Impacts of Alternate Wetting and Drying (AWD) Irrigation System on Water Productivity, Profitability and Household Income of Modern Varieties (MV) of Paddy Producer in Bangladesh

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Abstract

The present study attempts to estimate Impacts of Alternate Wetting and Drying (AWD) Irrigation System on Modern Variety (MV) Paddy Production in Bangladesh. Primary data were used in this study. A total of 140 MV boro producers were randomly selected from Manoharpur village of Monirampur Upazilla in Jessore district of which 70 farmers used technically advanced AWD irrigation technique and left 70 farmers used traditional irrigation technique in MV boro paddy cultivation. The necessary information on inputs and output of MV boro paddy cultivation the sampled farmers were colleted through comprehensive questionnaire. The findings of the study indicated that the average cost of irrigation per hectare MV boro paddy production was comparatively smaller in AWD irrigation than traditional irrigation system that was widely varied among the farmers. The sampled farmers used comparatively less proportion of chemical fertilizers such as urea, MP, zypsum, zinc, and manure except TSP in per hectare of MV boro paddy cultivation. The farmers used in more or less similar proportions of temporary hired and family supplied male and female labors in per hectare of MV paddy cultivation in both the irrigation techniques. The yield of MV boro was significantly higher in the method in AWD irrigation technique than in the method of traditional irrigation. Per hectare production cost of MV boro paddy cultivation was significantly lower in AWD irrigation technique than the application of traditional irrigation method. The net profit of per hectare MV boro paddy cultivation was more than four times higher in AWD irrigation than traditional irrigation technique. The study also found that the household income of the farmers who used AWD irrigation was significantly higher (about 1.20 times) than the farmers who used traditional irrigation technique in MV boro and aman paddy cultivation in the study area. The farmers had experienced constant return to scale in MV boro paddy farms using the AWD irrigation technique and traditional irrigation technique in the study area. The farm area, seed cost, pesticides cost, irrigation cost, urea cost and labor cost were the main factors that affect significantly the MV boro paddy production under the method of application AWD irrigation technique. On the other hand, the farm size, land preparation cost, urea, other chemical fertilizers and manure had significant positive impact on MV boro paddy under the application of traditional irrigation technique. The farmers did not optimally use the input

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resources in both the methods of AWD irrigation and the traditional irrigation technique in MV boro paddy cultivation and this hindered the generation of maximum level of output of paddy grain in the study area. The findings of the study also indicated that the water productivity of MV boro paddy production was significantly higher in AWD irrigation and traditional irrigation technique. In other words, water input efficiently used in MV boro paddy production in AWD irrigation technique compared to traditional irrigation technique.

Key words: Alternate Wetting and Drying (AWD) irrigation, water input efficiency, profitability, household income, MV paddy, Bangladesh.

JEL: O13, O33, Q15, Q55.

Introduction

Water is one of the main resources for agricultural production. Groundwater irrigation has significant impacts on MV paddy production that has increased rural household income significantly and reduced poverty and inequality of income distribution through MV paddy in Asian countries (Huang, et al. 2005; Rosegrant and Evenson; 1992, Hossain et al. 2000; Datta et al. 2004; Saleth, 1991; Selvarajan and Subramanian, 1981). The irrigation system has also increased employment through MV paddy and wheat production in South Asia (Patel, 1981). The productivity of groundwater irrigation depends on the number of application and its quality (Tyagi, et al. 2004; Panda, 1986). Intensive use of groundwater irrigation with poor drainage and management system led to raise salinity in semi-arid and arid zones (Pingali and Shah, 2001; Chambers, 1988; Abrol 1987, and Dogra 1986). The unequal water supply of canal with marginal quality water makes large variation in cropping pattern, irrigation application, land, and supplied water productivity of irrigation system (Tyagi, et al. 2004). Ground water is one of the main inputs for modern varieties (MV) of boro paddy cultivation along with seeds, pesticides and chemical fertilizers in Bangladesh. Due to massive use of irrigation water in boro season, ground water tables are declining gradually in Bangladesh and thus the water scarcity is increasing day by day.

The adoption of new or improved method of production can shift the production function. Production can be increased with new technology by using same amount of inputs that were normally used in old technology. In other words, the production level in old technology can be attained with new technology by using fewer amounts of inputs. The recent breakthrough of MV boro paddy cultivation in Bangladesh is AWD which is known as disembodied new technology (Basavaraja, et. al., 2008) and this type of new technical change is mainly due to improved management methods (Sankhayan, 1988). The Alternate Wetting and Drying (AWD) is a modern water-saving technology that the farmers normally apply to reduce their water use in MV boro paddy cultivation. The application of AWD irrigation technique in MV paddy cultivation is a newly introduced technology in Bangladesh. The farmers are gradually applying AWD irrigation technique in MV paddy cultivation and its use depends on the efficiency of extension workers in providing their services.

Over the past few decades several economic journals have published a large number research articles on groundwater resources, irrigation system, irrigation models, efficient use of water under different irrigation methods/systems, merits and demerits of irrigation water for HYV paddy production in terms of soil fertility. Recently, a few researchers have been conducted on the adoption, effects and efficiency of AWD irrigation for rice production in Northern part of Bangladesh (Rahman and Bulbul, 2014a; 2014b; 2015) and India (Kulkarni, 2011; Singh, et. al., 2013). However, the economic impacts of AWD irrigation technique on MV boro paddy production in Bangladesh have been paid less attention. Therefore, the present study (i) compares and contrasts the cost and returns, and water productivity of MV boro paddy cultivation in AWD irrigation technique and traditional irrigation technique; (ii) estimates the household income of MV paddy producers for both the AWD and traditional irrigation methods. Moreover, the study also determines the resource use efficiency of AWD irrigation technique and traditional irrigation technique on MV boro paddy cultivation. The findings of the present study are expected to be helpful benchmark information for economists, researchers, as well as policy makers and will provide useful information for the further development of MV paddy farming in Bangladesh.

Methodology of the Study

Sources of Data

To assess the impacts of technologically modified AWD irrigation technique on MV boro paddy production of Manoharpur village of Monirampur upazilla in Jessore district. Manoharpur village was purposively selected because a large number of farmers in this village have been adopted the use of AWD irrigation technique along with traditional irrigation system in MV paddy production. Primary data were used in this study. Initially, a detailed list of farmers who implemented AWD irrigation technique and traditional irrigation in MV paddy production was collected from upazilla agriculture office. A total of 140 farmers were randomly selected from this study village of which 70 farmers used AWD irrigation technique and another 70 farmers used traditional irrigation system in their MV boro paddy cultivation. The information on various inputs and output of MV paddy production under these two existing irrigation systems and the socio-economic information of farmers were collected through comprehensive questionnaire. The information covers the crop calendar 2015.

