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Assessing the Adoption and Adoption Gap of Selected BRRI-Released Boro Rice Varieties in Bangladesh

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ABSTRACT

Improved high-yielding modern rice varieties can reduce hunger and food insecurity in Bangladesh. However, lower adoption and higher adoption gap of modern rice varieties are the main concerns of rice researchers, extension specialists, and legislators. This study attempts to determine the adoption status and adoption gap of 10 selected BRRI-developed *Boro* rice varieties; to assess some selected socio-economic characteristics of the rice farmers; and to explore the contribution of the selected socio-economic characteristics of farmers to their adoption gap of selected BRRI-released *Boro* varieties. Necessary data were collected from 03 September to 31 December 2021 using a well-structured pre-tested interview schedule from 371 randomly selected farmers covering 12 agricultural blocks of four upazilas under Cumilla, Mymensingh, Tangail, and Bogura districts. The study revealed that most (73.05%) of the rice farmers had high and low adoption gap; 23.72% had moderate adoption as well as adoption gap; and the rest 3.23% of the respondents' farmers had low adoption and high adoption gap of BRRI-developed *Boro* rice varieties. Overall adoption and adoption gap of BRRI-released *Boro* rice varieties were 77.02% and 22.98%, respectively. Based on the descending order of the Adoption Index, BRRI dhan29 ranked 1st, followed by BRRI dhan28. The adoption indices of these two top-ranked varieties were 38.84 and 30.43, respectively, which were much higher than the others. Third to ninth ranked varieties were BRRI dhan58, BRRI dhan89, BRRI dhan88, BRRI dhan50, BRRI dhan74, BRRI dhan81, and BRRI dhan63. Reverse-ranked orders were observed based on the descending order of the adoption gap index (AGI). Stepwise multiple regression analysis indicated that 'knowledge on BRRI-released *Boro* rice varieties', 'extension contacts', 'rice farming profitability', 'rice farming experience', and 'satisfaction on BRRI-released *Boro* rice varieties' of the farmers had a significant negative contribution to their adoption gap, i.e., positive contribution to their adoption of BRRI-developed *Boro* rice varieties. The study concluded that policy interventions should be taken to improve farmers' knowledge of BRRI-released *Boro* rice varieties by increasing extension contact to all the low and highly experienced farmers to make them profitable and satisfied to increase adoption and decrease the adoption gap of BRRI- developed *Boro* rice varieties. These issues also urge policy interventions for the rethinking of current dissemination tactics to ensure the widespread adoption of newly released modern *Boro* rice varieties at the farm level.

Key words: Adoption, Adoption Gap, Boro, Rice, BRRI, *Boro* rice varieties, Bangladesh

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INTRODUCTION

Rice and food security are synonymous in Bangladesh (Brolley, 2015). Rice is the main staple food for more than 166.5 million people in Bangladesh (BBS, 2022; FPMU, 2020). Bangladesh ranks fourth among countries globally in rice consumption, with an annual per capita availability of rice of 213.5 kg (FPMU, 2020) and third in world rice production (Al Mamun *et al.,* 2021, FAO, 2022). Rice is Bangladesh's largest crop, occupying about 76% of the total cropped area (15.44 million hectares), of which about 88% was planted to modern varieties in 2019-20, with traditional landrace varieties covering 12% (BBS, 2022). The current rice intake in Bangladesh is about 367g capita-1, day-1, providing approximately 70% of total calories and 65% of total protein for adults (HIES, 2016). Rice is grown on more than 13 million farms on approximately 11.77 million hectares, summed over the winter (dry) and monsoon (wet) seasons (DAE, 2020). The contribution of rice to the value of the crop sub-sector is about 70% (Mottaleb *et al.*, 2016). It is predicted that the population of Bangladesh will be 215.4 million in 2050 and estimated 44.6 million tons (MT) of milled rice will be required to feed the increased population of the country (Kabir *et al.*, 2015).

Bangladesh Rice Research Institute (BRRI) is the center of excellence in terms of research and development of high-yielding rice varieties and production technologies. So far, BRRI has developed and released 111 modern rice varieties (MVs), including eight hybrids suitable for growing in three distinct seasons: *Aus, Aman*, and *Boro* **(**BRKB, 2022). Among the 111 MVs 50 are released for *Boro* (irrigated rice) season, considering different ecosystems. The foundation of the country's food security has been laid on *Boro* production. It's a major rice growing season alone contributing more than 54% of total food grain and was also the highest (3.44 t/ha) compared to *Aus* rice (1.66 t/ha) and *Aman* rice (1.99 t/ha) per unit production (Parvin, 2009). *Boro* is the most suitable season for rice production, and its production is higher due to proper operational management and weather conditions (Rahman *et al*., 2020). Because the yield of the contemporary *Boro* varieties is much more responsive to a high level of input use and timely crop management. However, due to various socio-economic constraints faced by farmers and their lack of understanding of approved *Boro* variety cultivation procedures, yields at the farmer level are lower (Islam *et al*., 2018).

