BAUET JOURNAL
Published by
Bangladesh Army University of Engineering & Technology
Journal Homepage: http://journal.bauet.ac.bd

Productivity Impact of Modern HYV Rice Among Smallholder Farmers in Bangladesh

Mohammad Samiul Islam[1*], Syed Nazmul Huda[2], Syful Islam[3], Aklima Begum[4]

[1]Department of Agribusiness and Bio-resource Economics, Faculty of Agriculture, University Putra Malaysia (UPM), Serdang,43400, Malaysia
[2]Bangamata Sheikh Fojilatunnesa Mujib Science & Technology University, Jamalpur-2000, Bangladesh
[3]Agricultural Economic Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh-2202, Bangladesh,
[4]Upazila Agriculture office, Fenchuganj Sylhet, Bangladesh

Abstract: Advances in agricultural technology have resulted in changes in production activities. The survey was conducted to determine the effect of improved high yielding varieties (HYV) rice on productivity in Madargonjand MelandahUpazila of Jamalpur district of Bangladesh. This study was done on the basis of a survey of 216 rice farmers using a three-stage stratified sampling method. The study used a structured questionnaire to collect the input-output data of the rice farmers. Data were analysed using the Cobb-Douglas production function. The study found that the technological change associated with the introduction of improved rice varieties was of a non-neutral type. Furthermore, adoption of HYV rice varieties has increased the productivity of rice by almost 46%. The main determinants of productivity of the adopters were seeds, land, fertilizers, herbs and education. Productivity among non-adopters was positively affected by seeds, land, pesticides and fertilizers. The survey concluded that improved HYV ricehave superior yield advantage. The study suggests simultaneous dissemination of improved HYV rice and their proposed inputs to increase rice productivity.

Keywords: *HYV rice; Productivity; Cobb-Douglas production function; Jamalpur district.*

Introduction: Rice, wheat and corn are the three most important food crops in the world. Of these, rice is the most commonly used by humans, eating more than half of the world's population. It provides 27% of the calories in the low and middle-income countries of the world [1]. About 900 million of the world's poor rely on rice as a consumer or producer (Pandey et al., 2010). Rice is one of the major staples of the developing world, accounting for about 19% of the total crop land harvested, , 20% of the caloric intake from staples and 50% of the food expenses by poor people in low- and middle-income countries [2]. Due to the rapid growth of the world's population, the demand for rice is increasing steadily. However, the process of urbanization and industrialization has taken less arable land for rice production. Therefore, the increase in paddy production through land expansion is no longer appropriate. Bangladesh is primarily a farming area of 163.65 million people, where rice is the most important food crop; agriculture plays an important role in accelerating economic growth through increasing productivity of paddy production [3]. Extensive farming (crops, animal farming, forestry and fishing) contributes about 14.23 percent of the country's gross domestic product (GDP) [4], providing employment to about 40.62 percent of the labor force [5].

The Green Revolution, by introducing modern varieties (including fertilizers and irrigation), helped to substantially increase the productivity of rice in the late 1960s. However, the adoption of modern HYV rice has displaced a large number of traditional species and contributed to the loss of biodiversity [6]. Although Bangladesh is a small landlocked country, it is the fourth largest rice producing country in terms of rice. Average annual consumption of rice per person in 2007 was 131 kg [7]. Rice provided 49% of their calories and 39% of protein in their diet in 2007 [7].
Bangladesh since her independence in 1971, has been contributing a remarkable progress in staple food like rice production. In the year 1971, the total rice production was around 10.96 million metric tonnes by cultivating 9.99 million hectare of land whereas it has been reached near about 35.3 million metric tonnes of rice by using 11.83million hectares of area in 2018[4,8]. That means, almost 3.5 times rice production has been increased along

Article history:
Received 23 April, 2020
Received in revised form 15 July, 2020
Accepted 30 July, 2020
Available online 15 August, 2020

Corresponding author details: M.S. Islam
E-mail address: msamiul.islam@irri.org

with expansion of 1.9 million hectares of cultivated areas during the last 50 years. This scenario is presented by the Figure 1. Besides, the yield rate has been more than 2 times during 1971 to 2018. Figure 1D depicts that the yield rate has been increased from 1.81 metric tons per hectare in 1971 to 4.55 metric tons per hectare in 2018. And it is also cleared that from the Figs. 1B and 1C , the irrigated Boro rice occupied the position of higher production due to replacing the area of Ausand this is the reasons for adopting more HYV rice by farmers across the country.

Fig.1A. Total rice production over the years.

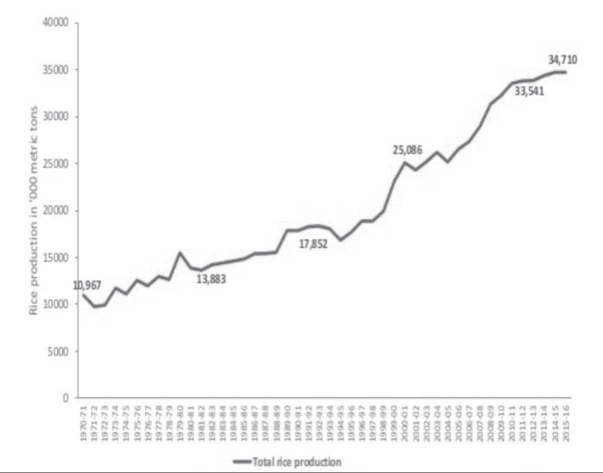


Fig.1B. Production of Aman, Boro and Aus rice.