Analytical Techniques

Profitability Analysis

The estimation of profit of MV paddy cultivation under the method of the AWD irrigation and traditional irrigation techniques is as follows:

$$\pi = \sum P_1.Q_1 + \sum P_2.Q_2 - \sum P_{xi}.X_i - TFC$$

Where,

π = Profit for the advanced technology (AWD) /traditional irrigation technique under study;

P_1=Per unit price of the crop (paddy) grown;

Q_1=Quantity of output (paddy) obtained;

P_2=Per unit price of by-product (straw);

Q_2=Quantity of by-product obtained (straw);

Px_i= Per unit price of the ith (variable) input,

X_i= Quantity of the ith input used for the crop, and

TFC = Total fixed cost.

Estimation of Household Income

Household income is a measure of the combined incomes of all people sharing a particular household or place of residence. It includes every form of income of household such as agriculture income from crop production, agricultural wages of family members, profit of livestock, and vegetables and off-farm income in the study area.

Estimation of Cobb-Douglas Production Function

To estimate the marginal value productivities of inputs and the production functions, similar to Cobb-Douglas production function of the following form was used:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + u_i$$

Where,

Y= Output of MV boro paddy (taka)

X_1= Farm size (hectare)

X_2= Seed cost (taka)

X_3=Land preparation cost (taka)

X_4= Pesticide cost (taka)

X_5= Irrigation cost (taka)

X_6= Urea cost (taka)

X_7= Other fertilizer cost (taka)

X_8= Manure cost (taka)

X_9= Labor cost (taka)

β_0 is intercept and β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 and β_9 are the coefficients of the regression.

u_i is normally and independently distributed with zero mean and constant variance.

Resource Use Efficiency

Neo-classical theory states that the resources would be efficiently used in agricultural production farming where marginal value product (MVP) is equal to their marginal factor cost (MFC) under perfectly competitive market. In general, the producers would choose the input levels that maximize the economic profit (TR-TC). The marginal value product (MVP) of an input would be estimated, the coefficient of production elasticity is multiplied by the output-input ratio of the geometric mean level, which can be shown in the following formula.

$$MVP = \frac{\bar{Y}_i}{\bar{X}_i}.\beta_i$$

Where, β_i = regression coefficient of input X_i

$\bar{X}_i$ = mean value (geometric mean) of X_i variable input

$\bar{Y}_i$ = mean value (geometric mean) of gross return of boro paddy.

The marginal value products (MVPs) of various capital inputs were compared with their respective prices. If MVP of an input is higher than the MFC (market price of that input), then increase in input in production system raise output that increases profit. If MVPs of inputs are negative, then there are possibilities of reduction of these inputs and so the production is carried out in the second stage of production function and the marginal productivities of these inputs become negative. On the other hand, positive MVPs represent the possibilities of further increase in inputs to raise output as well as profit.

If the input resources are efficiently used then profit will be maximized in MV boro paddy where the ratio of MVP to MFC will tend to be 1 (one) or in other words MVP and MFC for each inputs will be equal.

In order to test the resource use efficiency in MV boro paddy production the ratio of marginal value product (MVP) to the marginal factor cost (MFC) for each input is compared and tested for its equality to 1 (i.e., $\frac{MVP}{MFC} = 1$).

Conceptual Framework of the Study

AWD and traditional irrigation systems are commonly used in MV paddy production in Southwestern Bangladesh. The present study considers the impacts of agricultural technological change on groundwater irrigation input use in MV paddy production. The new AWD irrigation technology improves MV paddy yield using less inputs especially for irrigation that has directly impact on fertilizers. The hypothetical yield curves of two existed MV paddy production under AWD and traditional irrigation in MV paddy farming system in Bangladesh are depicted in figure 1.

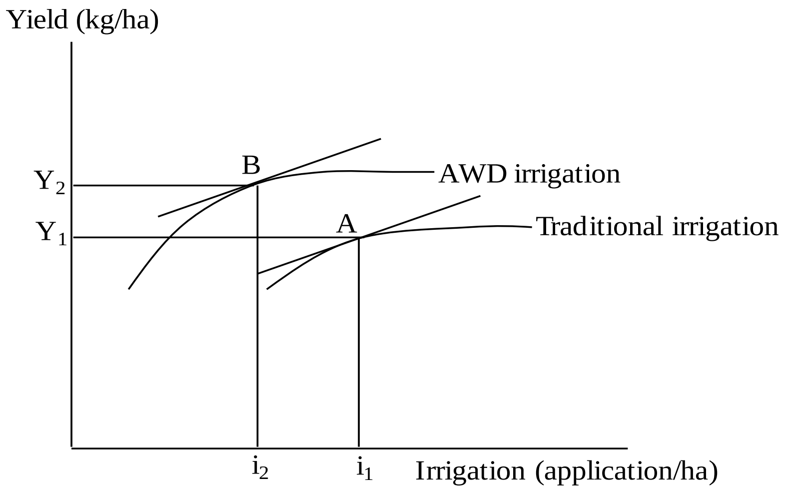

Fig 1. Hypothetical yield curves of modern variety (MV) of paddy under AWD irrigation technique and traditional irrigation technique in MV paddy farming systems in Bangladesh

The figure 1 shows that MV paddy farming yield curve under AWD farming system shifts upward from traditional irrigation system for MV paddy farming mainly because of agricultural technological progress. The advent of new technically progressed AWD farming system, farmers could be able to produce more paddy grain from per unit of farm land compared to traditional irrigation of paddy farming using same amount of groundwater irrigation. The main reason is that the paddy plants are able to receive optimal water from 15-20 cm depth of the top soils for survival. The farmers usually overflow the paddy field during irrigation period and this water is not fully absorbed by the paddy plants. A large portion of irrigated water to paddy field is vaporized and/or sometimes the farmers irrigate the paddy field even though the sufficient water in topsoils. In other words, sometimes the farmers excess or misuse groundwater for MV paddy cultivation. Therefore, it can be assumed that AWD irrigation technique reduce the application of irrigation in MV paddy production. As a result, less groundwater irrigation as well as chemical fertilizers is required for MV paddy production AWD irrigation technique. Under the traditional irrigation farming system, Y_1 amount of paddy could be produced using i_1 amount of irrigation, whereas, Y_2 amount of paddy can be produced using i_2 amount of irrigation under AWD irrigation technique. Now one of the most popular MV varieties of paddy named BR28 is being produced in the study villages. Along with BR28 paddy, some other varieties are also being produced in the study village and yield is almost same like BR28 MV paddy. Thus it is assumed that the yield of the variety is almost same at the best production environments in the study villages.

Concept of Water Productivity

In general, productivity is a measure of performance expressed as the ratio of output to input. Water productivity is defined as the ratio of per unit amount of grain yield to per unit water used in crop production. Depending on the water flows, water productivity can be defined as paddy grain yield per unit water evapotranspired or grain yield per unit total water input including irrigation and rainfall (Bouman and Tuong, 2001). The numerator (output derived from water use) can be defined in the following two ways- either physical output that can be total biomass or harvestable product or economic output that can be monetary value of output of agricultural production. The economic output (monetary unit) is particularly convenient than physical output to measure the water productivity when comparing different crops or different types of water use (Playan and Mateos, 2006).