The overall adoption of modern rice varieties remained relatively slow during the seventies and eighties; the coverage of modern varieties speeded up and increased to about 34% during the nineties (Hossain *et al.,* 2006). In the later period (2000 onward), farmers enormously increased the area under MV cultivation, which was triggered to 66% in 2005. According to the available statistics, the average coverage of modern rice varieties has reached to 79% in 2010 (Alam, 2012). After every MV is released for cultivation, the promotion and dissemination of those varieties are designated to other departments or agencies of the government. In most cases, the end-users could not harvest the fullest benefits of new BRRI varieties and matured technologies. Moreover, all those varieties having high potential, inadequate motivation, and slow diffusion are major reasons for lower adoption than traditional or aged MVs. It was reported that BRRI dhan28 and BRRI dhan29 are still popular among rice growers and traders across the country. Even though BRRI dhan58, BRRI dhan81, BRRI dhan88, and BRRI dhan89 are some of the varieties suggested to replace them **(**BRKB, 2019**)**. There was a significant positive relationship between the knowledge of the farmers and their adoption decision of different modern rice cultivation practices (Alam, 1997). Like farmers' knowledge, their other socio-economic characteristics may influence their adoption decision of different modern rice varieties, especially BBRI-developed *Boro* rice varieties. By understanding the adoption gap, researchers and policymakers can evaluate how effectively BBRI-developed *Boro* varieties are performing in terms of yield potential, adaptability to local conditions, and other desirable traits. For further research and development of the high-yielding *Boro* rice variety, it is imperative to inquire which variety is most popular and which is not. This information helps in identifying successful varieties and those needing improvement. Considering the above contextualization, this study attempts to address the following objectives to:

- Determine the adoption and adoption gap of selected BBRI-developed *Boro* rice varieties in Bangladesh;
- Assess some selected socio-economic characteristics of the rice farmers in Bangladesh; and
- Determine the contribution of the selected socio-economic characteristics of the farmers to their adoption gap of selected BBRI-developed *Boro* rice varieties in Bangladesh.

METHODO LOGY OF THE STUDY

Study Area

Four districts namely, Cumilla, Mymensingh, Tangail, and Bogura were selected purposively out of 64 districts of Bangladesh. Four upazilas were then randomly selected by taking one from one district. Twelve Agricultural Blocks (AB) were again selected randomly by taking three AB from each Upazila as the study area.

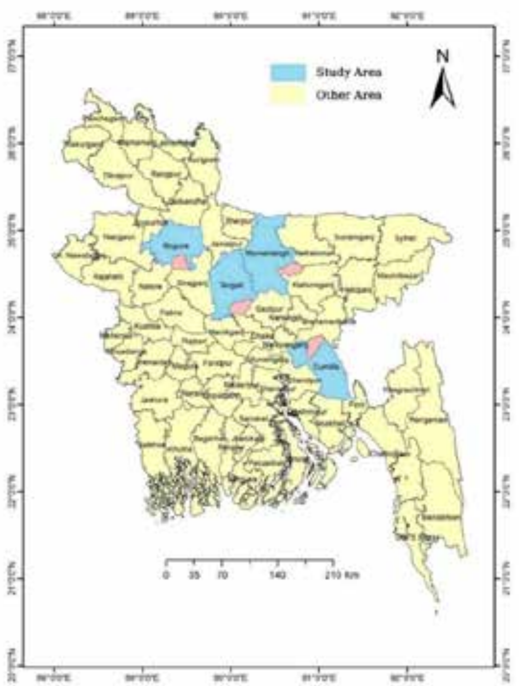

Fig. 1. Map of Bangladesh showing the study areas

Population and sample

There were 10069 *Boro* rice farmers in these selected 12 ABs which constituted the population of the study. Out of this population, by using sample size calculator developed by Creative Research Systems (1984), the sample size was determined as 370 by taking a 95% confidence level. Sample rice farmers were selected proportionately and randomly from the selected 12 ABs. For removing a fractional number of sample size after proportionate random sampling, the sample size was decided as 371 for the study.

Data collection

The researcher interviewed selected farmers face-to-face with the help of a pre-tested interview schedule from 03 September to 31 December 2021 for the collection of data for the study.