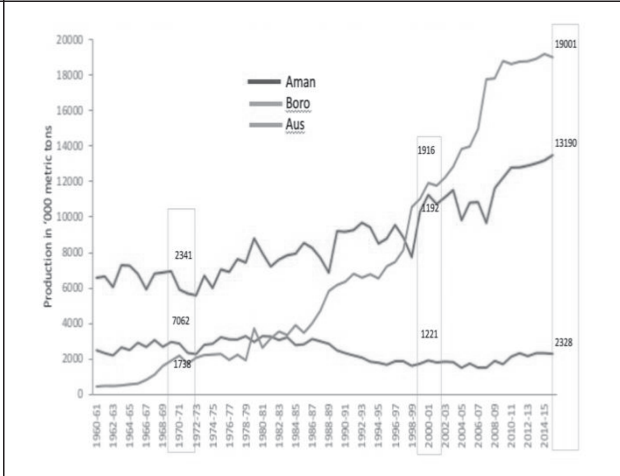


Fig.1C. Area coverage by Aus, Aman and Boro.

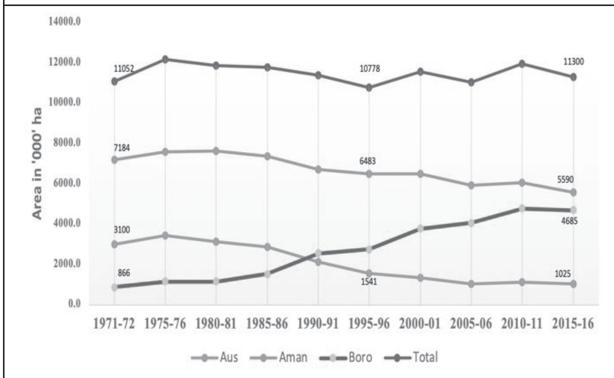
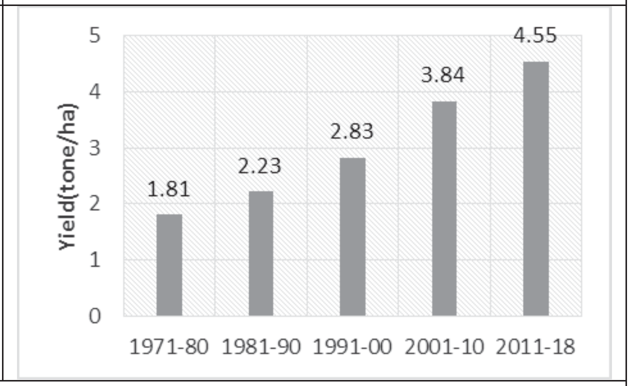


Fig. 1D. Production yield(t/ha).



Source: BBS,2018

Fig.1. Trend of production, area coverage and yield of rice over the year in Bangladesh.

Now, Bangladesh is entering gradually into the rice export regime. However, the future challenge is to maintain the current surplus of rice in order to sustain rice security of the country. Therefore, Bangladesh will need to produce more food grain with its limited resources in order to feed the escalating population which is projected to be 192.56 million in 2050 [8].

The successful story behind the Green Revolution in Bangladesh's agriculture is the adoption of modern HYV rice that are compatible with adverse climate change such as flood, drought and salinity. By 2019, about 136 modern HYV rice varieties have been released in Bangladesh, of which 130 have been published by the National Agricultural Research Organization and 6 by the non-governmental organizations [9]. Modern rice varieties can increase their productivity due to shorter growth periods (maturity and harvesting days) and higher yields [10]. Furthermore, with the increasing frequency of extreme weather events, the new challenge is to develop rice varieties that are tolerant to drought, water logging and salinity. In fact, several new high-yielding green super rice varieties have been invented [2]. The structure of the paper follows: Section 2 provides the empirical evidence of HYV modern rice on productivity and adoption level. Data collection procedures and insights from data including rice production and inputs are appeared inSection 3. Section 4 describes the results followed by adopting HYV rice on productivity, whereas conclusions appear in the final Section 5.