Water productivity can be increased by increasing yield and/or reducing water use. Bouman and Tuong (2001) showed that water productivity depends on water evapotranspiration. A wide variation of evapotranspiration reflects the large variation of grain yield in the lowland of paddy production in the tropics. The yield also depends on the variety of MV paddy and production environments such as climate, soil characteristics, and production management. A large number of studies have been explained on water productivity on MV paddy production on the basis of rain and irrigated water in tropical countries (Bhatti and Kijne, 1992; Bhuyan et. al., 1995; Sandhu et al, 1980; Kitamura 1990; Misra et. al., 1990; Khepar et al, 1997; Cabangon et. al., 2002). The present study considers monetary values of water usage in MV boro paddy production because the lack of data on total quantity of water usage in per unit MV boro paddy production in AWD and traditional irrigation technique. Moreover, the evapotranspiration of water, outflows, runoff and leakage of water from MV paddy field have ignored due to lake of data as well as for the sake of simplicity of the calculation of water productivity of MV boro paddy production between AWD and traditional irrigation technique.

Brief Profiles of the Study Villages/Areas

Monohorpur is an ideal village of Monirampur Upazila Under Jessore District. The area of this village is 607 hectare and her populations about 5,792 where male and female numbers are 2,982 and 2,810, respectively. Literate rate of this village is about 63%. The main occupation of the people of this village is agriculture and they are very much advanced to adapt modern agriculture technologies. Communication facilities are satisfactory and the socio-economic conditions of this village are quite good compare to other villages. Maximum lands are suitable for the production of different agricultural crops and cropping intensity is about 260%. In agricultural point of view it is located agro-ecological zone (AEZ) 14. The soil texture of the crop fields is clay to loamy in nature and belongs to maximum-medium high land.

Characteristics of Sampled Farmers

Application of AWD irrigation technique in MV paddy cultivation is a newly adopted technology in Bangladesh. This method is only applicable in MV paddy cultivation for farmers who transplant seedling in line by line in paddy field. At the early stage, most of the farmers in the study village are not aware about this application method of AWD irrigation technique in MV paddy cultivation. Initially, since the farmers lacked the basic knowledge about this particular technique in MV paddy cultivation they decided to go for trial and error basis but they did the experiment only on a portion of their total cultivable land. However, the farmers were satisfied with the improvement in their yield.

Awareness of the Concept of AWD Irrigation Techniques

The Alternate Wetting and Drying (AWD) is a modern water saving technology that the farmers normally apply to reduce their water use in irrigated paddy field in modern varieties (MV) of boro paddy cultivation. This water saving method is developed by International Rice Research Institution (IRRI) and adopted by Bangladesh Rice Research Institute (BRRI).

AWD is a single device that has been used to observe the water level in paddy field for deciding the frequency and time of irrigation. The field water tube can be made of 30 cm long plastic pipe or bamboo and have a diameter of 10 cm or more so that the water table is easily visible. Perforate the tube with many holes on all sides, so that water can flow readily in and out of the tube. AWD can be started after a few weeks (normally 1-2 weeks) transplanting of seedling of paddy in rice field. In AWD, irrigation water is applied a few days after the disappearance of the ponded water. As a result, the field is alternatively flooded and non-flooded. After the irrigation, the water depth will gradually decrease. When the water level has dropped to about 15 cm below the surface of the soil, irrigation should be applied to re-flooded the field to a depth of about 5 cm. The paddy field should be kept flooded and topping up to a depth of 5 cm as needed before one week of flowering. After flowering, during grain filling and ripening, water level can be allowed to drop again to 15 cm below the soil surface before re-irrigation. The number of days of non-flooded soil between irrigations can vary from 1 to more than 10 days depending on a number of factors such as soil type, weather and crop growth stage.

Results and Discussions

Inputs used in MV Paddy Production

Irrigation is the main inputs along with seeds, chemical fertilizer, pesticides, manure, and equipment of land preparation for MV paddy production since the introduction of the green revolution. Recently the farmers are using Alternate Wetting and Drying (AWD), as one of the major inputs instead of traditional irrigation technique, for MV paddy production in some parts of Bangladesh. As the present study wants to estimate the impacts of AWD irrigation technique, the comparison between main inputs used in MV boro paddy production under the two production practices are discussed in this section.

Chemical Fertilizer and Manure

Farmers use various types of chemical fertilizers and manure to enhance the soil fertility that assist in producing maximum rice yield. Chemical fertilizers such as urea, triple super phosphate (TSP), murate of potash (MP), gypsum and zinc sulfate are commonly used in MV paddy production in the study village. The main inputs used in per hectare MV boro paddy production under two practices are presented in Table 1.

Table 1. Inputs used in per hectare MV boro paddy production under two practices

Particulars	AWD irrigation	Traditional irrigation	Ratio
A. Inputs used in MV paddy production:			
(i) Seed (kg)	33.7	31.0	1.09
Chemical fertilizer:			
(ii) Urea (kg)	323.1	341.5	0.95
(iii) TSP (kg)	157.1	156.3	1.00
(iv) MP (kg)	106.2	120.8	0.88
(v) Gypsum (kg)	111.3	137.3	0.81
(vi) Zinc (kg)	10.0	11.2	0.90
Organic fertilzer:			
(vii) Manure (mound)	188.6	191.9	0.98
Hired labor:			
(viii) Hired male labor (man-day)	159.0	156.0	1.02
(ix) Hired female labor (man-day)	20.0	18.0	1.11
Family supplied labor:			
(xi) Family supplied male labor (man-day)	20.0	20.0	1.00
(xi) Family supplied female labor (man-day)	25.0	29.0	0.86
B. Boro paddy production (kg)	7031.5	6577.9	1.07

Source: Field Survey, 2015.

Notes (i) Average farm size was 0.37 ha and 0.78 ha for AWD and traditional irrigation users of MV paddy production.

(ii) 1US$=80.60 Taka, May, 2016.

Table 1 shows that on an average, the farmers used about 323.1 kg and 341.5 kg of urea in per hectare MV boro paddy cultivation under AWD irrigation and traditional irrigation technique, respectively. In other words, the farmers used comparatively slightly less amount urea in AWD irrigation technique compared to traditional irrigation technique in per hectare MV boro paddy cultivation. The sample farmers also used comparatively less amount Murate of Potash (MP) (106.2 kg/ha) and Gypsum (111.3 kg/ha) per hectare MV boro paddy production under AWD irrigation technique compared to traditional irrigation technique (120.8 kg of MP) and (137.3 kg of Gypsum). However, the sampled farmers used other chemical fertilizers such as triple super phosphate (TSP) and manure in similar proportions in per hectare MV paddy cultivation. The amount of chemical fertilizer and manure used in paddy production per hectare also varied significantly within the same farming system.