Measurement of adoption and adoption gap

Adoption is a decision to use an innovation by an individual and continue to use the innovation (Rogers, 1995). It is a mental process through which a person decides to adopt an innovation after carefully considering its relative advantage, compatibility, complexity, visibility, and adaptability in relation to his/her biophysical and socio-economic environment (Rogers, 1995). Different researchers (Ovwigho, 2013) measured the adoption of innovations in different ways. Dasgupta (1989) and Ray (1998) measured multi-practice behavior by Adoption Quotient. To measure the adoption and adoption gap of 10 selected BBRI-developed *Boro* varieties, the present researchers developed a scale with slight modification of this Adoption Quotient involving time score and land score with the following steps:

Time proportion score (TS): Time proportion score of adoption was measured by calculating the proportion of 'Awareness Period' (time required for awareness since the introduction of a variety) and 'Adoption period' (time required for adoption since the introduction of a variety) by using the following formula:

$$T_S = \frac{\text{Awarness period}}{\text{Adoption period}} = \frac{T2-T1}{T3-T1}$$

Where,

TS = Time proportion score

T_1 = Year of the introduction or release of the variety

T_2 = Year of awareness about the variety

T_3 = Year of adoption of the variety

Land proportion score: Land proportion score of adoption was measured by using the following formula:

$$L_S = \frac{La}{Lp}$$

Where,

L_S = Land proportion score

L_a = Land allotted for the variety

L_p = Potential land for *Boro* rice cultivation

Adoption: Adoption (A) of the variety of a farmer was determined by multiplying 'Time proportion score' (T_S) with 'Land proportion score" (L_S) and expressed in percentage in the following way:

$$A = TS \times LS \times 100$$

Where,

A = Adoption of the variety

T_S = Time proportion score of the variety

L_S = Land proportion score of the variety

Finally, a former's adoption of all the ten selected BRRI released *Boro* rice varieties was computed by adding all the adoption scores against all the varieties. Thus, the score of the adoption of 10 selected BRRI-released *Boro* rice varieties of the respondent farmers could range from 0 to 100, where '0' indicates no adoption and '100' indicates the highest adoption.

Adoption gap: The adoption gap of a farmer against all the ten selected BRRI released *Boro* rice varieties was computed by deducting the adoption of that farmer against all the ten selected BRRI released *Boro* rice varieties from 100 in the following way:

Adoption Gap = 100 - Adoption

Thus, the score of the adoption gap of ten selected BRRI-released *Boro* rice varieties of the respondent farmers could range from 0 to 100, where '0' indicates no adoption gap and '100' indicates the highest adoption gap.

Variety-wise adoption index: Variety-wise Adoption Index (AI) of each variety was computed by using the following two alternative formulas (Saka and Lawal, 2009)

$$AI = \frac{\text{Total adoption of the variety by all the respondents}}{\text{No. of sample respondent (n=371)}} \quad \text{.............................(i)}$$

or

$$AI = \frac{\text{Total adoption of the variety by all the respondents}}{\text{The highest possible adoption of the variety by all the respondents (i.e., } 100\times371)} \times 100 \quad \text{.............................(ii)}$$

The highest possible adoption of the variety by all the respondents

(i.e., 100×371)

Actually, each of the above two formulas produces the same result.

Variety-wise adoption gap index (AGI): Each of the 10 selected BRRI-released *Boro* rice varieties had an equal chance of being adopted across the entire study area. For this reason, the variety-wise AGI of each variety was computed in the following way:

AGI of a variety =
{(100/No. of varieties) - AI of that variety}

Empirical assessment of drivers of the adoption or adoption gap of MVs

IBM SPSS software package was used for the analysis of statistical data. Several socio-economic characteristics of the farmers may influence the adoption and adoption gap such as age, education, rice farming area, rice farming income, rice farming experience, rice farming profitability, extension contact, value chain contact, training exposure, decision-making ability, satisfaction on BBRI-developed *Boro* rice varieties, and knowledge on BBRI-developed *Boro* rice varieties were selected for the study after thorough consultation with relevant experts and reviewing literature. Measuring procedures of these socio-economic characteristics of the farmers were stat:

Socio-economic characteristic stat of the farmers	Measuring procedure
Age	One (1) score for one year of age at the time of interview from date of birth
Education	One (1) score for one (1) year of successful schooling, Zero (0) for illiterate
Rice farming area	Rice farm size in hectare(s)
Annual rice farming income	One (1) for 1000 Bangladeshi Taka (BDT.) income from annual rice farming
Rice farming experience	One (1) for one year of rice farming experience
Rice farming profitability	Actual score(s) is the ratio of benefit (or return) and the cost of rice farming.
Extension contact	Scores as 3, 2, 1, and 0 for regular, occasional, rare, and not at all contact for each of the 18 selected extension media contact
Value chain contact	Scores as 0 to 7 as per the degree of contact with each of the six selected value chain actors
Training exposure	One (1) score for each day of training received on rice farming
Decision-making ability	Scores as 1 to 4 as per the degree of decision-making for each of the 10 selected varieties.
Satisfaction with BBRI-developed *Boro* varieties	Scores 1, 2, and 3 for low, moderate, and high satisfaction on each of the 15 selected items of satisfaction on BBRI-developed Boro rice varieties
Knowledge of rice production	Two (2) scores for each of the 20 selected questions on rice production

RESULTS AND DISCUSSION

Adoption and adoption gap in the study areas

The possible range of adoption and adoption gap of BRRI-released *Boro* rice varieties was 0-100, and they were vice-versa. However, the observed range of adoption and adoption gap of BRRI-released *Boro* rice varieties of the farmers was 0 to 92.80. The mean adoption and adoption gap were 77.02 and 22.98 respectively. The standard deviation of adoption and adoption gap were the same as 22.09 because they were vice-versa. Based on adoption and adoption gap, the respondents were classified into three categories as shown in Table 1.

