes in production, yields, and the cropped area of lowland rice over the last 20 years and factors affecting their variations in Côte d′ Ivoire. *Field Crops Research*, *277*, 108424.

Kumar, A., Tripathi, G., & Joshi, P. K. (2020). Adoption and impact of modern varieties of paddy in India: evidence from a nationally representative field survey. *Journal of Agribusiness in Developing and Emerging Economies*, *11*(3), 255–279.

Lim, D. F., Singh, S. G., Ang, X. F., *et al.* (2009). Achieving low-temperature Cu to Cu diffusion bonding with self-assembly monolayer (SAM) passivation. *2009 IEEE International Conference on 3D System Integration*, 1–5.

Liu, T., Bruins, R. J., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, *10*(2), 432.

Maddala, G. S. (1983). Methods of estimation for models of markets with bounded price variation. *International Economic Review*, 361–378

Mariano, M. J., Villano, R., & Fleming, E. (2012). Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. *Agricultural systems*, *110*, 41–53.

Martey, E., & Kuwornu, J. K. (2021). Perceptions of climate variability and soil fertility management choices among smallholder farmers in northern Ghana. *Ecological Economics*, *180*, 106870

Massresha, S. E., Lema, T. Z., Neway, M. M., *et al.* (2021). Perception and determinants of agricultural technology adoption in North Shoa zone, Amhara regional state, Ethiopia. *Cogent Economics & Finance*, *9*(1), 1956774.

Melesse, B. (2018). A review on factors affecting adoption of agricultural new technologies in Ethiopia. *Journal of Agricultural Science and Food Research*, *9*(3), 1–4.

Miller, R. L. (2015). Rogers' innovation diffusion theory (1962, 1995). In *Information seeking behavior and technology adoption: Theories and trends*, 261–274. IGI Global.

Mottaleb, K. A., Mohanty, S., & Nelson, A. (2015). Factors influencing hybrid rice adoption: a Bangladesh case. *Australian Journal of Agricultural and Resource Economics*, *59*(2), 258–274.

Mutuku, M. M., Nguluu, S., Akuja, T., *et al.* (2017). Factors that influence adoption of integrated soil fertility and water management practices by smallholder farmers in the semi-arid areas of eastern Kenya. *Tropical and Subtropical Agroecosystems*, *20*(1).

Nazu, S. B., Khan, M. A., Saha, S. M., *et al*. (2021). Adoption of improved wheat management practices: an empirical investigation on conservation and traditional technology in Bangladesh. *Journal of Agriculture and Food Research*, *4*, 100143.

Okello, D., & Okello, P. (2021). Dairy agripreneurs' preference for production and animal health support services in Kenya—a choice experiment. *Tropical Animal Health and Production*, *53*(3), 1–10.

Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. *Electronic journal of information systems evaluation*, *14*(1), 110–121.

Onuoha, O. C. & Umebali, E. (2021). Determinants of adoption of new agricultural technologies by cooperative farmers in Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, *39*(9), 66–75.

Pello, K., Okinda, C., Liu, A., *et al*. (2021). Factors affecting adaptation to climate change through agroforestry in Kenya. *Land*, *10*(4), 371.

Rahman, M. C., Islam, M. A., Rahaman, M. S., *et al.* (2021). Identifying the threshold level of flooding for rice production in Bangladesh: An empirical analysis. *Journal of the Bangladesh Agricultural University*, *19*(2), 243–250. https://doi. org/10.5455/jbau.53297.

Rahman, Md. A., Islam, R., Falguni, M. R., *et al.* (2019). Adoption of BRRI dhan49 by the farmers of Bogura Sadar Upazila in Bangladesh. *Asian Journal of Research in Agriculture and Forestry*. https://doi.org/10.9734/ajraf/2019/v3i230037

Rahaman, M. S., Kabir, M. J., Sarkar, M. A. R., *et al.* (2020a). Factors affecting the adoption of BRRI released *Aus* rice varieties in Mymensingh District. *Agricultural Economics*, *5*(5), 210–217.