Labour Input

The utilization of labor in agricultural sectors depends on many factors, such as cropping patterns, cropping intensity, irrigation, and other intensive agricultural activities (Suryawanshi and Kapase 1985). The adoption of new technology has substantially increased total agricultural employment and has significantly contributed to the household income by increasing labor demand in developing countries (Estudillo and Otsuka 1999; Alauddin and Tisdell 1995). The diffusion of modern technology has increased the size of the labor market by increasing the demand for hired labor in Bangladesh (Hossain et al. 1990). The temporarily hired and family supplied male and female labor used in MV boro paddy cultivation is also presented in Table 1. The table shows that the sampled farmers used temporarily hired and family supplied male and female labor (man-day) in similar proportions in per hectare MV boro paddy cultivation.

Yield of MV Paddy Production

The yield produced per production of MV boro paddy is also shown in Table 1. It appears from tables that per hectare yield of both MV boro paddy production under AWD irrigation technique (about 7.0 ton/ha) was significantly higher than the technique of traditional irrigation (about 6.6 ton/ha). It is interesting to note that yield production per hectare varied significantly within and between the two practicing methods in the study village.

Cost and Return of MV Boro Paddy Production

The cost of and returns from MV boro paddy production under the method of technically advanced AWD irrigation technique and traditional irrigation are discussed in this section.

Per Hectare Cost of MV Boro Paddy

The cost of items associated with the MV paddy cultivation includes the cost of seed, irrigation, pesticides, land preparation (bullock and power tiller), hired labor, chemical fertilizers and manure. Gross return from MV paddy farming includes revenue from paddy and byproduct straw. Total cost includes the variable costs and fixed costs. The opportunity costs of home supplied seeds, family supplied labors (both male and female) and self-owned land was calculated based on the current market price in the locality.

The per hectare costs, gross revenue, and profit of MV boro paddy farming are presented in Table 2. The table shows that per hectare production cost of MV boro paddy cultivation was almost same in both practices but the cost of irrigation, pesticides, urea, MP, Gypsum, hired male labor and opportunity cost of family labor were different. The main reason for this was that comparatively less number of applications of irrigation is required in MV boro paddy cultivation in AWD irrigation technique than traditional irrigation technique simply because of characteristics of AWD irrigation technique (briefly discussed in section 3.4) in the study village. So, the cost of irrigation was also less in the technique of AWD irrigation compared to traditional irrigation technique. The table shows that the cost of irrigation of per hectare MV boro paddy production was about 30% lesser in AWD irrigation technique than traditional irrigation technique. Another reason may be that in AWD irrigation technique of

MV boro paddy cultivation the soils of paddy field becomes relatively dry than the clay paddy field or sometimes water-full paddy field in traditional irrigation technique. As a result, the applied chemical fertilizers comparatively more stay in the paddy fields under AWD irrigation technique than traditional irrigation technique. In general, insects prefer water-full or clayed soils paddy fields for their survival. Therefore, it is assumed that based on this hypothetical concept the farmers used comparatively less amount of chemical fertilizers and pesticides in MV boro paddy production using the method of the application of AWD irrigation technique than the method of the application of traditional irrigation. Table 2 shows that the costs of pesticides, urea, MP and Zinc were about 12%, 5%, 12%, and 18% lesser in per hectare MV boro cultivation under the technique AWD irrigation than traditional irrigation technique, respectively. The sampled farmers used slightly higher number of temporary hired and family supplied male labor in per hectare MV boro paddy production under AWD irrigation technique than traditional irrigation technique except temporary hired female labor.

Table 2. Costs and returns of per hectare boro paddy production under two practices

Particulars	AWD	Traditional irrigation	Ratio
A. Variable costs of MV paddy production:	(Taka)	(Taka)	
(i) Seedling cost	1581.7	1550.4	1.02
(ii) Irrigation cost	15888.6	22579.6	0.70
(iii) Pesticides cost	4229.0	4810.6	0.88
(iv)Land preparation cost	5267.2	5175.2	1.02
Chemical fertilizers:			
(v) Urea	5168.4	5464.4	0.95
(vi) TSP	3455.7	3439.2	1.00
(vii) MP	1380.3	1570.7	0.88
(viii) Gypsum	674.9	823.8	0.82
(ix) Zinc	1820.7	1951.7	0.93
Organic fertilizer			
(x) Manure	2322.8	2256.7	1.03
Labors			
(xi) Hired male labor	44716.6	39293.9	1.14
(xii) Hired female labor	3835.1	3948.8	0.97
B. Opportunity cost/Fixed cost			
(xiii) Family supplied male labor	5966.5	4943.2	1.21
(xiv) Family supplied female labor	4811.7	4716.0	1.02
(xv) Opportunity cost of land	25,000.0	25,000.0	1.00
C. Total costs (variable and fixed costs) (A+B)	**126,119**	**127,524**	**0.99**
Revenue from paddy production			
(i) Paddy	137595.3	119531.9	1.15
(ii) By-product of paddy	13667.9	13780.1	0.99
D. Total revenue (i)+(ii)	**151,263**	**133,312**	**1.13**
E. Net profit (D-C)	**25,144**	**5,788**	**4.34**
F. Benefit cost ratio (BCR)	**1.20**	**1.05**	**1.15**

Source: Field Survey, 2015.

Notes: (i) Average farm size was 0.37 ha and 0.78 ha for AWD and traditional irrigation produccers of MV paddy production.

(ii) 1US$=80.60 Taka, May, 2016.

Per Hectare Return of MV Boro Paddy

Gross revenue is calculated by multiplying the total volume of production of enterprises with the farm-gate price. Net profit is calculated by subtracting total production cost (fixed and variable costs) from gross revenue. As mentioned earlier that on an average, per hectare production of MV boro paddy was higher using the method of application AWD irrigation compared to the method of traditional irrigation, the revenue was also higher in the technique of AWD irrigation than traditional irrigation (Table 3). As average total cost of per hectare boro paddy production was same for the two adopted practices, net profit of per hectare MV boro paddy was also higher (4.34 times) in the method of application of AWD irrigation than traditional irrigation technique. As a result, benefit cost ratio (BCR=total revenue/total cost) of per hectare MV boro paddy production was about 1.15 times higher in AWD irrigation technique than traditional irrigation technique. Therefore, it may be concluded that MV boro paddy cultivation is more profitable under technologically advanced AWD irrigation technique than traditional irrigation technique. Moreover, AWD is water-saving irrigation technique than traditional irrigation technique for MV paddy cultivation. The total cost, revenue and net profit of per hectare MV aman paddy was not consider because aman paddy grows in rainy monsoon season. As a result, the sampled farmers did not use AWD irrigation technique in aman paddy cultivation in the study area.

