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Impacts of Granular Urea and Efficiency of Resource Use in MV Paddy Production: A Case Study of Jessore District

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Granular urea is technologically and physically modified normal urea that is used in MV paddy production in Bangladesh. The present study estimates the impact of granular urea and efficiency of resource use in MV paddy production in Bangladesh using primary data. Shimlagachi village of Sharsha upazila in Jessore district was purposively selected because a large number of farmers use granular urea along with traditional urea in MV paddy production. The findings of the study indicate that significantly less amount of granular urea is required per hectare for MV boro and aman paddy production than traditional urea. Moreover, the yield of MV boro and aman paddy is markedly higher with application of granular urea. On average, production cost per hectare of MV boro and aman paddy cultivation is less with application of granular urea. Consequently, net profit is significantly higher. The results of Cobb-Douglas production function, marginal value products (MVPs) and marginal factor cost (MFC) ratio tests show that the farmers do not use inputs efficiently and optimally in MV boro and aman paddy cultivation. They use more granular urea than traditional urea in MV boro paddy cultivation.

Keywords: Granular Urea, Cobb-Douglas Production Function, Yield, MV Paddy Production, Resource Use Efficiency, Bangladesh

JEL Classification: O13, O33, Q1, Q12, Q16, Q18

I. INTRODUCTION

Bangladesh is an agricultural country with scarcity of land. The country's population density is one of the highest compared to other countries of the world. The country has only about 11.53 million hectares of cultivable land against its huge population (BBS 2011). Agriculture is the single largest producing sector of

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the economy and it contributes about 20.24 per cent to the total gross domestic product (GDP) of the country. This sector also accommodates about 48.1 per cent of the total labour force (BBS 2011). The land area is gradually decreasing because of population growth, industrialisation and other infrastructure development. This resulted in a declining trend of per capita land availability from 0.13 hectare to 0.06 hectare during the last few decades (1960 to 2000) and this trend is still continuing (Hossain *et al.* 2006).

The population growth has declined rapidly from 2.17 per cent to 1.5 per cent per year over the last four decades; however, the nation's population is still growing at a rate of two million people every year (BBS 2012). This indicates that the supply of rice production needs to be increased by applying more and more sophisticated and advanced technological inputs in MV paddy production to meet the high demand of the growing population. Bangladesh has already made a remarkable progress in sustaining rice production over the last three decades through the adoption of modern varieties (MV) of paddy, despite of the declining availability of arable land. Rice is the dominant staple crop in Bangladesh. The crucial role of rice in the Bangladesh economy is manifested in terms of area, production and consumption. About three-fourth of the total cultivated area is devoted to the production of rice and a large number of farmers' families (13 million) are engaged in rice production. About 80 per cent of the total fertiliser (domestic production and imported) is used in the rice crop production (Balcombe *et al.* 2007, Bangladesh Bank 2010).

The government of Bangladesh has been trying to emphasize on the agriculture sector and has provided many subsidies in key inputs like fertilisers and irrigation. Although substantial advancement has taken place in the food grain production, its productivity is still lower compared to many neighbouring countries. This deviation may be attributed mainly due to low use of technological inputs. Ignorance of farmers and non acquaintance of farmers with the modern technologies are other factors that result in low per unit productivity. Thus, many farmers do not operate at a potential level.

Although Bangladesh has an excellent land, the yield per acre of rice is one of the lowest among the rice producing countries of the world. The yield is low because the technique of production is still outdated in many areas. However, introduction of the MVs of rice in Bangladesh has already created a remarkably good impact in the economy and this phenomenon has given a good amount of confidence to the farmers. Now-a-days they have become used to looking for the MVs for as many crops as possible.

There are some national and international organisations and researchers who have conducted research regarding the impacts of MV paddy farming on household income, labour demand, poverty alleviation and food self-efficiency in South Asia. Some literature concluded that the green revolution has significantly increased rural household income and reduced poverty and created inequality of income distribution through MV paddy and wheat production in Asia (Hossain 1988, David and Otsuka 1994, Huang *et al.* 2005, Rosegrant and Evenson 1992, Hossain *et al.* 2000, Datta *et al.* 2004, Saleth 1991, Selvarajan and Subramanian 1981). Some literature also summarised that technological progress in MV rice cultivation is crucial for sustaining food security in Bangladesh (Asaduzzaman 1979, Hossain *et al.* 1994, 2006). Also, a large number of research works have been conducted on the influencing socio-economic factors of the adoption of HYV paddy (Bera and Kelly 1990, Rahman and Thapa 1999, Rahman, 2002) and estimation of technical efficiency of MV paddy production in Bangladesh (Coelli *et al.* 2002). The growth of rice output remains a central concern and has very limited potential to expand cultivation of the arable land for paddy and use of irrigation (Alauddin and Hossain 2001, Hossain 2002). The application of granular urea in MV paddy cultivation is a newly introduced technology in Bangladesh. The farmers are gradually applying granular urea in MV paddy cultivation and its use depends on the availability of granular urea and the efficiency of extension workers in providing their services. However, the impacts of granular urea on MV paddy production in Bangladesh have been paid less attention. Therefore, the present study evaluates the impacts of granular urea on MV paddy production in Bangladesh. Moreover, the study also determines the resource use efficiency of granular and traditional urea used MV 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.

II. METHODOLOGY OF THE STUDY

2.1 Sources of Data

To assess the impacts of technologically modified granular urea on MV boro and aman paddy production, Shimlagachi village of Sharsha upazilla in Jessore district was selected. This village was purposively selected because the farmers in this village have adopted the use of granular urea along with traditional urea in MV paddy production. Initially, a detailed list of farmers who used granular urea and traditional urea in MV paddy production was collected from upazilla agriculture office. Primary data were used in this study. The information on various inputs and output of MV paddy production and the socio-economic information of farmers were collected through a comprehensive questionnaire. A total of 200 farmers were randomly selected from this study village, of which 100 farmers used traditional urea and another 100 farmers used granular urea in their MV boro and aman paddy cultivation.

