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TECHNICAL EFFICIENCY OF MUSTARD PRODUCTION IN JAMALPUR DISTRICT

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ABSTRACT

Present study was undertaken to determine the level of technical efficiency and analyse the status of resource allocation for mustard production in Jamalpur districts. The Cobb-Douglas stochastic production frontier model was used to analyse the data. The study revealed that cultivation of mustard is profitable but not at satisfactory level. By cultivating *Tory-7* variety of mustard, net return was only Tk 1,516/-, and gross margin was only Tk 4,516/- per hectare. The benefit cost ratio (BCR) was 1.11 for mustard. All of the farmers were found to have produced outputs with their mean technical efficiency was 80% (efficiency levels varying from 20% to 97%). On average, 20% technical inefficiency appears, which implies that the output per farm can be increased on average by 20% for mustard production under the prevailing technology (with *Tory-7* variety) without incurring any additional production costs. Side by side advanced technology (high yielding variety) could be adapted to increase production of this oil crop.

Key Words: Efficiency, Resource allocation, Cobb-Douglas production function, Problem of mustard production

INTRODUCTION

The shortage of edible oil has been prevailing in Bangladesh for a long time. The country faces a deficit in edible oil production by about 70%. Among the oil crops, rapeseed and mustard (*Brassica spp.*) which commonly use the term 'mustard' are important for Bangladesh. It tops the list in respect of area and production among the oil crops grown in the country. Although mustard is the principal oil crop in Bangladesh but its cultivation is very neglected. Total production and per hectare seed yield of mustard may be increase by applying improved production technology.

Mustard is one of the most important crop in Jamalpur district and also equally important for Bangladesh. Farmers cultivate it with their innovative ideas on variety, fertilizer dose and agronomic practices.

The measurement of the productive efficiency in agricultural production is an important issue from the standpoint of agricultural development exercise in developing countries since it gives pertinent information useful for making sound management decision in resource allocation and for formulating agricultural policies.

Except for a few descriptive studies, no econometric analysis has yet been conducted to examine the production function for mustard cultivation and its potential for future improvement. Similarly, there is a lack of information about the efficient use of inputs in mustard production. Considering the above facts, the present study is an attempt to examine the technical efficiency of production of mustard.

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Objectives

- (i) To determine the level of technical efficiency of the mustard producing farmers,
- (ii) To determine the status of resource allocation, and
- (iii) To assess the problems of mustard production

MATERIALS AND METHODS

Jamalpur district was selected, as it is one of the important mustard growing area. Six villages namely Kampapur, Langalzora and Horipur from Sadar Thana, and Shahpara, Morakandi and Morabon, from Islampur Thana of Jamalpur districts were selected, where this crop was cultivated extensively. A total of 105 mustard growers were selected. Simple random sampling technique was used to select the farmers. Data were collected by visiting each farm personally and by interviewing them with the help of a pretested interview schedule. Data also collected from the scientist of Regional Agricultural Research Station who works with oilseeds. The reference period for the survey was 2005-06.

Analytical Framework

The Stochastic Production Frontier and Technical Inefficiency Model

Following the standard assumption that farmers maximize expected profits (Zellner *et al.* 1966), a single equation stochastic frontier function for the cross-sectional data can be defined as:

$Y_i=f(X_i;\beta)\exp(V_i-U_i)$ ....(1)

Where Y_i denotes the production of the i-th sample ($i = 1,2,\ldots\ldots,n$); X_i is a (1xk) vector of functions of input quantities used by i-th farm; β is a (kx1) vector parameters to be estimated; V_is are assumed to be independently and identically distributed $N(0,\sigma v^2)$ random errors, independent of the U_is. U_is are non-negative random variables, associated with technical efficiency in production, which are assumed to be independently and identically distributed and truncated (at zero) of the normal distribution with zero mean.

According to Battese and Coelli (1995), the technical inefficiency effects, U_i in equation (1) could be expressed as:

$U_i = Z_i\,\delta + W_i$ ....(2)

where W_i s are random variables, defined by the truncation of the normal distribution with zero mean and variance, $\sigma^2_{u,}$ such that point of truncation by $-Zi\delta$, i.e., $W_i \geq Z_i\delta$

Besides the farm-specific variables, the Z-variable in equation (2) may also include input variables in the stochastic production frontier (1), provided that the inefficiency effects are stochastic. If Z-variables also include interactions between farm-specific and input variables, then the Huang and Lui (1994) non-neutral stochastic frontier is obtained.