Estimation of Household Income

Household Income of MV Paddy Farmers under Two Different Practices

Cost, return, profit, and agricultural income as well as household income of the farmers of MV paddy cultivation are discussed in this section. The cost of items in MV paddy farming include the costs of seed/seedling, land preparation (bullock), irrigation, pesticides, chemical fertilizers, manure and labor. The gross return includes revenue from paddy grain and byproduct straw. The calculation procedure of variable cost, fixed cost, labor cost, gross revenue, and net profit are presented in table 3 and 4.

It can be seen from table 3 and 4 that total cost, total revenue and net profit of MV boro cultivation using AWD irrigation technique and the traditional irrigation were taka 85,751, taka 101,760, taka 16,009, and taka101,847, taka 111,813 and taka 9,966, respectively. The net profit of MV boro paddy cultivation under the practice AWD irrigation technique was significantly higher than the traditional irrigation method.

Table 3. Costs and returns of per farm boro paddy production under two practices

Particulars	AWD irrigation	Traditional irrigation
A. Variable costs :	(Taka)	(Taka)
(i) Seedling cost	1,182.89	1,378.58
(ii) Irrigation cost	10,012.13	20,641.21
(iii) Pesticides cost	2,827.40	3,620.90
(iv) Land preparation	3,571.12	3,990.16
Chemical fertilizers:		
(v) Urea	3,487.41	4,255.09
(vi) TSP	2,316.36	2,643.80
(vii) MP	921.09	1,237.41
(viii) Gypsum	446.80	533.16
(ix) Zinc	1,227.42	1,290.20
Manure	1,557.11	1,759.93
Labors		
(x) Hired male labor	30,541.97	30,156.78
(xi) Hired female labor	2,557.94	3,179.69
Opportunity cost		
(xii) Family supplied male labor	4,055.49	3,691.96
(xiii) Family supplied female labor	3,493.66	3,034.40
(xiv) Opportunity cost of land	17,551.97	20,433.64
B. Total Costs (Variavle +Fixed)	**85,751**	**101,847**
C. Revenue from paddy production		
(i) Paddy	92,534.71	101,159.12
(ii) By-product of paddy	9,225.11	10,653.84
D. Total revenue	**101,760**	**111,813**
E. Net profit (C-B)	**16,009**	**9,966**

Source: Field Survey, 2016.

Notes: (i) 1US$=80.60 Taka, May, 2016.
(ii) Average farm size was 0.67 ha and 0.78 ha for AWD irrigation and traditional irrigation users MV paddy producers, respectively.
(iii) Sample size was 70.

The average total cost, average total revenue and average net profit of MV aman paddy cultivation using the two practices are shown in table 4. The table shows that the total production cost were taka 53,315, taka 64,393 and taka 11,078, and taka 66,322, 72,807 and 6,485, respectively. The figure also shows that the net profit of MV aman paddy under AWD irrigation technique was also significantly higher than the traditional irrigation technique. The net profit from both the MV boro and aman paddy cultivation was very small. This scenario is found everywhere in Bangladesh for MV paddy production simply due to higher input costs such as higher cost of labor and chemical fertilizers and lower output price.

Table 4. Costs and returns of per farm aman paddy production under two practices

Particulars	AWD irrigation	Traditional irrigation
A. Variable costs :	(Taka)	(Taka)
(i) Seedling cost	1,222.30	1,404.91
(ii) Irrigation cost	2,140.00	2,651.17
(iii) Pesticides cost	1,474.91	1,469.93
(iv) Land preparation	3,548.70	6,603.14
Chemical fertilizers:		
(v) Urea	1,664.00	3,115.75
(vi) TSP	1,777.66	2,208.23
(vii) MP	806.01	840.81
(viii) Gypsum	289.66	456.63
Labors		
(ix) Hired male labor	21,408.20	24,652.14
(x) Hired female labor	918.20	1,211.14
Opportunity cost		
(xi) Family supplied male labor	5,519.80	5,691.93
(xii) Family supplied female labor	1,230.70	1,420.93
(xiii) Opportunity cost of land	12,537.12	14,595.45
B. Total costs (Variable+Fixed)	**53,315**	**66,322**
C. Revenue from paddy production		
(i) Paddy	57,630.20	64,461.56
(ii) By-product of paddy	6,763.00	8,345.50
D. Total revenue	**64,393**	**72,807**
E. Net profit (C-B)	**11,078**	**6,485**

Source: Field Survey, 2016.

Notes: (i) 1US$=80.60 Taka, May, 2016.

(ii) Average farm size was 0.67 ha and 0.78 ha for AWD irrigation and traditional irrigation users MV paddy producers, respectively.

(iii) Sample size was 70.

Agricultural and Household Income of the Farmers Using Two Different Methods

Components and their ratios of household income of the farmers who use AWD irrigation and traditional irrigation technique for MV paddy cultivation are presented in table 5. The table shows that agricultural income remains the principal source of income for the sampled households in the study villages who use AWD irrigation and traditional irrigation technique. Farm income of farmers, who used AWD irrigation, was significantly higher than that of farmers who used traditional irrigation in the both MV boro and aman paddy cultivation. The farmers earned more agricultural income from MV boro paddy cultivation than MV aman paddy cultivation under the AWD irrigation and traditional irrigation technique. The off-farm income of farmers, who used AWD irrigation, was about two times higher than that of paddy farmers who used traditional irrigation technique. The main reason was that the farmers who used AWD irrigation in paddy cultivation were engaged in various types of off-farm activities compared to the farmers who used traditional irrigation. However the income from agricultural wage, livestock and homestead gardening were almost same for the farmers who used both the methods. Therefore, it can be concluded from the table that the farmers who used AWD irrigation have gained more agricultural income and household income compared to the farmers who used traditional irrigation in MV paddy farming in the study area.

Table 5. Household income (taka) of MV paddy farmers

Sources of income	AWD irrigation	Traditional irrigation	Ratio	t-ratio
	Taka	Taka		
(i) Profit/agricultural income (Boro paddy)	16,009.06	9,966.05	1.61	4.67***
(ii) Profit/agricultural income (Aman paddy)	11,078.24	6,484.90	1.71	5.34***
(iii) Opportunity cost of land				
(a) Boro paddy production	17,551.97	20,433.64	0.86	-2.87***
(b) Aman paddy production	12,537.12	14,595.45	0.86	-2.67***
(iv) Opportunity cost of family labors				
(a) Male (Boro paddy)	4,055.49	3,691.96	1.10	2.15**
(b) Female (Boro paddy)	3,493.66	3,034.40	1.15	2.77***
(c) Male (Aman paddy)	5,519.80	5,691.93	0.97	-2.94***
(d) Female (Aman paddy)	1,230.70	1,420.93	0.87	-2.35**
(v) Agricultural wage	18,445.00	17,560.00	1.05	2.46***
(vi) Livestock	37,245.35	30,335.70	1.23	3.36***
(vii) Off-farm income	28,644.00	16,385.85	1.75	6.64***
(viii) Homestead gardening	7,260.50	6,512.00	1.11	2.19**
Total household income	**163,071**	**136,113**	1.20	2.52***

Source: Field survey, 2016.