2.2 Analytical Techniques

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

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

Where,

Y= Output of MV 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 fertiliser cost (taka)

X_8= Labour cost (taka)

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

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

2.3 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 maximise 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.

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

where, β_i = regression coefficient of input X_i

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

$\overline{Y}_i$ = mean value (geometric mean) of gross return of *boro* and *aman* 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 raises 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 maximised in MV *boro* and *aman* 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 and aman 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., $\frac{MVP}{MFC} = 1$ (Gujarati 1965).

III. SCENARIO OF MV PADDY PRODUCTION IN BANGLADESH

3.1 MV Paddy Production System in Bangladesh

Currently, three different types of paddy are being produced in Bangladesh in three distinct seasons: *aus* (April to August), transplanting *aman* (T. *aman*) (August to December), and *boro* (January to April). Among them, *aus* and T. *aman* paddy are produced in rain fed water and MV *boro* paddy is produced in irrigated water (ground water or rivers and canals). Modern varieties of paddy were introduced in Bangladesh for the *boro* and *aus* season in 1967 and *aman* season in 1970 (Hossain *et al.* 2000). In 2011, only 45.78 per cent of the area was irrigated under MV paddy production in Bangladesh (BBS 2011). Irrigation and chemical fertilisers are not used for local *aus* and T. *aman* paddy production because the paddy fields go under water. Farmers transplant MV *boro* paddy from mid-January to mid-February and harvest them from mid-April to mid-May. Farmers usually use chemical fertilisers, pesticides, and irrigation for *boro* paddy production. Along with paddy crops, farmers also cultivate oil seeds, potato and vegetables in a comparatively higher land during the winter season.

3.2 Production and Application of Granular in MV Paddy Production in Bangladesh

A sophisticated machine is used to transform the normal urea into granular urea in Bangladesh which is called "Brequater." The Agricultural Ministry of Bangladesh has provided Brequater for the transformation of normal urea in every upazilla. The farmers in the locality go to the upazilla agricultural office to transform the normal urea into granular urea. Farmers usually subsequently place a piece of granular urea in the mid-point of four plants of each column and row of MV paddy cultivation. The farmers in the study area use it only once during paddy cultivation. On the other hand, the farmers top dress the traditional normal urea 3-4 times during the paddy cultivation.

3.3 Characteristics of Sampled Farmers

Application of granular urea 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 granular urea 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. On the contrary, the availability of granular urea in the study village is not wide spread because the machine called the "Brequater" is not available and also the machine cannot covert the sufficient amount of fertiliser required for the cultivation of the MV paddy. Recently the availability of the machine increased and the farmers are also satisfied with the improvement in their yield, so they have decided to use the granular urea to their total cultivable land based on the availability of the granular urea in the study area.

IV. RESULTS AND DISCUSSIONS

4.1 Inputs Used in MV Paddy Production

Seeds, irrigation, chemical fertiliser and land preparation equipment are the main inputs of MV paddy production since the introduction of the green revolution. As most of the agricultural cultivable land has already been used in crop cultivation, mainly in MV paddy production, the farmers are trying to increase the maximum level of output by using the method of trial and error for the available scarce inputs and technologies that were already adopted in MV paddy cultivation in Bangladesh. Recently the farmers are using granular urea, as one of the major inputs instead of traditional urea for MV paddy production in some parts of Bangladesh. As the present study wants to estimate the impacts of granular urea in MV boro and aman paddy production, the comparison between main inputs used in MV boro and aman paddy production under the two production practices that used granular and traditional urea in Bangladesh are discussed in this section.

4.1.1 Chemical Fertiliser

Farmers use various types of chemical fertilisers to enhance the soil fertility that will assist in producing maximum rice yield. The farmers' practice of inorganic fertiliser management varied widely across and within the villages, as did the cropping patterns and seasons, soil textures, and geographical areas. Chemical fertilisers such as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulfate are commonly used in MV paddy production in Bangladesh. The main inputs used in per hectare MV boro and aman paddy production under two practices (method of the application of granular urea and traditional urea) are presented in Table I and Table II.

Tables I and II show that, on an average, the farmers used only 164 kg and 124 kg of granular urea in per hectare MV boro and aman paddy cultivation respectively, whereas 319 kg and 247 kg of traditional urea was used in MV boro and aman paddy cultivation. In other words, the farmers used half of the granular urea compared to traditional urea in per hectare MV boro and aman paddy cultivation. The main reason behind this is that in the case of top-dressing method used in traditional urea the chemical, nitrogen, evaporates before the plants can absorb them properly but this is not the scenario in the case of granular urea technology as it is placed within the soil. However, the sampled farmers used other chemical fertilisers such as triple super phosphate (TSP), murate of potash (MP), zypsum and zinc in similar proportions in per hectare MV paddy cultivation. The amount of chemical fertiliser used in paddy production per hectare also varied significantly within the same farming system. In the study village, the farmers usually use comparatively less amount of chemical fertilisers in aman paddy than in boro paddy cultivation.

TABLE I
INPUTS USED IN PER HECTARE MV BORO PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea	Normal urea	Ratio
A. Inputs used in MV paddy production			
Chemical fertiliser			
(i) Urea (kg)	163.8	318.7	0.51
(ii) TSP (kg)	140.6	141.5	0.99
(iii) MP (kg)	125.3	112.9	1.11
(iv) Gypsum (kg)	112.8	108.7	1.04
(v) Zinc (kg)	10.4	10.9	0.96
Hired labour			
(vi) Hired male labour (man-day)	113.4	95.6	1.19
(vii) Hired female labour (man-day)	3.7	20.0	0.18
Family supplied labour			
(viii) Family supplied male labour (man-day)	64.6	57.4	1.13
(ix) Family supplied female labour (man-day)	19.0	23.0	0.83
B. Boro paddy production (kg)	7164.0	6475.0	1.11

Source: Field Survey, 2013.
Notes: (i) 1US$=83.60 Taka, May, 2013.
(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers.
(iii) Sample size was 100.