Table 1. Distribution of farmers according to their adoption and adoption gap of BBRI-developed *Boro* rice varieties.

Adoption category	Adoption gap category	Respondent	
		Frequency	Percentage
High adoption (>66.67)	Low adoption gap (up to 33.33)	271	73.05
Moderate adoption (>33.33-66.67)	Moderate adoption gap (>33.33-66.67)	88	23.72
Low adoption (up to 33.33)	High adoption gap (>66.67)	12	3.23
Total		371	100

Note: Mean adoption = 77.02 Mean adoption gap = 22.98 Standard Deviation= 22.09

Findings revealed that most (73.05%) of the rice farmers had high adoption and low adoption gap; 23.72% of them had moderate adoption and adoption gap; and the rest 3.23% of respondent farmers had low adoption and high adoption gap of BRRI released *Boro* rice varieties. These findings were in congruence with the findings of Nguezet *et al*. (2012) and Singh *et al.* (2014). Hossain (2003) found that the majority (67%) of the *Boro* rice farmers had medium adoption, 17% had low adoption and 16% had high adoption of modern *Boro* rice cultivation practices. Haider *et al.* (2001) found four categories of adoption levels of farmers, viz five percent were non-adopters, 62% were low adopters, 24.5% were medium adopters, and 8.5% were high adopters. Razzaque (1977) studied the extent of adoption of HYV rice in three villages of the Bangladesh Agricultural University Extension Project area and observed that among the respondent growers, 6.6%of the farmers had high adoption of HYV rice, 33.3% had medium adoption and 40% had low adoption.

Variety-wise adoption index (AI) and adoption gap index (AGI)

The adoption and adoption gap of all the selected ten BBRI-developed Boro varieties were 77.02% and 22.98% respectively of the respondent farmers of the study area. Based on descending order of variety wise adoption index (AI) and adoption gap index (AGI) of the study area, Rank Orders were made to compare the varieties (Table 2).

Based on descending order of AI, BRRI dhan29 ranked first, followed by BRRI dhan28. AI of these two top-ranked varieties (BRRI dhan29 and BRRI dhan28) were 38.84 and 30.43 respectively, which were much higher than others. Third to ninth ranked varieties were BRRI dhan58, BRRI dhan89, BRRI dhan88, BRRI dhan50, BRRI dhan74, BRRI dhan81, and BRRI dhan63. There was no adoption of BRRI dhan67 in the study area. Salam *et al.*, (2019) also reported that more than 60% of the rice cultivation area of Bangladesh was covered by BRRI dhan29 and BRRI dhan28 varieties during Boro season. After the release of these two (BRRI dhan28 and BRRI dhan29) *Boro* mega varieties in 1994, the second silent green revolution of rice occurred in Bangladesh.

As each of all the ten selected BBRI-developed Boro rice varieties had an equal chance of being adopted across the entire study area, the highest AGI of a variety could be 100/No. of varieties or 100/10, i.e., 10. Based on the descending order of AGI, BRRI dhan67 ranked first (full AGI of 10), followed by BRRI dhan63, BRRI dhan81, BRRI dhan74, BRRI dhan50, BRRI dhan88, BRRI dhan89, BRRI dhan58, BRRI dhan28 and BRRI dhan29. As the AI of BRRI dhan29 and BRRI dhan28 were 38.84 and 30.43 respectively; their AGIs were -28.84 and -20.43 respectively. Negative AGI means these two varieties were cultivated more than the expected area.

Two new *Boro* varieties BRRI dhan88 and BRRI dhan89 released later (in 2018), but their AGI was lower than BRRI dhan50, BRRI dhan74, and BRRI dhan81 which were released earlier. Due to higher yield potentiality BRRI dhan88 and BRRI dhan89 were getting faster popularity than BRRI-released old *Boro* varieties like BRRI dhan50, BRRI dhan74, and BRRI dhan81. Miah (1989) reported that when deciding to introduce a new variety, breeders considered many attributes other than yield, but yield is the still main attribute considered for fast adoption. Fig. 1 shows the adoption and adoption gap of BBRI-developed Boro varietie.

Table 2. Variety-wise adoption index (AI) and adoption gap index (AGI) with rank order.