Note: (i) *** and ** indicate statistically significant at 1% and 5%, respectively.

Efficiency Measure and Resource Use Efficiency

The estimation of the efficiency measures and resource use efficiency of MV boro and aman paddy production under the method of application of AWD irrigation and the traditional irrigation technique in the Cobb-Douglas production function, and marginal value product (MVP) and marginal factor cost (MFC) are briefly discussed in this section.

Summary Statistics of Inputs and Output of Cobb-Douglas Model

The descriptive statistics of value of the key variables in the Cobb-Douglas production are presented in table 6. The inputs and outputs of MV paddy production under the practices of AWD irrigation and traditional irrigation technique were calculated in terms of monetary unit instead of quantitative units mainly because the present study estimates the resource use efficiency based on the coefficients of Cobb-Douglas production function. The table reveals that considerable variation exists among the farmers in terms of production practices. The input and output data were obtained on per farm basis in the farm survey. The average revenue (Y) from the sale of MV boro paddy under the practices of AWD irrigation and traditional irrigation was taka 92534.7 and taka 99649.8, respectively and it significantly varied among the farms.

The mean farm size (X_1) of the farm that applied AWD irrigation and traditional irrigation technique was 0.67 and 0.78 hectare, respectively, and it significantly varied among the farms. The mean seed cost (X_2) per farm for MV boro paddy cultivation was almost same in both practices and widely varied among the farms. The mean land preparation cost (X_3) of MV boro paddy cultivation was almost same in both practices even though a wide variation exists among the farms. The main reason was that the famers almost used same modes of cultivator (power tiller) for plowing the paddy fields.

Table 6. Summary statistics of the sampled variables in MV boro paddy production in Jessore district

	AWD irrigation technique				Traditional irrigation technique			
Name of varables	Mean	SD	Min	Max	Mean	SD	Min	Max
Paddy grain (taka)	92534.71***	75887.7	35520	420480	99649.8***	76570.7	15540	343200
Area (hectare)	0.67***	0.55	0.27	3.21	0.78***	0.60	0.13	2.67
Irrigation cost (taka)	10012.13***	7759.0	3640	46320	20641.2***	45786.2	2570	384750
Pesticide cost (taka)	2827.40***	2372.7	900	14520	3620.9***	2636.9	570	10200
Land preparation (taka)	3571.13***	2917.6	1280	16200	3990.16***	3052.1	600	13400
Seed (taka)	1182.89***	1093.5	387	6600	1378.58***	1056.6	215	4500
Urea (taka)	3487.41***	3018.3	1120	19200	4255.09***	3394.4	672	15680
Other fertilizer (taka)	4911.6***	3946.3	1656.5	20892	5704.62***	4472.4	906.5	19260
Manure (taka)	1557.11***	1261.6	420	7344	1759.93***	1447.7	180	6240
Labor (taka))	40649.06***	36380.2	12000	194400	40062.83***	31833.3	6880	146000

Notes (i) Sample size of both MV boro and aman paddy production was 70.
(ii) Field survey, 2016.

Pesticides and irrigation are the main inputs for MV paddy cultivation. Cost of pesticides is an important input for MV boro paddy production. The mean pesticide cost (X_4) per farm for MV boro paddy production under the practice of AWD irrigation technique was significantly less than under the traditional irrigation technique and it significantly varied among the farms. The causes of comparatively less pesticide cost in the method of AWD irrigation technique have been discussed earlier. The mean irrigation cost (X_5) per farm for both the MV boro paddy cultivation under the practice of AWD irrigation technique was significantly smaller than the practice of traditional irrigation technique and it widely varied among the farms.

Chemical fertilizers such as urea, TSP, MP, gypsum, Zn are also the main inputs of MV paddy production. As the present study estimates the impact of AWD irrigation technique on the urea usages of MV boro paddy cultivation, that is why we have separated the cost of urea from the costs of other chemical fertilizers-TSP, MP, gypsum, and Zn. The mean cost of urea (X_6) was significantly smaller in the MV boro paddy cultivation under the practice of AWD irrigation technique than the traditional irrigation technique and a wide variation exists among the farms. The main reason was that after transplantation of seedling, most of the time the paddy field is remain dry during MV boro paddy cultivation. As a result, soaking is comparatively smaller in AWD irrigation technique than the traditional irrigation technique and relatively small amount of urea is required to produce MV paddy in AWD irrigation technique. The mean cost of other fertilizers (X_7) was also smaller in MV boro paddy cultivation under the AWD irrigation technique than traditional irrigation technique.

The mean labor cost (both hired and family supplied male and female) (X_8) per farm for MV paddy production under the practice of AWD irrigation technique was also relatively smaller than the practice of traditional irrigation technique.

Affecting Factors of Cobb-Douglas Production Function of MV Paddy Production

The model parameters in the Cobb–Douglas production function allowed us to compare empirically the impact of input variables on output. Cobb-Douglas production function has been fitted to work out the elasticity values of production of inputs which in turn have been used to calculate their (inputs) marginal value products (MVP) (at their geometric means) for the average farms. The single equation Cobb-Douglas production has been estimated by the ordinary least square (OLS) method. The empirical results of the Cobb-Douglas production of MV boro paddy cultivation under the method of the application of AWD and traditional irrigation technique are presented in table 7.

The regression coefficients of Cobb-Douglas production function indicated the elasticity values of an input production and the sum of these elasticity values indicates the nature of returns to scale. The returns to scale are decreasing, constant and increasing as the sum of regression coefficients is less than, equal to or greater than unity. It can be observed from the table that the sum of the elasticity values of MV boro paddy production was 1.06 and 1.09 which were close to unity, indicating that both the farmers had experienced constant return to scale in MV boro paddy farms using the AWD irrigation technique and traditional irrigation technique in the study area. The values of R^2 for MV boro paddy cultivation were quite high. These indicate that the variables appearing in the Cobb-Douglas production equations explained quite a high proportion of variations in MV boro paddy production under the method of AWD irrigation (0.97) and traditional irrigation (0.98) in the production process, respectively and they were statistically significant at 1% level.