4.1.2 Labour Input

The utilisation of labour in agricultural sectors depends on many factors, such as cropping patterns, cropping intensity, potentiality of irrigation and other intensive agricultural activities (Suryawanshi and Kapase 1985). The green revolution has changed the agricultural land and labour productivity, and it has had considerable impact on labour demand and/or employment in developing countries. The adoption of new technology has substantially increased total agricultural employment and has significantly contributed to the household income by increasing labour demand in developing countries (Estudillo and Otsuka 1999). The diffusion of modern technology has increased the size of the labour market by increasing the demand for hired labour in Bangladesh (Hossain *et al.* 1990). However, Alauddin and Tisdell (1995) argued that modern agricultural technology increased labour demand four-fold from the 1960s to the 1980s in the dry season but the labour demand was stagnant in the wet season. The employment-generating effects of modern agricultural technology have slowed down in recent years in Bangladesh. The green revolution has increased labour absorption at its early stage but the labour absorption decreased in most developing countries after the adoption of the new labour-saving chemical and mechanical innovations (Jayasuriya and Chand 1986).

The application of the granular urea technology in MV paddy production requires skilled labours those are well trained about the method of application. The temporarily hired and family supplied male and female labour used in MV boro and aman paddy cultivation is also shown in Table I and Table II. The tables show that the farmers, who used granular urea instead of traditional urea, used comparatively higher temporarily hired and family supplied male labour (man-day) and used lower temporarily hired and family supplied female labour in both per hectare MV boro and aman paddy cultivation. The main reason was that the application of granular urea is a skilled labour-intensive technology than the application of the method of top dressing traditional urea in paddy production. It can be concluded from Tables I and II that with the use of granular urea technology more skilled temporarily hired and family supplied male labour is required compared to temporarily hired and family supplied female labour in different proportions but the overall number of labour used is more or less equal in both boro and aman MV paddy cultivation. The similar pattern is also reflected in terms of cost in Tables III, IV and V. The tables show that the labour cost remains almost similar in both boro and aman MV paddy production in the study area.

TABLE II
INPUTS USED IN PER HECTARE MV AMAN PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea	Normal urea	Ratio
A. Inputs used in MV paddy production			
Chemical fertiliser			
(i) Urea (kg)	123.6	246.5	0.50
(ii) TSP (kg)	103.1	113.0	0.91
(iii) MP (kg)	93.2	90.9	1.02
(iv) Gypsum (kg)	78.5	73.3	1.07
(v) Zinc (kg)	5.6	5.8	0.97
Hired labour			
(vi) Hired male labour (man-day)	109.7	92.7	1.18
(vii) Hired female labour (man-day)	2.8	23.3	0.12
Family supplied labour			
(viii) Family supplied male labour (man-day)	66.4	57.2	1.16
(ix) Family supplied female labour (man-day)	17.7	23.1	0.76
B. Aman paddy production (kg)	5242.0	4865.0	1.08

Source: Field Survey, 2013.
Notes: (i) 1US$=83.60 Taka, May, 2013.
(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers.
(iii) Sample size was 100.

4.2 Yield of MV Paddy Production

Yield produced per production of MV boro and aman paddy is also shown in Tables I and II. It appears from the tables that per hectare yield of both MV boro and aman paddy production using the method of application of granular urea was significantly higher than the method of application of traditional urea. It is interesting to note that yield production per hectare varied significantly within and between the two practicing methods in the study area.

V. COSTS AND RETURN OF MV PADDY PRODUCTION

The cost of and returns from MV boro and aman paddy production under the method of application of granular and traditional urea are discussed in this section.

5.1 Per Hectare Cost of MV 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 labour and chemical fertilisers. 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 labours (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 and aman paddy farming are presented in Table III and Table IV. The tables show that per hectare production cost of MV boro paddy cultivation was almost the same in both practices but the cost of urea and pesticides was different. The main reason for this was that compared to the method of application of traditional urea, half urea was used in MV boro paddy cultivation using the method of the application of granular urea. So, the cost of urea was also less in the method of granular urea compared to traditional urea. Another reason may be that during the application of granular urea in paddy cultivation the soils moved more topsy-turvy than during the application of the method of traditional urea. As a result, the insects fly to other paddy fields. Therefore, it is assumed that based on this hypothetical concept the farmers used comparatively less amount of pesticides in MV boro paddy production using the method of the application of granular urea than the method of the application of traditional urea. Most probably this was also the reason for the requirement of comparatively more hired labour in the method of the application of granular urea than traditional urea in MV paddy production.

TABLE III

COSTS AND RETURNS OF PER HECTARE BORO PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea (Taka)	Normal urea (Taka)	Ratio
A. Variable costs of MV paddy production			
(i) Seedling cost	1873.6	1874.6	1.00
(ii) Irrigation cost	22888.7	22581.8	1.01
(iii) Pesticides cost	2416.9	3574.0	0.68
Chemical fertilisers			
(iv) Urea	3599.6	6425.0	0.56
(v) TSP	3082.6	3109.4	0.99
(vi) MP	1894.5	1682.9	1.13
(vii) Gypsum	663.2	637.9	1.04
(viii) Zinc	1593.2	1707.2	0.93
Labours			
(ix) Hired male labour	22679.1	19116.3	1.19
(x) Hired female labour	88.0	2488.1	0.04
B. Opportunity cost/Fixed cost			
(xi) Family supplied male labour	12660.5	11481.8	1.10
(xii) Family supplied female labour	2946.8	3205.5	0.92
(xiii) Opportunity cost of land	29,824.2	29,836.7	1.00
C. Total costs (variable and fixed costs) (A+B)	**106,211**	**107,721**	0.99
Revenue from paddy production			
(i) Paddy	131345.9	112453.8	1.17
(ii) By-product of paddy	11491.1	10494.5	1.09
D. Total revenue (i)+(ii)	**142,837**	**122,948**	0.86
E. Net profit (D-C)	**36,626**	**15,227**	0.42

Source: Field Survey, 2013.