Name of the Boro variety	Year of introduction *	Yield potential (ton/ha) *	Variety-wise adoption (%) **	Variety-wise adoption index (%)	Rank order (Based on AI)	Variety-wise adoption gap index (AGI)	Rank order (Based on AGI)
BRRI dhan28	1994	6.0	38.46	30.43	2	-20.43	9
BRRI dhan29	1994	7.5	47.59	38.84	1	-28.83	10
BRRI dhan50	2008	6.0	0.96	0.74	6	9.26	5
BRRI dhan58	2012	7.2	05.10	3.78	3	6.22	8
BRRI dhan63	2014	6.5	0.20	0.19	9	9.81	2
BRRI dhan67	2014	6.0	0.00	0.00	10	10.00	1
BRRI dhan74	2015	7.1	0.39	0.3389	7	9.67	4
BRRI dhan81	2017	6.5	0.42	0.3386	8	9.67	3
BRRI dhan88	2018	7.0	0.89	0.79	5	9.21	6
BRRI dhan89	2018	8.0	1.86	1.59	4	8.41	7
Overall adoption			95.87	77.02		22.98	

*Source: *Adhunik Dhaner Chash* (Modern Rice Cultivation), BRRI (2022)

** Adoption is measured by using the traditional method commonly used by different scientists.

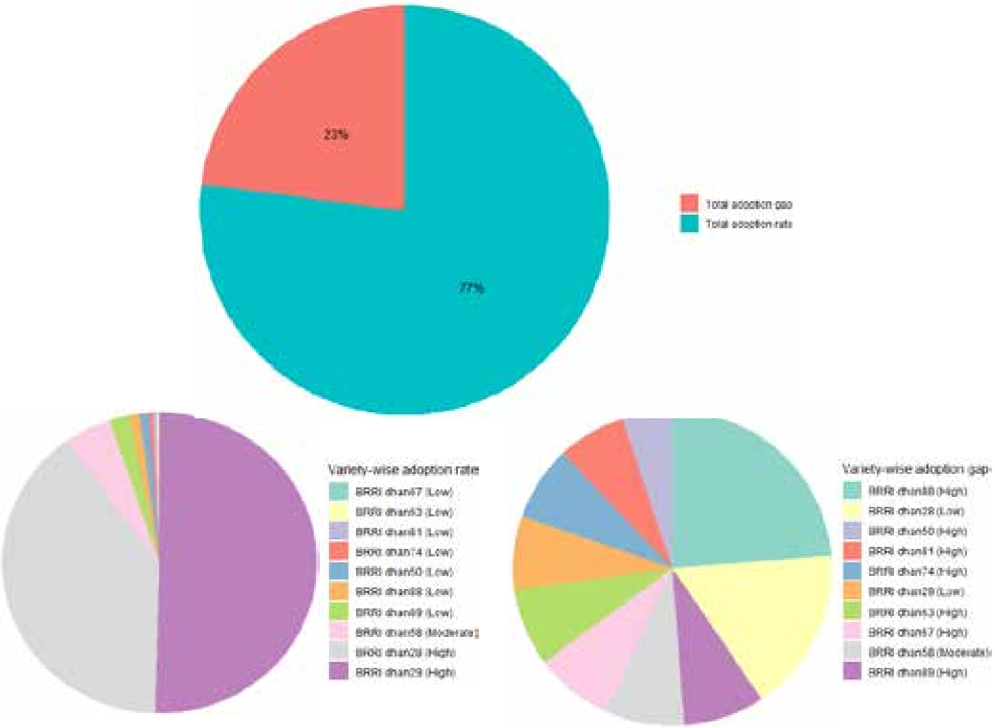

Fig. 1. Comparative adoption and adoption gap of selected 10 BBRI-developed *Boro* rice varieties.

Rahaman *et al*. (2020) reported that 99.2% of the land of Bangladesh was planted with high-yielding rice varieties during the Boro season, of which 67.04% was developed by the Bangladesh Rice Research Institute (BRRI). BRRI dhan28 and BRRI dhan29 were the dominant varieties. The coverage of recently released BRRI varieties was lower compared to the old varieties.

Selected socio-economic characteristics of the rice farmers

Socioeconomic characteristics of the farmers might have a contribution to their adoption gap of BBRI-developed *Boro* rice varieties. For this reason, salient features like possible range, observed range, mean, and standard deviation (SD) of the selected socio-economic characteristics of the 371 sample rice farmers of the study areas were assessed (Table 3).

Table 3. Descriptive statistics of different factors of 10 BRRI released *Boro* rice varieties.

Variable	Possible range	Observed range	Mean	SD
Age (Score)	Unknown	24-80	48.93	11.94
Education (Score)	Unknown	0-16	6.07	4.27
Rice farming area (Score)	Unknown	0.11-6	1.22	0.72
Rice farming income (Score)	Unknown	16-904	193.14	120.64
Rice farming experience (Score)	Unknown	5-55	25.49	9.98
Rice farming profitability (Score)	Unknown	1-2	1.65	0.25
Extension contacts (Score)	0-54	5-38	20.80	7.42
Value chain contact (Score)	0-42	8-39	17.48	5.32
Training exposure (Score)	Unknown	0-28	0.52	2.46
Decision-making ability (Score)	10-40	10-40	28.18	5.60
Satisfaction on BBRI-developed *Boro* rice varieties (Score)	0-45	11-45	30.00	8.48
Knowledge of BRRI-released *Boro* rice varieties (Score)	0-40	8-40	27.26	7.88

Correlation between farmers' socioeconomic characteristics and the adoption gap of selected BBRI-developed *Boro* rice varieties

Before determining the contribution of the selected characteristics of the farmers to their Adoption of BBRI-developed *Boro* rice varieties, initially, Pearson's Product Moment correlation test was initially done to explore the relationship of each of the selected characteristics of the farmers with their adoption gap. Table 4 shows the correlation coefficient of each of the selected characteristics of the respondent farmers with their adoption gap.