Rahaman, M. S., Sarkar, M. A. R., Rahman, M. C., *et al.* (2020b). Drivers of adoption of BRRI cultivars in *Boro* season among farm households of Mymensingh district, Bangladesh. *Journal of the Bangladesh Agricultural University*, *18*(3), 660–666.

Rahman, M. M., & Connor, J. D. (2022). The effect of high-yielding variety on rice yield, farm income and household nutrition: evidence from rural Bangladesh. *Agriculture and Food Security*, *11*(1), 1–11. https://doi.org/10.1186/s40066-022-00365-6

Rogers, C. R. (1962). The interpersonal relationship: The core of guidance. *Harvard Educational Review*. *32*(4), 416–429.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Ruzzante, S., Labarta, R., & Bilton, A. (2021). Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development*, *146*, 105599.

Salam, M. U., Mahalder, B. K., Bhandari, H., *et al.* (2018). Policy directions toward increasing rice productivity lessons from Bangladesh. *Advances in Rice Research for Abiotic Stress Tolerance*, 895–913 https://doi.org/10.1016/B978-0-12-814332-2.00044-7

Scott, S., & McGuire, J. (2017). Using Diffusion of Innovation theory to promote universally designed college instruction. *International Journal of Teaching and Learning in Higher Education*, *29*(1), 119–128.

Shelley, I. J., Takahashi-Nosaka, M., Kano-Nakata, M., *et al.* (2016). Rice cultivation in Bangladesh: Present scenario, problems, and prospects. *Journal of International Cooperation for Agricultural Development*, *14*.

Shew, A. M., Durand-Morat, A., Putman, B., *et al.* (2019). Rice intensification in Bangladesh improves economic and environmental welfare. *Environmental Science and Policy*, *95*. https://doi.org/10.1016/j.envsci.2019.02.004

Singh, A., MacGowan, B., O'Donnell, M., *et al.* (2018). The influence of demonstration sites and field days on adoption of conservation practices. *Journal of Soil and Water Conservation*, *73*(3), 276–283.

Takam-Fongang, G. M., Kamdem, C. B., & Kane, G. Q. (2019). Adoption and impact of improved maize varieties on maize yields: Evidence from central Cameroon. *Review of Development Economics*, *23*(1), 172–188.

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of agricultural economics*, *64*(3), 597–623.

Timu, A. G., Mulwa, R., Okello, J., *et al.* (2014). The role of varietal attributes on adoption of improved seed varieties: the case of sorghum in Kenya. *Agriculture & Food Security*, *3*(1), 1–7.

Tiongco, M., & Hossain, M. (2015). *Adoption of modern varieties and rice varietal diversification on household farms in Bangladesh*. HarvestPlus Working Paper 22, International Food Policy Research Institute: Washington, DC.

Ullah, A., Saqib, S. E., & Kächele, H. (2022). Determinants of Farmers' Awareness and Adoption of Extension Recommended Wheat Varieties in the Rainfed Areas of Pakistan. *Sustainability*, *14*(6), 3194.

Verma, D. K., Singh, H., & Meena, G. L. (2021). Factors Affecting Production of Cereal Crops in Rajasthan: The Cobb-Douglas Analysis. *Economic Affairs*, *66*(2), 195–200.

Zakaria, A., Azumah, S. B., Appiah-Twumasi, M., *et al*. (2020). Adoption of climate-smart agricultural practices among farm households in Ghana: The role of farmer participation in training programmes. *Technology in Society*, *63*, 101338.

Zeleke, B. D., Geleto, A. K., Komicha, H. H., *et al.* (2021). Determinants of adopting improved bread wheat varieties in Arsi Highland, Oromia Region, Ethiopia: A double-hurdle approach. *Cogent Economics & Finance*, *9*(1), 1932040.