Review of Literature: There are many research articles in several countries where it has been revealed that improved rice varieties have significant implications for increasing productivity.For instance, in West Africa, the yield was gained about 2500 kg ha-1 with less use of inputs and yield of 5000 kg ha-1 or more intelligent fertilizer use, similarly, on average Uganda yielded 2200 kg ha-1 [11], an additional yield of 3500 kg ha-1 in Guinea and 0.14 tonnes ha-1 yield gains in Gambia [12];[13]has been widely reported. In fact, high yield gains between 3000 and 6000 kg ha-1 under rainfed coast have been equally reported [14]. On the other hand, Hossain et al.(2006) conducted a study in Bangladesh on productivity impact of modern HYV rice varieties and they found that the rice-cropped area has increased from 10.3 million hectares in 1969–70 to 10.7 million hectares in 2001–02, and production has increased from 17.6 million tons to 37.7 million tons of un-husked rice. In addition, they revealed that the average rice yield has increased from 1.7 to 3.5 t/ha for all rice crops, an annual rate of growth of 2.3% per year[15]. The Darwanto, in 1993, conducted a research on Rice varietal improvement and productivity growth in Indonesia, he found that the increase in rice productivity was made possible by adoption of the latest generation of modern rice varieties. He also found that adoption of the latest generations of modern rice varieties developed through the rice varietal improvement program, either the National Improved Varieties (NIV) or the IRRI Varieties (IRV) showed a significant impact of Total Factor Productivity (TFP) growth indicating that the rice varietal improvement program had a positively significant contribution on rice productivity[16]. According to Fan et al. (2005), improved rice varieties has contributed significantly to the increase of rice production, which has been 14% in India, 24% of China's total production value for the last two decades [17]. Recently, Brennan and Malabayabas (2011) estimated the impact of IRRI's research on rice production in three Southeast Asian countries from 1985 to 2009. They measured IRRI's contribution to the development of modern rice varieties by examining the pedigree of each variety, providing larger weights to varieties that were direct products of IRRI research or developed from IRRI varieties. The results indicated that, between 1985 and 2009, the estimated NPV during the 25-year period was approximately US$ 16 billion in Indonesia, US$5 billion in the Philippines, and US$ 15 billion in Vietnam. Furthermore, the authors calculated a benefit-cost ratio (BCR) of 21.7[18]. Besides, Rice varietal improvement research, there are some studies have been reviewed to see the productivity impacts on other agricultural crops like maize, and wheat. For example, Shiferaw et al. (2014) conducted a study on wheat in Ethiopia evaluates the impact of the adoption of improved varieties on food security using a recent nationally-representative dataset and endogenous switching regression treatment effects over 2000 farm households. They found a consistent result across models indicating that adoption increases food security and farm households and adopting households have higher levels of consumption and less vulnerable to shocks[19]. According to Becerriland Abdulai (2010),the adoption of improved maize germplasm in Oaxaca and Chiapas in Mexico. They employed a propensity score-matching approach to analyze the impact of the adoption of improved maize varieties on household income and poverty reduction, using cross-sectional data of 325 farmers. The findings revealed that a robust positive and significant impact of improved maize variety adoption on farm household welfare measured by per capita expenditure and poverty reduction. Specifically, the empirical results suggest that adoption of improved maize varieties helped raise household per capita expenditure by an average of 136–173 Mexican pesos, thereby reducing their probability of falling below the poverty line by roughly 19–31%[20]. Manda et al.(2020)conducted research to assess the adoption and impacts of improved cowpea varieties on cowpea yields, net returns and production costs using a survey data from a sample of 1,525 cowpea- growing households in northern Nigeria. They applied a control function approach and propensity score matching models to estimate the causal effects of adoption of improved cowpea varieties. Their results showed that 38% of the cowpea plots were planted with improved varieties, and cowpea yields, net returns and production costs increase significantly with the adoption of improved cowpea varieties. Adoption of improved cowpea varieties is associated on average with 26% yield gains, 61% increase in net returns and 14% increase in

production costs. We also show that farmers who have a lower propensity to adopt improved cowpea varieties also face higher costs of production[21]. Lunduka et al.(2019) conducted a study to assess the impact of smallholder farmers' adoption of Drought Tolerance (DT) maize varieties on total maize production. Data for the study came from a survey of 200 randomly sampled households in two districts of Chiredzi and Chipinge in south-eastern Zimbabwe. The study found that total maize yield was 436.5 kg/ha for a household that did not grow DT maize varieties and 680.5 kg/ha for households that grew DT maize varieties. The results show that households that grew DT maize varieties had 617 kg/ha more maize than households that did not grow the DT maize varieties [22]. Moreover, a same study conducted by Ahmed et al.(2019) in Ghana to assesses the effect of improved maize variety adoption on farm income. The results found that adoption is significantly and positively related to farm income and that improved maize varieties increased gross farm income of maize farmers by GH¢852[23].
Therefore, from the above evidence of productivity impacts of the improved rice variety appears to be very less existing and not recent in Bangladesh. This study investigates the magnitude of the impact of the improved rice variety on the productivity of rice and the determinants of such productivity gains among the adopters and non-adopters.