Results reveal that out of 12 selected characteristics of the farmers, nine characteristics such as age, education, rice farming experience, rice farming profitability, extension contact, value chain contact, decision-making ability, satisfaction on BBRI-developed *Boro* rice varieties, and knowledge on BBRI-developed *Boro* rice varieties had a significant negative relationship with their adoption gap.

Full model regression analyses were then run by involving all the 12 selected characteristics of the farmers like age (X_1), education (X_2), rice farming area (X_3), annual rice farming income (X_4), rice farming experience (X_5), rice farming profitability (X_6), extension contact (X_7), value chain contact (X_8), rice production training exposure (X_9), decision making ability (X_{10}), satisfaction on BBRI-developed *Boro* rice varieties (X_{11}), and knowledge on BBRI-developed *Boro* rice varieties (X_{12}) as independent variables with their adoption gap of BBRI-developed *Boro* rice varieties as the dependent variable (Y).

Table 4. Correlation coefficients of selected characteristics of the respondent farmers with their adoption gap.

Farmers' characteristic	Correlation co-efficient (r)
Age	-0.421**
Education	-0.207**
Rice farming area	-0.039[NS]
Annual rice farming income	-0.037[NS]
Rice farming experience	-0.438**
Rice farming profitability	-0.516**
Extension contact	-0.574**
Value chain contact	-0.258**
Rice production training exposure	-0.094[NS]
Decision-making ability	-0.456**
Satisfaction on BBRI-developed *Boro* rice varieties	-0.544**
Knowledge on BRRI release *Boro* rice varieties	-0.665**

[NS] Not significant, *Significant at 0.05 level of probability, **Significant at 0.01 level of probability

Table 5 presents the results of full model regression analyses.

The full model regression results revealed that out of 12 selected characteristics of the farmers, seven characteristics such as rice farming area, annual rice farming income, rice farming experience, rice farming profitability, extension contact, satisfaction on BBRI-developed *Boro* rice varieties, and knowledge on BBRI-developed *Boro* rice varieties had a significant contribution to their adoption gap.

James *et al*., (2013) reported that a Variance Inflation Factor (VIF) 5 or less is not problematic for collinearity in a multivariable (linear or logistic) model. Miles (2014) suggested that generally, a VIF above 4 or tolerance below 0.25 indicates that multicollinearity might exist, and further investigation is required. When VIF is higher than 10 or tolerance is lower than 0.1, there is significant multicollinearity that needs to be corrected. In the full model regression analysis results, it was found that the VIF of 'rice farming area' and 'annual rice farming income' were greater than 10 and their tolerance was less than 0.1. It means that there was significant multi-collinearity among rice farming areas and annual rice farming income.

Keeping these facts in view, linear stepwise multiple regression analysis was used to explore the contribution of the selected characteristics of the farmers to their adoption gap of BBRI-developed *Boro* rice varieties as suggested by Droper and Smith (1981) to insert variables in turn until the regression equation was satisfactory. Therefore, in order to avoid misleading results due to the problem of multi-collinearity and to determine the best explanatory variables, the method of stepwise multiple regression was employed by involving the selected characteristics of the farmers as independent variables with their adoption gap of BBRI-developed *Boro* rice varieties as dependent variable. The objective of the stepwise multiple regression model was to find out the contribution of the variables, only those were significant. Ali (2009, Moonmoon (2021), and Malek (2021) also followed these procedures in their studies.

Table 5. Results of full model regression analysis showing the contribution of all the 12 independent variables to the adoption gap.