Notes: (i) 1US$=83.60 Taka, May, 2013.
(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers.
(iii) Sample size was 100.

5.2 Per Hectare Return of MV 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 of granular urea compared to the method of application of traditional urea, the revenue was also higher in the practice of granular urea than traditional urea (Table III). As average total cost of per hectare boro paddy production was the same for the two adopted practices, net profit of per hectare MV boro paddy was also higher (2.41 times) in the method of application of granular urea than traditional urea.

Similarly, on an average the average total cost was almost the same in the case of MV aman paddy cultivation using both the method of application of granular and traditional urea (Table IV). However, the cost of urea and pesticides was comparatively less in the method of application of granular urea than the traditional urea like in the case of MV boro production. However, it is interesting to see that the per hectare production cost of aman paddy cultivation was higher than total revenue under the method of application of traditional urea. As a result, the net profit of per hectare aman paddy cultivation using traditional urea is negative, whereas net profit of per hectare aman paddy using granular urea is positive. In other words, in the study area the farmers earned positive and negative profit of the cultivation for per hectare MV aman paddy using the method of application of granular urea and the method of traditional urea respectively.

TABLE IV

COSTS AND RETURNS OF PER HECTARE AMAN PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea (Taka)	Normal urea (Taka)	Ratio
A. Variable costs of MV paddy production			
(i) Seedling cost	1437.2	1604.8	0.90
(ii) Irrigation cost	7758.0	6410.8	1.21
(iii) Pesticides cost	2239.5	2998.4	0.75
Chemical fertilisers			
(iv) Urea	2691.6	4954.2	0.54
(v) TSP	2269.1	2475.2	0.92
(vi) MP	1408.9	1356.9	1.04
(vii) Gypsum	601.4	379.6	1.58
(viii) Zinc	610.5	636.4	0.96

(Contd. Table IV)

Particulars	Granular urea (Taka)	Normal urea (Taka)	Ratio
Labours			
(ix) Hired male labour	22095.0	18547.5	1.19
(x) Hired female labour	49.8	3002.8	0.02
B. Opportunity costs/Fixed costs			
(xi) Family supplied male labour	13477.3	11436.8	1.18
(xii) Family supplied female labour	2490.7	3261.1	0.76
(xiii) Opportunity cost of land	28,333.0	28,344.9	1.00
C. Total costs (variable and fixed costs) (A+B)	**85,462**	**85,409**	1.00
Revenue from paddy production			
(i) Paddy	79280.0	71815.7	1.10
(ii) By-product of paddy	10866.7	10861.6	1.00
D. Total revenue (i)+(ii)	**90,146.8**	**82,677.3**	1.09
E. Net profit (D-C)	**4,684.8**	**-2,731.9**	-1.71

Source: Field Survey, 2013.
Notes: (i) 1US$=83.60 Taka, May, 2013.
(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers.
(iii) Sample size was 100.

VI. ESTIMATION OF HOUSEHOLD INCOME

6.1 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 fertilisers and labour. The gross return includes revenue from paddy grain and by-product straw. The calculation procedure of variable cost, fixed cost, labour cost, gross revenue and net profit are presented in Tables V and VI.

It can be seen from Tables V and VI that total cost, total revenue and net profit of MV boro cultivation using the method of application of granular urea and the method of traditional urea were taka 101,955, taka 111,277, taka 129,481, taka 120,076, taka 27,527 and taka 8,799 respectively. The net profit of MV boro paddy cultivation under the practice of granular urea was about three times higher than the traditional urea method.

TABLE V

COSTS AND RETURNS OF PER FARM BORO PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea (Taka)	Normal urea (Taka)	Ratio
A. Variable costs			
(i) Seedling cost	1,698.45	1,830.82	0.93
(ii) Irrigation cost	20,748.53	22,054.27	0.94
(iii) Pesticides cost	2,190.88	3,490.53	0.63
(iv) Land preparation	5,570.49	5,972.27	0.93
Chemical fertiliser cost			
(v) Urea	3,263.06	6,275.00	0.52
(vi) TSP	2,794.37	3,036.73	0.92
(vii) MP	1,717.34	1,643.59	1.04
(viii) Gypsum	601.23	623.05	0.96
(ix) Zinc	1,444.26	1,667.30	0.87
Hired labour cost			
(x) Hired male labour	20,558.55	18,669.74	1.10
(xi) Hired female labour	79.79	2,429.95	0.03
B. Opportunity cost/fixed cost			
(xii) Family supplied male labour	11,476.69	11,213.54	1.02
(xiii) Family supplied female labour	2,671.25	3,130.62	0.85
(xiv) Opportunity cost of land	27,140.00	29,240.00	0.93
C. Total cost (A+B)	**101,955**	**111,277**	0.92
D. Revenue from paddy production			
(i) Paddy	119,064.78	109,826.89	1.08
(ii) By-product of paddy	10,416.62	10,249.33	1.02
D. Total revenue	**129,481**	**120,076**	1.08
E. Net profit (D-C)	**27,527**	**8,799**	3.13

Source: Field Survey, 2013.

Notes: (i) 1US$=83.60 Taka, May, 2013.

(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers, respectively.

(iii) Sample size was 100.

The average total cost, average total revenue and average net profit of MV aman paddy cultivation using the two practices are shown in Table VI. The table shows that the total production cost was higher than the revenue generated from MV aman paddy cultivation in the case of both the methods of urea application. As a result, the net profit from the MV aman paddy cultivation was negative. This scenario is found everywhere in Bangladesh for MV paddy production simply due to higher input costs such as higher cost of labour and chemical fertilisers and lower output price.