Materials and Methods: Data and Sampling Method: A cross-sectional survey was conducted in the Madargonj and Melandah Upazila of Jamalpur district of Bangladesh. These two Upazilas had a high concentration of both adopters and non-adopters of the improved rice variety. A three-stage stratified random sampling method was used to select 216 rice farmers from the two Upazilas. This method was chosen due to its ability to ensure a high degree of representativeness by providing the elements with equal chances of being selected [24]. The first stage involved selection of three operational areas from each of the Upazilas (totalling six) using simple random sampling method. The simple random sampling was used to ensure that every rice farmer had the chance to be included in the study. The six selected operational unions areas were Balizuri, Jurkhali, and Adarvita from the Madargonj Upazila, and Durmot, Fulkocha, and Adra from the Melandah Upazila. Next, two rice growing communities were randomly sampled from each of the selected operational areas. This yielded 12 rice growing communities from the two municipalities. The final stage involved the selection of 18 rice farmers from each of the selected communities based on the strata – adopters and non-adopters. In each stratum, nine rice farmers were randomly sampled. The random sample of the rice farmers was done based on a compiled list of rice farmers in each rice growing the community by the agricultural extension officers. This totalled 216 rice farmers. However, due to missing data on input use of 8 rice farmers, only data on 208 rice farmers were used. These comprised 103 non-adopters and 105 adopters of the improved rice variety. Input-output data were collected for the major season of the 2018 rice production season using a structured questionnaire. The structured questionnaire was used to collect information on inputs such as land, seed, fertiliser, herbicide; yield of rice production as well as the demographic characteristics of the rice farmers. Data were collected by the researcher with support from agricultural extension agents.

Empirical Model: In the study the *C*obb-Douglas production function was used to estimate the effect of improved rice varieties on productivity. The production function was estimated in the logarithmic form for the pooled sample of rice farmers (PII) and separately for the adopters (A) and non-adopters (NA). Featured dataset consisting of both *adopters* and non-*adopters* in a polled sample of paddy farmers. The production function consists of the following forms:

$InY_{NA}=In\alpha_1+a_1InS_1+ a_2InLd_2+ a_3InLF_3 + a_4InH_4+a_5InL_5+a_6InA_6+a_7InE_7+u.$ --------------(1)

$InY_A=In\alpha_1+b_1InS_1+ b_2InLd_2+ b_3InLF_3 + b_4InH_4+b_5InL_5+b_6InA_6+b_7InE_7+u$…………… .(2)

$InY_{Pt}=In\alpha_1+c_1InS_1+ c_2InLd_2+ c_3InLF_3 + c_4InH_4 +c_5InL_5+c_6InA_6+c_7InE_7+u$……………. (3)

$InY_{PII}=In\alpha_1+dInS_1+ d_2InLd_2+ d_3InLF_3 + d_4InH_4 +d_5InL_5+d_6InA_6+d_7InE_7+u$……………. (4)

Where:

Y =Rice output (kg);

α =Total factor productivity;

S =Total quantity of seeds (kg);
Ld =Cultivated area (ha);
F =Total quantity of fertiliser (kg);
H =Total quantity of herbicide (l);
L =Labour (person-days);
A =Farmer's age (years);
E =Farmer's education (years of formal education);
DV =Dummy variable for the improved rice variety;
U =Error term

However, before estimating the production functions, the null hypothesis of parameter stability (i.e., no structural change) was empirically tested. Also, the hypothesis that the technical change from the introduction of the improved variety was of the neutral type was tested. These two hypotheses were tested using the F-test. Following Gujarati (2004)[25], the F-test is specified as:

$$F = \frac{(RSS_R - RSS_{UR}) / k}{(RSS_{UR}) / (n_1 + n_2 - 2k)} \sim F_{[k,(n_1+n_2-2k)]} \quad (5)$$

where:
SSE_R = Restricted residual sum of squares for the pooled regression;
SSE_{UR} = Unrestricted residual sum of squares for the regression of the adopters and non-adopters;
k = Number of estimated parameters including the intercept;
n_1 = Number of observations for the regression equation of the adopters;
n_2 = Number of observations for the regression equation of non-adopters.

The structural break test equations (1) and (2) provide the justification of the hypothesis. However, in order to capture the effect of improved rice varieties on productivity, a variable dummy variable was introduced in the Pooled Production Function (PII). The use of pooled regression with dummy variables for productivity analysis has both theoretical and empirical evidence [26, 25, 27].

Results and Discussions:

Descriptive Statistics of the Variables Used in the Model: Table 1 depicts the mean and standard deviations of the variables that were used for the Cobb-Douglas production functions. The average farm size for both the adopters and the non-adopters was less than 1 hectare. This explains that the rice farmers were mainly small farmers. Non-adopters have higher seed rate (168.37 kg) and amount of herbicide (11.571), compared with adapter (105.58 kg and 7.891, respectively). The high demand for seeds for the production of unsupported varieties is that low quality seeds can be used, which have low germination rates. In addition, the average amount of fertiliser (594.64 kg) and labour (250.49 person-days) were higher for the adopters than the non-adopters (391.99 kg and 227.40 person-days, respectively).It is suggested that the production of improved rice varieties was highly responsive and labour-intensive for fertilizers. Rice output was also higher for the adopters compared to the non-adopters; which indicates that the improved rice varieties had the higher yields than the non-improve varieties. The output of rice was also higher for the adopters compared to the non-adopters; indicating that the improved rice variety had higher yield advantages compared with the unimproved varieties. The average output of the improved variety is consistent with the range of outputs reported by Kijima et al. (2006), JICA (2006) and Zenna et al. (2008) [11,13,14].