Selected characteristic	Unstandardized coefficient		Standardized coefficient			Collinearity statistics	
	B	Std. Error	Beta	T	Sig.	Tolerance	VIF
Constant	104.244	5.949		17.522	0.000		
Age (X_1)	0.035	0.104	0.019	0.335	0.737	0.366	2.731
Education (X_2)	-0.045	0.194	-0.009	-0.232	0.817	0.820	1.219
Rice farming area (X_3)	-12.686	3.900	-0.412	-3.253	0.001	0.072	13.866
Annual rice farming income (X_4)	0.081	0.023	0.441	3.452	0.001	0.071	14.061
Rice farming experience (X_5)	-0.308	0.125	-0.139	-2.468	0.014	0.364	2.747
Rice farming profitability (X_6)	-14.887	3.924	-0.167	-3.794	0.000	0.602	1.662
Extension contact (X_7)	-0.830	0.127	-0.279	-6.526	0.000	0.634	1.577
Value chain contact (X_8)	0.122	0.153	0.029	0.793	0.428	0.851	1.175
Rice production training exposure (X_9)	-0.177	0.313	-0.020	-0.566	0.572	0.952	1.050
Decision making ability (X_{10})	-0.011	0.178	-0.003	-0.064	0.949	0.571	1.751
Satisfaction on BBRI-developed *Boro* rice varieties (X_{11})	-0.279	0.120	-0.107	-2.330	0.020	0.547	1.829
Knowledge on BBRI-developed *Boro* rice varieties (X_{12})	-0.973	0.145	-0.347	-6.719	0.000	0.434	2.302

R = 0.756, R square = 0.585, Adjusted R square = 0.571

After running stepwise multiple regression, it was found that out of 12 independent variables, five (5) variables namely, knowledge of BBRI-developed *Boro* rice varieties (X_{12}), extension contact (X_7), rice farming profitability (X_6), rice farming experience (X_5), and satisfaction on BRRI released *Boro* rice varieties (X_{11}) were entered into the regression equation. Table 6 presents the results of this stepwise multiple regression analysis.

Table 6. Summary of stepwise multiple regression analysis showing the contribution of the significant variables to the adoption gap.

Variable entered	Standardized partial 'b' coefficient	Value of 't' (with probability level)	Adjusted R^2	Increase in R^2	Variation explained (%)	Collinearity Statistics	
						Tolerance	VIF
Knowledge of BRRI release *Boro* rice varieties (X_{12})	- 0.364	-7.577 (0.000)	0.441	0.441	44.1	0.512	1.955
Extension contacts (X_7)	- 0.251	-6.066 (0.000)	0.525	0.084	8.4	0.689	1.452
Rice farming profitability (X_6)	- 0.127	-3.012 (0.003)	0.545	0.020	2.0	0.660	1.514
Rice farming experience (X_5)	- 0.126	-3.240 (0.001)	0.557	0.012	1.2	0.776	1.289
Satisfaction on BBRI-developed *Boro* rice varieties (X_{11})	- 0.117	-2.571 (0.011)	0.564	0.007	0.7	0.573	1.744
		Total		0.564	56.4		

Multiple R = 0.755
R-square = 0.570
Adjusted R-square = 0.564
F-ratio = 292.45 significant at 0.000 level
Constant = 101.27

Table 6 presents the data that indicate the multiple R, $R^{2,}$ and adjusted R^2 in the stepwise multiple regression analysis were 0.755, 0.570, and 0.564 respectively, and the corresponding F-ratio of 292.45 were significant at 0.000 levels.

The regression equation obtained was as follows:

$$Y = 101.27 - 0.364X_{12} - 0.251X_7 - 0.127X_6 - 0.126X_5 - 0.117X_{11}$$

Stepwise multiple regression analysis revealed that the whole model of 12 independent variables explained 56.4% of the total variation in the adoption gap of BBRI-developed *Boro* rice varieties. However, since the standardized regression coefficient of five variables formed the equation and was significant, it might be assumed that whatever contribution was there, it was due to these five variables.

VIF of the significant variables were 1.955, 1.452, 1.514, 1.289, and 1.744 which were less than 2; again, the tolerance of these variables was 0.512, 0.689, 0.660, 0.776, and 0.573 which were higher than 0.25. It means that multi-collinearity did not exist in these significant variables as suggested by James *et al*. (2013) and Miles (2014).

Results of stepwise multiple regression analysis again indicated that ‘Knowledge of

BRRI released *Boro* rice varieties (X_{12})' of the farmers was by far the most important characteristic that strongly and negatively influenced their adoption gap of BRRI-released *Boro* rice varieties. 'Extension contacts (X_7)', 'rice farming profitability (X_6)', 'rice farming experience (X_5)', and 'satisfaction on BBRI-developed *Boro* rice varieties (X_{11}) of the farmers also had remarkable negative influence upon their adoption gap of BRRI-released *Boro* rice varieties. Since the rest seven variables or characteristics of the farmers did not enter into the regression model, it was inferred that these seven characteristics either had a multi-collinearity problem or had a minimum contribution to the total explained variation of 56.4%. On the basis of stepwise regression analysis, contributions of significant five independent variables to the adoption gap of BBRI-developed *Boro* rice varieties are discussed below in order to importance.