TABLE VI
COSTS AND RETURNS OF PER FARM AMAN PADDY PRODUCTION UNDER TWO PRACTICES

Particulars	Granular urea	Normal urea	Ratio
A. Variable costs	(Taka)	(Taka)	
(i) Seedling cost	1,302.88	1,567.23	0.83
(ii) Irrigation cost	7,032.65	6,261.02	1.12
(iii) Pesticides cost	2,030.07	2,928.39	0.69
(iv) Land Preparation	5,234.63	5,797.56	0.90
Chemical fertilisers			
(v) Urea	2,439.80	4,838.44	0.50
(vi) TSP	2,056.94	2,417.34	0.85
(vii) MP	1,277.24	1,325.14	0.96
(viii) Gypsum	545.20	370.71	1.47
(ix) Zinc	553.40	622.04	0.89
Hired Labour cost			
(x) Hired male labour	20,029.15	18,114.18	1.11
(xi) Hired female labour	45.19	2,932.70	0.02
B. Opportunity cost / Fixed cost			
(xii) Family supplied male labour	12,217.14	10,860.00	1.12
(xiii) Family supplied female labour	2,257.78	3,184.89	0.71
(xiv) Opportunity cost of land	25,783	27,778	0.93
C. Total cost (A+B)	**82,805**	**88,998**	0.93
D. Revenue from paddy production			
(i) Paddy	71,867.19	70,138.08	1.02
(ii) By-product of paddy	9,850.66	10,607.84	0.93
D. Total revenue (taka)	**81,717.85**	**80,745.92**	1.01
E. Net profit (D-C)	**-1,087**	**-8,252**	0.13

Source: Field Survey, 2013.
Notes: (i) 1US$=83.60 Taka, May, 2013.
(ii) Average farm size was 0.98 ha and 0.91 ha for normal urea and granular urea users MV paddy producers, respectively
(iii) Sample size was 100.

6.2 Agricultural and Household Income of the Farmers using Two Different Methods

Components and their ratios of household income of the farmers who use granular and traditional urea for MV paddy cultivation are presented in Table VII. The table shows that agricultural income remains the principal source of income for the sampled households in the study villages who use granular and traditional urea. Farm income of farmers, who used granular urea, was more than three times higher than that of farmers who used traditional urea in the MV boro paddy cultivation. However, the farmers did not earn positive net profit from MV aman paddy cultivation in the case of both the methods. The off-farm income of farmers, who used granular urea, was more than eleven times higher than that of paddy farmers who used traditional urea. The main reason was that the farmers who used granular urea in paddy cultivation were engaged in various types of off-farm activities compared to the farmers who used traditional urea. However, the income from livestock and homestead gardening was almost the same for the farmers who used both the methods. Therefore, it can be concluded from the table that the farmers who used granular urea have gained more agricultural income and household income compared to the farmers who used traditional urea in MV paddy farming in the study area.

TABLE VII
HOUSEHOLD INCOME (TAKA) OF MV PADDY FARMERS

Sources of income	Granular urea	Normal urea	Ratio
(i) Profit/agricultural income (Boro paddy)	27,527	8,799	3.13
(ii) Profit/agricultural income (Aman paddy)	-1,087	-8,252	0.13
(iii) Opportunity cost of land	15,543	10,013	1.55
(a) Boro paddy production	27,140	29,240	0.93
(b) Aman paddy production	25,783	27,778	0.93
(iv) Opportunity cost of family labours			
(a) Male (Boro paddy)	11,477	11,214	1.02
(b) Female (Boro paddy)	2,671	3,131	0.85
(c) Male (Aman paddy)	12,217	10,860	1.12
(d) Female (Aman paddy)	2,258	3,185	0.71
(vi) Livestock	35,620	34,587	1.03
(vii) Off-farm income	22,975	2,038	11.27
(viii) Homestead gardening	6,627	6,764	0.98
Total household income	**188,750**	**139,357**	**1.35**

Source: Field survey, 2013.

VII. 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 granular urea and the traditional urea in the Cobb-Douglas production function, and marginal value product (MVP) and marginal factor cost (MFC) are briefly discussed in this section.

7.1 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 VIII. The inputs and outputs of MV paddy production under the practices of granular and traditional urea 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 granular and traditional urea was taka 118,810 and taka 110,171 respectively and it significantly varied among the farms. On the other hand, the average revenue per farm that used granular and traditional urea for MV aman paddy production was taka 71,268 and taka 68,858 respectively and it also significantly varied among the farms.

The mean farm size (X_1) of the farm that applied granular urea and traditional urea was 0.91 and 0.98 hectare respectively, and it significantly varied among the farms. The mean seed cost (X_2) per farm for boro and aman paddy cultivation was almost same in both practices and widely varied among the farms. The mean land preparation cost (X_3) of MV boro and aman 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 the same modes of cultivator (power tiller) for plowing the paddy fields.