Hypotheses Tests on the Data: Several diagnostics were examined in the data before analyzing the model. These were multicollinearity, normality tests and stability tests. Multicollinearity was tested using the variance inflation factor, and the results suggest that none of the explanatory variables exceed the marginal value of 10. So, there was no problem with the multicollinearity in the data. Testing for residual normality for all the estimated production functions revealed that the residuals were normally distributed. The production functions were estimated using a heteroscedasticity-correction method to correct for potential heteroscedasticity problem in the data.An acceptability test was performed using the Chow-test to test the hypothesis that tested the concept of intercept and optical coefficients separately for the adopters and non-adopters. The introduction of improved rice varieties in this experiment sought to determine whether the technological change was of the neutral type or of the non-neutral type. The variance analysis found an F-ratio of 8.159 with 8 and 192 degrees of freedom and was statistically significant at the 1% level. Thus, the null hypothesis was rejected in favour of the alternative hypothesis. The results indicate that structural changes existed in the production process for the adopters and non-adopters. This suggests that the technological change responsible for the introduction of improved rice varieties was not neutral.It is the hypothesis that the output elasticities agreed with the different inputs were not the same in the individual variants for the adopters and the non-adopters, if the constant terms were allowed to differ in the two regressions. Thus, this study estimates separate production functions for both the adopters and the non-adopters. However, here research has used dummy variable methods to influence the productivity of improved rice varieties. So, Shideed and Saleem (2005) and Lin (1994) justified the use of the dummy variable method to quantify the effect of a qualitative variable on a quantitative outcome [26,27].

Impact of the Improve Rice Variety on Productivity: The output elasticities from the non-adopters and adopters Cobb-Douglas production functions are presented in Table 2. The explanatory powers (R^2) of the various production functions are 0.701, 0.770, and 0.720 for the adopters, non-adopters and pooled (II) production functions, respectively. The results suggested that the three models usually fit the data well at the 1% significance level. This denoted that the variations in the (log of) production were elucidated by 70% to 72% of the (logs) of all the explanatory variables, respectively, in all the production functions. Further, the output elasticities satisfied priori expectations. For non-adopters, the results indicate that herbicides, seeds, land and fertilizers are statistically significant. The output elasticity of these changes' variable is consistent with the expected signs and economic rationale. For example, the output elasticity of seed, land, fertiliser, and herbicide was 0.294, 0.528, 0.046, and 0.105, respectively. On the contrary, keeping other factorsconstant, a 1% increase in seeding rate was associated with an average of about 0.3% increase in rice production. Similarly, on the average, a 1% increase in total cultivated land led to about 0.5% increase in production, keeping all other factors constant. Moreover, keeping all other factors constant, fertilizer consumption increased by 1%, thereby increasing production by 0.5% increase. Altogether, land, seeds, herbicides and fertilizers were the main determinants of unimproved rice varieties in the two Upazilas. The low impact of fertilizers on production may be due to the lack / delay / shortage of fertilizer application among non-adopters. These results are consistent with the past studies of Abdullahi (2012) and Resmi et al. (2013),Tsinigoet al. (2017) who reported similar findings [28-30].

Table 1 Mean and Standard Deviations of Variables for the Cobb-Douglas Model.

Variables	Non-Adopters	Adopters	Pooled
Production (kg)	4345.57 (3113.04)	5348.39 (3717.62)	4851.80 (3514.29)
Seed (kg)	168.37 (113.03)	105.58 (73.23)	136.67 (99.90)
Land (ha)	0.95 (0.64)	0.74 (0.56)	0.84 (0.61)
Fertiliser (kg)	391.99 (373.69)	594.64 (563.71)	494.29 (488.65)
Herbicide (l)	11.57 (12.55)	7.89 (6.84)	9.71 (10.22)
Labour (person-days)	227.40 (266.48)	250.49 (203.35)	263.81 (236.54)
Age (years)	46.54 (13.37)	49.51 (13.06)	48.04 (13.27)
Education (years)	2.60 (4.12)	4.20 (5.40)	3.41 (4.87)

Note: Values in parentheses indicate standard errors.

Table 2 Estimated Production Functions for the Rice Farmers.

Variables	Non-Adopters	Adopters	Pooled I	Pooled II
Constant	6.428*** (0.895)	7.410*** (1.072)	6.978*** (0.790)	7.123***(0.712)
Seed	0.294**(0.127)	0.400** (0.164)	0.067 (0.110)	0.256**(0.104)
Land	0.528*** (0.0.191)	0.610*** (0.196)	0.691*** (0.141)	0.679***(0.0.133)
Labour	-0.057 (0.0.067)	-0.142*** (0.039)	-0.008 (0.052)	-0.095* (0.049)
Fertiliser	0.046*** (0.015)	0.037*** (0.013)	0.0845*** (0.011)	0.053*** (0.0.012)
Herbicide	0.105* (0.063)	0.058** (0.027)	0.065 (0.040)	0.071** (0.030)
Age	0.072 (0.144)	-0.046 (0.093)	0.165 (0.102)	0.001 (0.092)
Education	0.001 (0.040)	0.057** (0.029)	0.059** (0.027)	0.029 (0.0.023)
DV_1	-	-	-	0.457*** (0.063)
No. obs.	103	105	208	208
R^2	0.701	0.770	0.718	0.720
F-value	31.856***	46.339***	72.923	63.807***
JB test	3.435	0.182	8.623	3.075

Note: *P<0.10, **P<0.05, ***P<0.001; JB: Jarque-Bera test of normality. Pooled I and II: Polled production function without and with dummy variable, respectively. Values in parentheses indicate standard errors. DV_1: Dummy variable for improved rice variety.