The coefficients of farm area (1.022), and pesticides cost (0.0515) were positive and statistically significant at 1% level, whereas the coefficient of irrigation cost (0.0450) and labor cost (0.069) were also positive but it was statistically significant at 10% level for MV boro paddy production under the method of application of AWD irrigation technique. This indicates that farm area, pesticides cost, irrigation cost, and labor cost were the main factors that affect significantly the MV boro paddy production under the method of application AWD irrigation technique. However, the coefficient of seed cost (-0.085) and urea cost (-0.059) were negative and statistically significant at 1% land 10% level, respectively, which indicated that the AWD irrigation technique also had significant impact on MV boro paddy cultivation. In other words, the farmers were able to produce same level of paddy grain output with the application of fewer amounts of seed and urea in MV boro paddy cultivation. The coefficients of the cost of other chemical fertilizers (0.0841) and manure (0.0149) were positive and the cost of land preparation (-0.082) was negative and they were statistically insignificant in the MV boro paddy cultivation in AWD irrigation technique.

Table 7. Estimated value of co-efficients and related statistics of Cobb-Douglas production model for AWD and traditional irrigation usage of boro paddy production in Jessore district

	AWD irrigation technique			**Traditional irrigation technique**		
Name of variables	Coefficients	Standard error	t-ratio	Coefficients	Standard error	t-ratio
Constant	12.181***	1.081	11.26	11.123***	1.381	8.05
Area (ha) (X_1)	1.022***	0.124	8.27	1.134***	0.159	7.10
Seed cost (X_2)	-0.085***	0.027	-3.11	-0.0357	0.053	-0.67
Land preparation cost (X_3)	-0.082	0.064	-1.28	-0.159**	0.077	1.96
Pesticide cost (X_4)	0.0515***	0.023	2.275	0.023	0.048	0.46
Irrigation cost (X_5)	0.0450*	0.027	1.67	-0.044	0.057	-0.77
Urea cost (X_6)	-0.059**	0.033	-1.79	0.071**	0.021	1.92
Other fertilizer cost (X_7)	0.084	0.095	0.88	0.108***	0.060	2.80
Manure (X_8)	0.0149	0.027	0.55	0.063***	0.025	2.51
Labor cost (X_9)	0.069*	0.041	1.68	-0.070*	0.039	-1.8
Sum of elasticities β_i	1.06			1.09		
R^2	0.97***			0.98***		

Notes (i) ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively.
(ii) Sample size was 70.

On the other hand, the coefficients of farm size (1.134), the cost of other chemical fertilizers (0.108) and manure (0.063) were positive and statistically significant at 1% level and the cost of urea (0.071) was also positive but statistically significant at 5% level under the method of application of traditional irrigation technique in MV boro paddy cultivation. These imply that the farm size, cost of urea, other chemical fertilizers and manure had significant positive impact on MV boro paddy under the application of traditional irrigation technique in MV boro paddy cultivation. The coefficient of the cost of pesticides (0.023) was positive and it was statistically insignificant. On the other hands, the cost of land preparation (-0.159), and labor (-0.070) were negative and they were statistically significant at 5% and 10%, respectively, and the coefficient of cost of seed (-0.0357) was negative and it was statistically insignificant in the application of traditional irrigation in MV boro paddy cultivation in the study area.

Resource Use Efficiency of MV Paddy Production

The marginal value products (MVPs) of various capital inputs were worked out at the geometric mean (GM) levels for AWD irrigation technique and the traditional irrigation technique in MV boro paddy cultivation and were compared with their respective prices.

Marginal factor cost (MFC) of all inputs is expressed in terms of an additional taka spent for providing individual inputs in Cobb-Douglas production. Therefore, to calculate the ratio of MVP to MFC the denominator would be one and consequently the ratio would be equal to their MVP of an input in the production process. The marginal value product (MVP) and the ratio of MVP to MFC of MV boro paddy cultivation under the method of application of AWD irrigation and the traditional irrigation are presented in Table 8. The figures in Table 8 show that none of the marginal value products (MVPs) of inputs was equal to one, indicating that the sampled farmers in the study area failed to show their efficiency in using the resources both in the AWD irrigation technique and traditional irrigation technique used for MV boro paddy cultivation.

The MVP and MFC ratio of seed costs of MV boro paddy production were -6.649 and -2.580 in AWD irrigation technique and traditional irrigation technique, respectively, which was negative and greater than unity and it were statistically significant at 1% level for AWD irrigation technique and statistically insignificant for traditional irrigation technique, indicating that the farmers used excessive seeds to produce MV boro paddy cultivation in both the irrigation technique in the study village. So, there was an opportunity for the farmers to maintain the same level of production by using less seed input. Similarly, the MVP and MFC ratio for land preparation cost were negative for both the irrigation technique and it was significant in traditional irrigation technique (statistically significant at 5% level) and greater than unity which indicates that the farmer spent significantly excessive money for land preparation for MV boro paddy cultivation in the short-run keeping the use of other resources at a constant level.

On the other hand, the ratio of urea (-1.565) were negative for AWD irrigation technique (statistically significant at 5% level) but positive (1.662) for traditional irrigation technique (statistically insignificant) and greater unity which indicates that the farmers who used AWD irrigation technique used excessive urea in MV boro paddy cultivation, however, had no opportunity to reduce urea to maintain the same level of MV boro paddy production who used traditional irrigation technique in the study area.

Table 8. Resource use efficiency in Cobb-Douglas production for both AWD and traditional irrigation techniques use in boro paddy cultivation

	AWD Irrigation Method			**Traditional Irrigation Method**		
Name of variables	Coefficients	MPV	MVP/MFC	Coefficients	MPV	MVP/MFC
Seed (X_1)	-0.085***	-6.649	-6.649	-0.0357	-2.580	-2.580
Land preparation cost (X_2)	-0.082	-2.124	-2.124	-0.159**	-3.970	-3.970
Irrigation cost (X_3)	0.0450*	0.415	0.415	-0.044	-0.212	-0.212
Pesticide cost (X_4)	0.0515***	1.685	1.685	0.023	0.632	0.632
Urea (X_5)	-0.059**	-1.565	-1.565	0.071**	1.662	1.662
Other fertilizer cost (X_6)	0.084	1.582	1.582	0.108***	1.886	1.886
Manure (X_7)	0.0149	0.885	0.885	0.063***	3.567	3.567
Labor (X_8)	0.069*	0.157	0.157	-0.070*	-0.174	-0.174

Notes: (i) MVP=Marginal value product, MFC=Marginal factor cost, MFC=1 for each inputs

(ii) ***, ** and * indicate statisticaly significant at 1%, 5% and 10%, respectively.

The MVP and MFC ratios of irrigation (0.415) and labor (0.157) were positive and statistically significant at 10% level but less than unity for the farmers who used AWD irrigation technique for MV boro paddy cultivation which indicates that there was no further opportunity to increase paddy production using more irrigation and labor. However, the ratios of irrigation (-0.212) and labor (-0.174) (statistically significant at 10% level) and less than one, indicating that the farmers who used traditional irrigation technique used little bit excessive irrigation and labor for MV boro paddy production. This implied that the farmers had no ample opportunity to reduce these inputs to maintain the same level of MV boro paddy production.