TABLE VIII

SUMMARY STATISTICS OF THE SAMPLED VARIABLES IN MV BORO AND AMAN PADDY PRODUCTION

Name of variables		Granular urea using MV paddy production farm				Normal urea using MV paddy production farm			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Paddy grain (taka) (Y)	Boro	118810.3***	63572.8	31387.5	324000	110171.5***	85977.3	30800	799250
	Aman	71268.24***	37347.2	9660.0	181475	68858.3***	48989.3	20400	450000
Area (hectare) (X_1)	Boro	0.91***	0.49	0.20	2.40	0.98***	0.72	0.27	6.68
	Aman	0.91***	0.49	0.20	2.40	0.98***	0.72	0.27	6.68
Seed (taka) (X_2)	Boro	1598.4***	1255.4	400	7000	1616.5***	1215.0	360	10000
	Aman	1305***	708.8	0	3600	1485.5***	1104.0	400	10000
Land preparation (taka) (X_3)	Boro	5550***	3010.6	1200	15300	5923***	4361.4	1500	40000
	Aman	5136.3***	2734.2	975	15300	5603.6***	3570.8	1500	30000
Pesticide cost (taka) (X_4)	Boro	2291.1***	2096.2	300	12000	3529.3***	3507.6	800	30000
	Aman	2087.1***	1682.5	225	9000	2859.9***	2177.7	500	15000
Irrigation cost (taka) (X_5)	Boro	20689.5***	12616.0	4800	63000	23008***	21055.4	4800	190000
	Aman	6929***	6207.5	450	50000	6391.5***	5920.2	1000	55000
Urea (taka) (X_6)	Boro	3255.7***	1765.2	825	9350	6274.3***	4335.4	1440	33000
	Aman	2497.7***	1376.7	132	6732	4589.9***	2660.7	800	19800
Other fertiliser (taka) (X_7)	Boro	7747.3***	4603.3	1720	28390	9254.5***	7896.4	1978	73800
	Aman	4527.2***	2599.1	560	12988	5020***	3983.2	1264	37600
Labour cost (taka) (X_8)	Boro	35986.8***	21702.4	8325	110700	36379***	24929.0	7700	207500
	Aman	37386.5***	26159.9	5451	149073	35978.5***	24853.8	8400	215000

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

Chemical fertilisers such as urea, TSP, MP, gypsum and Zn are also the main inputs of MV paddy production. As the present study estimates the impact of granular urea on MV paddy cultivation, that is why we have separated the cost of urea from the costs of other chemical fertilisers-TSP, MP, gypsum and Zn. The mean cost of urea (X_6) was significantly smaller in the MV boro and aman paddy cultivation under the practice of granular urea than the traditional urea and a wide variation exists among the farms. The main reason was that comparatively small amount of granular urea than traditional urea is required to produce MV paddy. The mean cost of other fertilisers (X_7) was also smaller in MV paddy cultivation under the method of granular urea than traditional urea.

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

7.2 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 granular urea and traditional normal urea are presented in Table IX.

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 0.99 and 1.02, which were close to unity, indicating that both the farmers had experienced constant return to scale in MV boro paddy farms using the method of application of granular urea and traditional urea 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 application of granular (0.98) and traditional urea (0.97) in the production process respectively and they were statistically significant at 1 per cent level.

The coefficients of farm area (1.056), seed cost (0.096) and land preparation (0.189) were positive and statistically significant at 1 per cent level, whereas the coefficient of labour was also positive but it was statistically significant at 10 per cent level for MV boro paddy production under the method of application of granular urea. This indicates that farm area, seed cost and land preparation and labour cost were the main factors that affect significantly the MV boro paddy production under the method of application of granular urea. However, the coefficient of cost of granular urea was negative (-0.559) and statistically significant at 5 per cent level, which indicated that the granular urea also had significant impact on MV boro paddy cultivation. In other words, the farmers were able to produce the same level of paddy grain output with the application of less amount of granular urea in MV boro paddy cultivation. The coefficients of the cost of irrigation (0.041) and other chemical fertilisers (0.084) were positive and the cost of pesticides (-0.006) was negative and they were statistically insignificant in the MV boro paddy cultivation.

On the other hand, the coefficients of farm size (0.823) and the cost of other chemical fertilisers (0.168) were positive and statistically significant at 1 per cent level and the cost of traditional urea (0.38) was also positive but statistically significant at 5 per cent level under the method of application of traditional urea in MV boro paddy cultivation. These imply that the farmland, cost of traditional urea and other chemical fertiliser had significant positive impact on MV boro paddy under the application of traditional urea in MV boro paddy cultivation. The coefficients of the cost of seed (0.084) and land preparation (0.028) were positive and the cost of pesticides (-0.015), irrigation (-0.024) and labour (-0.082) were negative and they were all statistically insignificant in the application of traditional urea in MV boro paddy cultivation in the study area.

TABLE IX

ESTIMATED VALUE OF CO-EFFICIENTS AND RELATED STATISTICS OF COBB-DOUGLAS PRODUCTION MODEL FOR GRANULAR AND NORMAL UREA USAGE OF BORO PADDY PRODUCTION

Name of variables	Granular urea use			Normal urea use		
	Coefficients	Standard error	t-ratio	Coefficients	Standard error	t-ratio
Constant	11.936***	1.999	5.97	10.291***	1.122	9.17
Area (ha) (X_1)	1.056***	0.238	4.44	0.823***	0.121	6.79
Seed cost (X_2)	0.096***	0.024	4.02	0.084	0.059	1.42
Land preparation cost (X_3)	0.189***	0.081	2.33	0.028	0.060	0.46
Pesticide cost (X_4)	-0.006	0.021	-0.29	-0.015	0.025	-0.61
Irrigation cost (X_5)	0.0410	0.036	1.14	-0.024	0.037	-0.63
Urea cost (X_6)	-0.559**	0.273	-2.05	0.038**	0.021	1.90
Other fertiliser cost (X_7)	0.084	0.095	0.88	0.168***	0.060	2.80
Labour cost (X_8)	0.089*	0.054	1.65	-0.082	0.070	-1.16
Sum of elasticities β_i	0.99			1.02		
R^2	0.98***			0.97***		

Notes: (i) ***, ** and * indicate statistically significant at 1%, 5% and 10% respectively.
(ii) Sample size was 100.

The empirical results of the Cobb-Douglas production function of MV aman paddy cultivation under the method of application of granular urea and traditional urea are presented in Table X. It appeared from the table that the sum of the elasticity values of MV aman paddy production was 0.97 and 0.94, which were less than unity, indicating that both the farmers have experienced decreasing return to scale in MV aman paddy farms using the method of application of granular urea and traditional urea in the study village. 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 application of granular (0.97) and traditional urea (0.97) in the production process, respectively and they were statistically significant at 1 per cent level.