The output elasticity for adopters indicates that statistically significant variables are seed, land, labor, fertilizer, herbal and education. Except labor, all the significant variables had their expected signs like seed, land, and labour had output elasticities are of 0.400, 0.610, and -0.142, respectively. Hence, the land was the most important factor in the production of improved rice varieties. On average, a 1% increase in arable land increases the total production by about 0.6%, keeping all other factors constant. Accordingly, the seed rate was increased by 1% while keeping all other factors constant, thereby increasing the average production by 0.4%. Labor output elasticity was negative and thus it was suggested that holding all other factors in a constant, 1% increase in labor input leads to a decrease of about 0.1% in production; depicting diminishing marginal returns to labour. Thus, there was excessive use of labor among the adopters, partly because of the laborious nature of it. Because improved rice varieties were in demand for labor, the recipients took the use of labor to a point where the use of excess labor increased or decreased the yield of rice. Thus, labor-saving technology should be provided. The output elasticity of the fertiliser input was 0.037, indicating that, holding all other inputs constant, a 1% increase in fertilization would result, on the average, in about a 0.04% increase in the production of the improved rice. The lower impact of fertilization on production is due to the use of fertiliser below its proposed level. Likewise, ceteris paribus, a 1% increase in the application of herbicides would on the average increase the production of the improved rice by about 0.06%. Finally, the output elasticity of education was 0.057; suggesting that an additional year of education of the adopters would lead to about 0.06% increase in production, all other factors held constant. The resultsare consistent with Abdullahi (2012, Balakrishna (2012), Basavaraja et al. (2008), and Resmi et al. (2013)[28,31,32,29]. In the Polled II model, the variable intercept dummy, that is, DV1, was used to measure the effect of improved rice varieties on productivity. For this model, the data were driven, that is, the data were consolidated for the adopters and non-adopters and DV1 was launched. The estimated pooled regression model (Pooled II) showed that seed, land, labour, fertiliser, herbicide and the varietal dummy variable (DV1) were statistically significant (Table 2). All variables had their expected signs expect labour. The findingsshowed that a percentage increase in seeding rate, land, fertiliser, and herbicide would, on the average, lead to a corresponding percentage increase in the output, ceteris paribus. However, if the percentage increase in the lab or the input increases, on average, the same output may decrease. The survey estimates that improved rice varieties have a significantly greater impact on rice productivity than local rice varieties. The output elasticity of the varietal dummy variable measures the shift in the intercept of the production function due to the improved rice variety. The output elasticity of this variable was 0.457 and was statistically significant at the 1% level.

It is suggested that the improved rice varieties increased the total factor productivity in the study area by 46% compared to the local varietyof rice. However, the change in the production process is not of a neutral type, it was implied that improved rice varieties do not give a higher output per unit of input. That is, the output increase was due to non-neutral technological change. These results are consistent with the results obtained by Tiamiyu et al. (2009), Arega and Ousmane (2009), and Adegbola et al. (2006) and Tsinigo et al.(2017)[33,34,35,30].

In general, the output elasticity of seed and land was higher for the adopters compared to the non-adopters. The positive effect of land on output refuted the commonly held contradict relationship between land size and output. Similarly, the positive effect of seed on production reduces the importance of certified seed in rice production. In contrast, non-adopters reported higher output elasticities for fertiliser and herbicide. Fertilizers have been shown to have little effect on improved rice seed production due to splitting of fertilizers for improved rice varieties of other varieties. This view further emphasized the determination of the farmers that the improved paddy varieties also benefit from higher yields with minimal fertilizer application. The significance and positive effect of variable inputs is consistent with Balakrishna (2012), Basavaraja et al. (2008), Kumar and Singh (2013), Shideed and Salem (1999) [31,32,26,36].