The ratios of MVP to MFC for other chemical fertilizers were 1.582 (statistically insignificant) and 0.885 for AWD irrigation technique, and 1.886 and 3.567 for traditional irrigation technique and both were positive and greater than unity except manure for AWD irrigation technique, indicating that the farmers under both irrigation technique did not utilize the opportunity of fully using the inputs in MV boro paddy cultivation. So, there was a little opportunity for the farmers to increase production by using urea input. Therefore, it may be concluded that the farmers did not efficiently and optimally use the input resources in both the AWD irrigation technique and the traditional irrigation technique in MV boro paddy cultivation and this hindered the generation of maximum level of output of paddy grain in the study area.

Water Productivity and Water-Saving

The factors share as well as water productivity of MV boro paddy production under two farming system are presented in table 9. It appears from the table that the average cost of irrigation (water input) of per hectare MV boro paddy production in AWD irrigation technique was significantly smaller than traditional irrigation technique. On the other hand, per hectare paddy grain yield was higher in AWD irrigation technique than traditional irrigation technique. The cost share of irrigation of per hectare MV boro paddy production was 0.09 (9%) and 0.13 (13%) for MV boro paddy cultivation in AWD and traditional irrigation technique, respectively. The cost share of irrigation in AWD irrigation technique is smaller compared to traditional irrigation technique simply due to the appropriate and proper use of irrigation water that is not possible in traditional irrigation technique. The cost share of labor utilization and chemical fertilizers in per hectare MV paddy cultivation was almost same (about 30%) for both the irrigation techniques. The water productivity of MV boro paddy production was about 10.04 and 6.31 in AWD irrigation and traditional irrigation technique, respectively, indicating that the water productivity was about 1.6 times higher in AWD irrigation technique compared to traditional irrigation technique. In other words, water input efficiently used in MV boro paddy production in AWD irrigation technique compared to traditional irrigation technique. The productivity of other two main inputs chemical fertilizers and labor inputs for MV boro paddy was slightly higher in AWD irrigation technique than traditional irrigation technique in the study area. Therefore, it may be concluded that water inputs as well as other inputs were efficiently used in MV boro paddy cultivation in AWD irrigation technique compared to traditional irrigation technique.

Table 9. Per hectare input costs, factor shares and factor productivity of MV boro paddy production

Particulars	AWD irrigation	Traditional irrigation	AWD irrigation	Traditional irrigation
	Input costs (Taka)		**Factor Share**	
Seeding	1581.7	1550.4	0.01	0.01
Land preparation	5267.2	5175.2	0.03	0.03
Irrigation	15888.6	22579.6	0.09	0.13
Pesticides	4229.0	4810.6	0.02	0.03
Chemical fertilizers	12500.0	13249.8	0.07	0.07
Organic manure	2322.8	2256.7	0.01	0.01
Total labor cost	53803.8	52822.1	0.30	0.29
Hired labor	48551.7	43242.7	0.27	0.24
Family labor	10778.2	9659.2	0.06	0.05
Opportunity cost land	25000	25000	0.14	0.14
Total input cost	**179,923**	**180,346**		
Total output (Taka)	**159,448**	**142,376**		
Major Input Productivity:				
Water productivity	10.04	6.31		
Chemical fertilizers	12.76	10.75		
Labor productivity	2.96	2.70		

Source: Field survey, 2016.

Conclusions and Policy Options

Rice is the main staple food of the people in Bangladesh. The government of Bangladesh has been trying to achieve food self-sufficiency using the scarce input resources efficiently and optimally in production processes using our limited land resources to meet the continuous increasing demand to increasing rapid population growth. In this regard the farmers are always trying to use trial and error technique to use the inputs efficiently in paddy cultivation. AWD irrigation technique is one such trial and error technique of modified irrigation system that is being used recently in MV paddy cultivation in Bangladesh.

The findings of the study indicated that the less number of applications of irrigation is required to produce MV paddy in AWD irrigation compared to the traditional irrigation system in the study area. As a result, the average cost of per hectare MV boro paddy production was comparatively smaller in AWD irrigation than traditional irrigation system. The sampled farmers used comparatively less proportion of chemical fertilizers such as urea, MP, zypsum, zinc, and manure except TSP in per hectare of MV boro paddy cultivation. The amount of chemical fertilizer used in paddy production per hectare of MV boro paddy cultivation also varied significantly within the same farming system. The farmers used in more or less similar proportions of temporary hired and family supplied male and female labors in per hectare of MV paddy cultivation in both the irrigation techniques. On an average, the yield (production per hectare) of MV boro was significantly higher in the method in AWD irrigation technique than in the method of traditional irrigation.

Per hectare production cost of MV boro paddy cultivation was significantly lower in case of the application of AWD irrigation technique than the application of traditional irrigation method. As yield of MV boro paddy was significantly higher in farms that used AWD irrigation instead of traditional irrigation, the revenue as well as net profit of per hectare MV boro paddy was also higher for the farmers who used AWD irrigation instead of traditional irrigation technique. The net profit of per MV boro paddy cultivation was more than four times higher in AWD irrigation than traditional irrigation technique. The study also found that the household income of the farmers who used AWD irrigation was significantly higher (about 1.20 times) than the farmers who used traditional irrigation technique in MV boro and aman paddy cultivation in the study area. These results indicated that the farmers could produce same level of output (paddy grain) from MV boro paddy cultivation using comparatively fewer amount of AWD irrigation that was not possible using traditional irrigation technique. Therefore, it may be concluded that the AWD irrigation has significant impact on MV paddy production as well as on the household income of the farmers in the study area.

The results of the Cobb-Douglas production function found that both the farmers had experienced constant return to scale in MV boro paddy farms using the AWD irrigation technique and traditional irrigation technique in the study area. The farm area, seed cost, pesticides cost, irrigation cost, urea cost and labor cost were the main factors that affect significantly the MV boro paddy production under the method of application AWD irrigation technique. On the other hand, the farm size, land preparation cost, urea, other chemical fertilizers and manure had significant positive impact on MV boro paddy under the application of traditional irrigation technique.

The results of the ratios of MVP to MFC showed that none of the marginal value products (MVPs) of inputs was equal to one, indicating that the farmers did not optimally use the input resources in both the methods of AWD irrigation and the traditional irrigation technique in MV boro paddy cultivation and this hindered the generation of maximum level of output of paddy grain in the study area.

The findings of the study also indicated that the water productivity of MV boro paddy production was significantly higher in AWD irrigation and traditional irrigation technique. In other words, water input efficiently used in MV boro paddy production in AWD irrigation technique compared to traditional irrigation technique.

Therefore if government takes the initiatives to boost up the availability of AWD irrigation in every farm and ensures efficient extension services in every village this will lead to an increased paddy production which will contribute to greater food self-sufficiency in Bangladesh.

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