The coefficient of farm size was 0.762 and it was statistically significant at 1 per cent level, which indicates that the farmland had significant positive impact on MV aman paddy production under the method of application of granular urea in paddy cultivation. However, the coefficients of major inputs such as cost of land preparation (-0.112), irrigation (-0.058), granular urea (-0.33) and other chemical fertilisers (-0.123) were negative and they were statistically significant at 1 per cent level except the cost of land preparation (significant at 10 per cent level). The negative coefficients indicated that the farmers had expensed the excessive money for land preparation, irrigation, granular and other chemical fertilisers in MV aman paddy under the method of application of granular urea. The farmers could produce the same amount of MV aman paddy grain with the application of less amount of granular urea like MV boro paddy cultivation in the study area. The coefficients of the cost of seed (-0.132) and pesticides (-0.010) were negative and labour cost (0.066) was positive and they were not statistically significant in the MV aman paddy cultivation under the method of application of granular urea.

TABLE X

ESTIMATED VALUE OF CO-EFFICIENTS AND RELATED STATISTICS OF COBB-DOUGLAS PRODUCTION MODEL FOR GRANULAR AND NORMAL UREA USAGE OF AMAN PADDY PRODUCTION

Name of variables	Granular urea use			Normal urea use		
	Coefficients	Standard error	t-ratio	Coefficients	Standard error	t-ratio
Constant	9.427***	1.260	7.48	11.345	1.194	9.50
Area (ha) (X_1)	0.762***	0.161	4.73	0.927***	0.127	7.25
Seed cost (X_2)	-0.132	0.137	-0.96	0.057	0.056	1.03
Land preparation cost (X_3)	-0.112*	0.061	-1.84	0.194***	0.062	3.11
Pesticide cost (X_4)	-0.01	0.026	-0.38	-0.045*	0.024	-1.85
Irrigation cost (X_5)	'-0.058***	0.024	-2.4	-0.042	0.032	-1.32
Urea cost (X_6)	0.330***	0.081	4.09	-0.161***	0.049	-3.30
Other fertiliser cost (X_7)	0.123***	0.032	3.8	0.159***	0.052	3.04
Labour cost (X_8)	0.066	0.050	1.33	-0.148**	0.076	-1.93
Sum of elasticities β_i	0.969			0.941		
R^2	0.97***			0.97***		

Notes: (i) ***, ** and * indicate statistically significant at 1%, 5% and 10% respectively.
(ii) Sample size was 100.

On the other hand, the coefficients of farm size (0.927), cost of land preparation (0.194) and the cost of other chemical fertilisers (0.159) were positive and statistically significant at 1 per cent level under the method of application of traditional urea in MV aman paddy cultivation. These imply that the farmland, cost of land preparation and other chemical fertilisers had significant positive impact on MV aman paddy under the application of traditional urea in MV aman paddy cultivation. However, the coefficients of the pesticides (-0.045), irrigation (-0.042), normal urea (-0.161) and labour (-0.148) were negative and they all were statistically significant at 1 per cent level except pesticide cost (significant at 10 per cent level) in the application of traditional urea in MV aman paddy cultivation in the study area. The coefficient of seed cost (0.057) was positive and statistically insignificant in the MV aman production.

7.3 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 the method of application of the granular urea and the traditional urea in MV boro and aman 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 and aman paddy cultivation under the method of application of granular urea and the traditional urea are presented in Tables XI and XII. The figures in Tables XI and XII 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 method of application of granular and traditional urea used for MV boro and aman paddy cultivation.

In the case of farmer's who use granular urea, the ratios of MVP to MFC for the costs of seed (7.671), land preparation (4.044), and other chemical fertilisers (1.303) were positive and greater than unity and they were statistically significant at 1 per cent level except other chemical fertilisers. These indicated that the farmer's who used granular urea did not utilise the opportunity of fully using the inputs in MV boro and aman paddy cultivation. So, there were ample opportunities for the farmers to increase production by using more of these inputs. The ratio of irrigation cost (0.242) and labour cost (0.303; significant at 10 per cent level) were positive but less than one in the case of farmers who used granular urea, which indicates that there was no further opportunity to increase paddy production using more irrigation and labour. However, the ratio of granular urea (significant at 1 per cent level) was negative and greater than one, which indicates that the farmers who used granular urea (-0.20.332) applied significantly excessive granular urea and pesticide (-0.378) for MV boro paddy cultivation.

On the other hand, in the case of the farmers who used traditional urea, the ratio of MVP to MFC for the cost of seed (5.819) and other chemical fertilisers (2.041, significant at 1 per cent level) was positive and greater than unity, while the ratios of land preparation (0.18), pesticides (-0.520), irrigation (-0.124) and normal urea (0.678; significant at 5 per cent level) were smaller than unity. These implied that the farmers who used traditional normal urea had small opportunity to increase MV boro paddy production using more seed and other chemical fertilisers. In the case of traditional normal user farmers applied much normal urea in MV boro paddy cultivation.