The sum of the output elasticities for the variable inputs gave 0.916, 0.963, and 0.964 for the adopters, non-adopters, and pooled (II) production functions, respectively. It suggested that the rice cultivars experienced a reduction in the production season of 20, but there was no evidence to prove that these values were statistically different. Thus, a linear similarity constraint was tested for the Cobb-Douglas production function. The null hypothesis was that the sum of the output elasticities of the Cobb- Douglas production function sum to one. The F-test reported F (1, 95) = 0.006 with p-value of 0.937; F (1, 97) = 0.682 with p-value of 0.411 and F (1, 199) = 0.124 with p-value of 0.725 for the adopters, non-adopters, and pooled production functions, respectively. Thus, the hypothesis of constant returns to scale was not rejected. The finding advised that the data were consistent with the hypothesis of constant returns to scale (and not diminishing returns to scale). This suggested that the choice of the Cobb-Douglas production model was appropriate for the data. Therefore, the major production seasons were characterized by constant returns to scale in the two Upazilas during the study year 2018. On the other side, a one percent increase in all inputs leads to the same percentage increase in output, while all other factors remain constant. There was revealed that rice production can be increased through greater use of cultivated land, seeds, fertiliser, and herbicides.

Conclusions: In this study, we investigated the impact of the improved rice variety on the productivity of rice. The study has established that the improved rice variety has a superior yield advantage over the unimproved or local rice variety. The technological change responsible for the introduction of improved paddy varieties was neutral, meaning it was not labour-intensive and cost-effective. With the introduction of improved rice varieties, the productivity of rice increased by 46%.Among the adopters, productivity growth was driven by seeds, land, fertilizers, herbs and education. For the non- adopters, productivity gains were due to seed, land, herbicide and fertiliser. Our demonstration that the improved rice variety had increased productivity implies that productivity gains can be increased through greater use of cultivated land, seeds, fertiliser, and herbicides. The policy makers' challenge is to simultaneously disseminate the use of advanced rice varieties and their recommended inputs to rice farmers, remove barriers that prevent large-scale use of modern materials, and provide credit facilities for the timely purchase and use of paddy productive assets. Overall, this can lead to improved production gains in improved rice varieties. These are disseminated together with the proposed inputs and are linked to the delivery of an effective input and the efficient use of inputs in education programs

Acknowledgements: The first author is grateful to Dr. Humnath Bhandari, the country representative, International Rice Research Institute(IRRI)-Bangladesh for his kind cooperation in developing the research idea. In addition, the authors owe a debt of gratitude to the rice farmers in the six unions of the Jamalpur districts who made the empirical findings of this study possible.

Authors contributions: Mohammad Samiul Islam conceived and designed the research topic, and wrote and revised the manuscript; Syed Huda, Aklima Begum, and Syful Islam detailed the research procedure, analysed the data, and wrote the manuscript.

Conflict of interests: The authors declare no conflict of interests.

References:

[1]D. Dawe, S. Pandey, A. Nelson. Emerging trends and spatial patterns of rice production. Rice in the global economy: strategic research and policy issues for food security. Los Banos, Philippines: International Rice Research Institute (IRRI); 2010. pp.15-35

[2]Jr. J. M. Yorobe, J. Ali, V.O. Pede, R. M.Rejesus, O.P. Velard, H. Wang, Yield and income effects of rice varieties with tolerance of multiple abiotic stresses: the case of green super rice (GSR) and flooding in the Philippines. *Agricultural Economics*. *47*(2016)261-271.

[3] Bangladesh Bureau of Statistics(BBS). Bangladesh Economic Review(BER),Ministry of Finance, Government of the People's Republic of Bangladesh, 2018.

[4]Bangladesh Bureau of Statistics (BBS). Yearbook of Agricultural Statistics, 30th series, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, 2018.