Knowledge of BBRI-developed *Boro* rice varieties (X_{12}): From the results of stepwise multiple regression analysis, it was revealed that knowledge of BBRI-developed *Boro* rice varieties of the farmers had a strong negative contribution to their adoption gap. Co-efficient of correlation also showed a significant negative relationship between the knowledge farmers and their adoption gap. It means that farmers' knowledge of BBRI-developed *Boro* rice varieties had a strong positive contribution to their adoption of BBRI-developed *Boro* rice varieties. Knowledge plays an important role in the decision-making process. It is the precursor to the adoption of any innovation. A knowledgeable person could understand the merits and demerits of any technology easily in a short time. Therefore, farmers having high knowledge could easily reduce their adoption gap of BBRI-developed *Boro* rice varieties. This might be the reason for knowledge having a negative influence on the adoption gap. Reddy *et al.* (1987) found a significant association between knowledge and the use of improved packages of practices in paddy production by participant and non-participant farmers. This was also supported by the studies of Asaduzzaman (2002), Islam (2003) Hamidi (2004), Kumar *et al*. (2010), and Singh (2014).

Extension contacts (X_7): The extension contact of farmers had the 2nd highest significant and negative influence on their adoption gap and it was found to be the second most important contributor. The value of co-efficient of correlation (r) also showed a significant negative relationship between the extension contact of the farmers and their adoption gap. Farmers having greater contact with the extension agents obviously had a lower adoption gap. This might be the reason for extension contact having a negative influence on the adoption gap. Hamidi (2004) also found a significant positive relationship between the farmers extension contact and their adoption of rice cultivation. This result was consistent with earlier findings of Langyintuo and Mungoma, (2008); Kassie *et al.*, 2011; Asfaw *et al.*, (2012); Feleke and Zegeye (2006); Mignouna *et al.*, (2011); and Mariano *et al.*, (2012).

Rice farming profitability (X_6): Rice farming profitability of the farmers was the 3rd important contributor and had a significant and negative influence on their adoption gap of BBRI-developed *Boro* rice varieties. Coefficient of correlation value also supported this relationship between the concerned variables. It was very logical that farmers could adopt profitable innovations in shortest period of time and profit could reduce the adoption of innovations. The result was consistent with earlier findings of Langyintuo and Mungoma, (2008); Kassie *et al.*, 2011; Asfaw *et al.*, (2012); Feleke and Zegeye (2006); Mignouna *et al.*, (2011); and Mariano *et al.*, (2012).

Rice farming experience (X_5): The experience in rice farming of the farmers had a significant and negative influence on their adoption gap and it was found to be the fourth important negative contributor to the adoption gap, i.e. positive contributor to the adoption of BBRI-developed *Boro* rice varieties. Co-efficient of correlation also showed a significant negative relationship between the rice farming experience of the farmers and their adoption gap. Experience in rice farming makes farmers efficient and judicious in their adoption decisions. The present study proved that the farmers who have more experience in rice farming on this matter obviously had a lower adoption gap. Hamidi (2004) found a significant positive relationship between the experience in rice farming of the farmers and the adoption.

Satisfaction on BBRI-developed *Boro* rice varieties (X_{11}): Satisfaction on BBRI-developed *Boro* rice varieties of the respondents was the 5th important contributor and had a significant negative influence on their adoption gap. Co-efficient of correlation also showed a significant negative relationship between the satisfaction of the farmers on BBRI-developed *Boro* rice varieties and their adoption gap. Actually, farmers having more satisfaction on BBRI-developed *Boro* rice varieties had the capacity to take the challenge and buy inputs for new variety adoption which might be the cause for this finding. The result was consistent with earlier findings of Langyintuo and Mungoma 2008; Kassie *et al.* 2011; Asfaw *et al*., 2012; Feleke and Zegeye, 2006; Mignouna *et al.*, 2011; and Mariano *et al.*, 2012.

CONCLUSION

Most of the rice farmers had high adoption and low adoption gap; 23.72% had moderate adoption and adoption gap; and the rest 3.23% of respondent farmers had low adoption and high adoption gap of BBRI-developed *Boro* rice varieties. The older two varieties BRRI dhan28 and BRRI dhan29 are still more popular than the new varieties. Knowledge on BBRI-developed *Boro* rice varieties, extension contacts, rice farming profitability, rice farming experience, and satisfaction on BBRI-developed *Boro* rice varieties of the farmers had a significant negative contribution to their adoption gap, i.e., positive contribution to their adoption of BBRI-developed *Boro* rice varieties. Full model regression analysis also revealed that the 'rice farming area' and 'annual rice farming income' of the farmers also had significant negative contributions to their adoption gap, i.e., positive contribution to their adoption of BBRI-developed *Boro* rice varieties. Therefore, it may be concluded that to popularize newly released BRRI-*Boro* rice varieties emphasis should be given to increasing the farmers knowledge by increasing extension contact through rapid information dissemination, demonstration, farmers' participatory research, training, etc. for all categories of farmers with low to high experience, low to high rice farming area and having low to high annual rice farming income to make them satisfied and to table to understand the profitability of BBRI-developed *Boro* rice varieties. Planners and decision-makers need to consider these issues for enhancing and promoting the adoption of BBRI-developed *Boro* rice varieties and minimize their adoption gap.

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CONFLICT OF INTERESTS

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

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