TABLE XI

RESOURCE USE EFFICIENCY IN COBB-DOUGLAS PRODUCTION FOR BOTH GRANULAR AND NORMAL UREA USE IN BORO PADDY CULTIVATION

Name of variables	Granular urea			Normal urea		
	Coefficients	MPV	MVP/MFC	Coefficients	MPV	MVP/ MFC
Seed cost (X_2)	0.096	7.671***	7.671	0.084	5.819	5.819
Land preparation cost (X_3)	0.189	4.044***	4.044	0.028	0.518	0.518
Pesticide cost (X_4)	-0.006	-0.378	-0.378	-0.015	-0.520	-0.520
Irrigation cost (X_5)	0.04	0.242	0.242	-0.024	-0.124	-0.124
Urea cost (X_6)	-0.559	-20.332**	-20.333	0.038	0.678**	0.678
Other fertiliser cost (X_7)	0.084	1.303	1.303	0.168	2.041***	2.041
Labour cost (X_8)	0.09	0.303*	0.303	-0.082	-0.250	-0.250

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

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

The ratios of MVP to MFC for MV aman paddy cultivation under the method of the application of granular and traditional normal urea are presented in Table XII. In the case of granular urea user farmers for MV aman paddy cultivation, the ratios of granular urea (9.584) and other chemical fertilisers (1.995) were positive and greater than unity and they were statistically significant at 1 per cent level, indicating that the farmers had ample opportunity to increase MV aman paddy production to increase these inputs in cultivation in the study area. On the other hand, the ratios of seed (-7.167) and land preparation (-1.551; significant at 10 per cent level) were negative but greater than unity which indicated that excessive use of these inputs had gone beyond the economic optima. In other words, the farmers who used granular urea could produce same level of output of MV aman paddy using fewer amounts of these inputs. The ratios of pesticide cost (-0.389) and irrigation cost (-0.677) were negative, while it was positive for labour cost (0.134), which indicated that there were no greater opportunity of increasing production by increasing more or less use of pesticides, irrigation and labour inputs in MV aman paddy production in the study area.

On the other hand, in the case of farmers who use traditional urea in MV aman paddy cultivation, the ratios of MVP to MFC for the seed cost (2.684), land preparation cost (2.381; significant at 1 per cent level) and other chemical fertilizers cost (2.223; significant at 1 per cent level) were positive and greater than unity, which indicated that the farmers used excessive amount of these inputs in MV aman paddy cultivation. On the other hand, the ratios of pesticide costs (-0.174) and urea cost (-2.412) were negative but greater than unity, which indicated that the farmers had an opportunity to use fewer amount of these inputs to get maximum output of MV aman paddy cultivation. The ratios of irrigation (-0.490) and labour cost (-0.288; significant at 5 per cent) were negative but less than unity. This implied that the farmers had no ample opportunity to reduce these inputs to maintain the same level of MV aman paddy production.

Therefore, it may be concluded that the farmers did not efficiently and optimally use the input resources in both the methods of application of the granular urea and the traditional urea in MV boro and aman paddy cultivation and this hindered the generation of maximum level of output of paddy grain in the study area.

TABLE XII

RESOURCE USE EFFICIENCY IN COBB-DOUGLAS PRODUCTION FOR BOTH GRANULAR AND NORMAL UREA USE IN AMAN PADDY CULTIVATION

Name of variables	Granular urea			Normal urea		
	Coefficients	MPV	MVP/ MFC	Coefficients	MPV	MVP/MFC
Seed cost (X_2)	-0.132	-7.166	-7.166	0.057	2.684	2.684
Land preparation cost (X_3)	-0.112	-1.551*	-1.551	0.194	2.381***	2.381
Pesticide cost (X_4)	-0.010	-0.389	-0.389	-0.045	-1.174*	-1.174
Irrigation cost (X_5)	-0.058	-0.677***	-0.677	-0.042	-0.490	-0.490
Urea cost (X_6)	0.33000	9.584***	9.584	-0.161	-2.412***	-2.412
Other fertiliser cost (X_7)	0.123	1.995***	1.995	0.159	2.223***	2.223
Labour cost (X_8)	0.066	0.134	0.134	-0.148	-0.288**	-0.288

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

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

VIII. 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. Granular urea is one such trial and error technique of modified urea that is being used recently in MV paddy cultivation in Bangladesh. Cobb-Douglas production function was used to estimate the contribution of scarce inputs such as farmland, seed, irrigation, pesticides, land preparation, labour, urea and other chemical fertilisers on MV paddy production. The ratio of marginal value products (MVP) to marginal factor cost (MFC) was used to test the resource use efficiency in MV paddy production. Moreover, to determine the impacts of granular urea on MV boro and aman paddy cultivation, two types of farmers were chosen who used completely modified granular urea and traditional urea in MV paddy production.

The findings of the study indicated that the farmers used half of the granular urea compared to traditional urea in per hectare MV paddy cultivation. However, other chemical fertilisers such as triple super phosphate (TSP), murate of potash (MP), zypsum and zinc were used in more or less similar proportions in per hectare of MV paddy cultivation. The amount of chemical fertiliser used in paddy production per hectare of MV paddy cultivation also varied significantly within the same farming system. The farmers used comparatively more temporarily hired and family supplied male labour in both per hectare of MV boro and aman paddy cultivation that used granular urea instead of traditional urea. The main reason was that the application of granular urea is a labour-intensive technology compared to the application of top dressing traditional urea in MV paddy cultivation. However, on an average, the yield (production per hectare) of MV boro and aman was significantly higher in the method of the application of granular urea than in the method of traditional urea.

Per hectare as well as per farm production cost of MV boro and aman paddy cultivation was significantly lower in the case of the application of granular urea technique than the application of traditional urea method. As yield of MV boro and aman paddy was significantly higher in farms that used granular instead of traditional normal urea, the revenue as well as net profit was also higher for the farmers who used granular urea instead of traditional urea. The study also found that the farmers who used granular urea earned household income that is more than three times higher than the farmers who used traditional urea in MV boro and aman paddy cultivation in the study area.

The results of the Cobb-Douglas production function found that granular urea had significant negative impact on boro while positive impact on aman paddy production. On the other hand, traditional urea had significant positive impact on boro and negative impact on aman paddy cultivation in the study area. These results indicated that the farmers could produce the same level of output (paddy grain) from MV boro paddy cultivation using comparatively fewer amount of granular urea that was not possible using traditional urea. Therefore, it may be concluded that the granular urea 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 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 application of the granular urea and the traditional urea in MV boro and aman paddy cultivation and this hindered the generation of maximum level of output of paddy grain in the study area.

Therefore, if government takes the initiatives to increase the availability of granular urea 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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