[5] Bangladesh Bureau of Statistics(BBS). Labour Field Survey(LFS). Labour and Industry Wing, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, 2017.
[6] M. Hossain, W. M. H. Jaim, T. R. Paris, B. Hardy. Adoption and diffusion of modern rice varieties in Bangladesh and eastern India. Los Baños (Philippines): *International Rice Research Institute*; 2010. pp. 25
[7] F. FAOSTAT. Agriculture Organization of the United Nations, 2011.
[8] World Population Review(WPL), World Population Prospects, United Nations population estimates and projections. http://worldpopulationreview.com/, 2019.
[9] Bangladesh Rice Research Institutes (BRRI), Annual Report-2019, Gazipur, Bangladesh, 2019.
[10] S. Sall, D. Norman, A. M. Featherstone, Quantitative assessment of improved rice variety adoption: the farmer's perspective. *Agricultural systems*. *66*(2000), 129-144.
[11] Y. Kijima, D. Serunkuuma, K. Otsuka, How revolutionary is the NERICA revolution? Evidence from Uganda. *Dev. Econ*.44(2006). pp. 252–267. DOI: 10.1111/j.17461049.2006.00016.x.
[12] L. Dibba. Estimation of NERICA adoption rates and impact on productivity and poverty of the small-scale rice farmers in The Gambia. Unpublished master's thesis).Kumasi, Ghana: Department of Agricultural Economics, Agribusiness, and Extension, Kwame Nkrumah University of Science and Technology, 2010.
[13] JICA. Proceedings of JAICAF/WARDA/JICA joint seminar on NERICA dissemination in Africa. Accra, Ghana: JICA, 2006.
[14] N. S. Zenna, Z.Gebre-Tsadik, T. Berhe. Moving up in Ethiopia. Ethiopia: International Rice Research Institute. Available from: http://irri.org/knowledge/publications/rice-today/features/features-africa/moving-up-in-ethiopia. [Assessed 4 October 2016], 2008.
[15] M. Hossain, M. L. Bose, B. A. Mustafi, Adoption and productivity impact of modern rice varieties in Bangladesh. *The Developing Economies*. *44*(2006), pp.149-166.
[16] D. H. Darwanto. Rice varietal improvement and productivity growth in Indonesia, 1993.
[17] S. Fan, C. Chan-Kang, K. Qian, K.Krishnaiah, National and international agricultural research and rural poverty: the case of rice research in India and China, *Agricultural Economics*. 33(2005) 369-379.
[18] J. P. Brennan, A. Malabayabas. International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia. ACIAR Impact Assessment Series Report No.
74. Australian Centre for International Agricultural Research: Canberra, 2011, 111pp.
[19] B. Shiferaw, M. Kassie, M. Jaleta, C. Yirga, Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*. *44*(2014) 272-284.
[20] J. Becerril, A. Abdulai,The impact of improved maize varieties on poverty in Mexico: a propensity score-matching approach. *World development*. *38*(2010)1024-1035.
[21] J. Manda, A. D. Alene, A. H. Tufa, T. Abdoulaye, A. Y. Kamara, O. Olufajo, &V. M. Manyong, Adoption and Ex-post Impacts of Improved Cowpea Varieties on Productivity and Net Returns in Nigeria. *Journal of Agricultural Economics*. *71*(2020)65-183.
[22] R. W. Lunduka, K. I. Mateva, C. Magorokosho, P. Manjeru,Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe. *Climate and development*. *11*(2019)35-46.
[23] H. Ahmed, E. Martey, B. T. Anang, Impact of improved variety adoption on farm income in Tolon district of Ghana. *Agricultural Socio-Economics Journal*. *19*(2019)105-115.
[24] E.R. Babbie, *The practice of social research*, 13th ed., Belmont, California: Thompson Learning. ISBN-10: 1133049796, 2007.
[25] D. N. Gujarati, Basic econometrics. 4th ed., New York: The McGraw−Hill Companies. ISBN: 978-3-319-07662-1, 2004.
[26] K. Shideed, K. K. Salem,The impact of barley varietal technology in Iraq. *IPA Agricultural Research Center*, 1999.
[27] J. Y. Lin,Impact of hybrid rice on input demand and productivity. *Agric. Sys*., 10(1994)153–164. DOI:10.1016/0169-5150(94)90004-3.
[28] A. Abdullahi, Comparative economic analysis of rice production by adopters and non-adopters of improved varieties among farmer in Paikoro Local Government Area of Niger State. *Nigerian Journal of Basic and Applied Sciences*. *20*(2012)146-151.
[29] P. Resmi, L. B. Kunnal, H.Basavaraja, A.R.S.Bhat, J.A.Handigol, J. S. Sonnad,Technological change in black pepper production in Idukki district of Kerala: A decomposition analysis.Karnataka *J. Agr. Sci.*26(2013)76-79. Available from: https://www.14.139.155.167/test5/index.php/kjas/article/view/6 761/6981 [Assessed 4 October 2016].
[30] E. Tsinigo, K. Ohene-Yankyerah, & S.C.Fialor,Impact of Improved Rice Variety on Productivity Among Smallholder Farmers in Ghana. *Turkish Journal of Agriculture-Food Science and Technology*. *5*(2017)164-169.
[31] A. Balakrishna, Economics of Bt cotton in India. J. Dev. Agric. Econ., 4(2012): 119 – 124. DOI: 10.5897/JDAE11.095.

[32] H. Basavaraja, S. B. Mahajanashetti, P. Sivanagaraju, Technological change in paddy production: A comparative analysis of traditional and SRI methods of cultivation. *Indian J. Agric.Econ*., 63(2008)629-640. Available from:https://www.environmentportal.in/files/Indian%20Journal%20O f%20Agr%20Eco%203.pdf [Assessed 4 October 2016].
[33] S. A. Tiamiyu , H. O. Akintola, M. A. Y. Rahji,Technology adoption and productivity difference among growers of New Rice for Africa in Savannah Zone of Nigeria. Tropicultura. 27(2009)193-197.
[34] D. A. Arega, C. Ousmane, The impact of agricultural research on productivity and poverty in sub-Saharan Africa. *Food Policy*. 34(2009) 198 – 209, DOI: 10.1016/j.foodpol.2008.10.014.
[35] P. Y. Adégbola, A. Arouna, A. Diagne, A. A. Souléïmane, Evaluation de l'impactéconomique des nouvellesvariétés de riz NERICA au Bénin: évidence avec les modèlesbasés sur l'approchecontrefactuel. *In first Africa Rice Congress*. 31(2006).
[36] Kumar, H.,&Singh, R. (2013). Economic analysis of freshwater aquaculture production: A comparative analysis of different production systems. Russ. *J. Agric. Soc.-Econ. Sci.,* 1(2013)49-55. Available from: https://ideas.repec.org/a/scn/031261/14105162.html [Assessed 8 October 2016].