The technical efficiency of the ith sample firm, denoted by TE_i, is given as:

$TE_i -\exp(-U) = Y_i / \{f(X_i;\beta)\exp(V_i)\}$..............................(3)

where $f(X_i;\beta)\exp(V_i)$ is the stochastic frontier production. The prediction of technical efficiencies is based on the conditional expectation of the expression (3), given by the model specifications (Battese and Coelli 1988).

Parameter V represents the symmetric error term form and u represents the one-sided error component. In the stochastic production function f(X)exp (V), V has a symmetric distribution to capture the random effects of measurement error and exogenous shocks, which cause the placement of the deterministic kernel f(X) to vary across firms. Technical inefficiency relative to the stochastic production frontier is then captured by the one-sided error component exp (-U), U≥0. The condition U≥0 ensures that all observations lie below the stochastic production frontier. Unfortunately, there is no way of determining whether the observed performance of a particular observation compared with the deterministic kernel of the frontier is due to inefficiency or to random variation in the frontier. This constitutes the main weakness of the stochastic frontier model. It is not possible to decompose individual residuals into their two components, and so it is not possible to estimate technical inefficiency by observation. The best that one can do is to obtain an estimate of mean efficiency over the sample.

Empirical Model of Stochastic Frontier

In order to estimate the level of technical efficiency in a manner consistent with the theory of production function, Cobb-Douglas type stochastic frontier production function was used in the present study.

The Cobb-Douglas form of production function has some well-known properties that justify its wide application in economic literature. It is a homogeneous function that provides a scale factor enabling one to measure the return to scale and to interpret the elasticity coefficients with relative ease. It is also easy to estimate and mathematically manipulate. At the same time, the Cobb-Douglas production function makes several restrictive assumptions. It is assumed that the elasticity coefficients are constant, implying constant share for the inputs. The elasticity of substitution among factors is unity in the Cobb-Douglas form. Moreover, this being linear in logarithm, output is zero if any of the inputs is zero, and output expansion path is assumed to pass through the origin. However, it is also argued that if interest rests on efficiency measurements and not on an analysis of the general structure of the underlying production technology, the Cobb-Douglas specification provides an adequate representation of the production technology. In addition, its simplicity and widespread use in agricultural economics outweigh its drawbacks. Translog stochastic production function is also used to estimate the significant relation of different variables which in turn affects the level of efficiency. Translog function is a flexible functional form. But it is more difficult to mathematically manipulate and can suffer from degree of freedom and multicollinearity problems (Rahman, 2002) However, large sample size is needed for Translog functional form. Total sample size of the present study was 80, which may be considered not large enough for Translog functional form.

In consideration of the above fact, Cobb-Douglas type functional form had been tried in this study.

The Cobb-Douglas stochastic production frontier model can be specified as:

$$\mathrm{Ln}y_i = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \varepsilon_i \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

All lower case variables are defined in natural logs. The subscripts i refers to the ith observation where i = 1,2,3, ...n (farms).

y_i : production of mustard; x_i : inputs use in mustard cultivation and $\varepsilon_i = (v_i\text{-}u_i)$ is a composite error, where $v_i \sim$ i.i.d. N $(0,\sigma^2)$ and $/u_i/ \sim$ i.i.d. N (μ,σ^2). The technical efficiency $TE_i = (u_i)$ of the ith firm is a non-negative random variable and follows a normal distribution truncated at zero. The mean technical efficiency input is output variable and Xs are input related variables, defined previously; and the technical inefficiency effects, μ_i is given by the efficiency model in equation (5).

$$\mu_i = \delta_0 + \sum_{i=1}^{3} \delta_i z_i \quad \text{...(5)}$$

The efficiency-effects are proxies by Zs, which are farm specific variables and δ_0 is unknown parameters to be estimated.

The parameters for the stochastic production frontier model and those for the technical inefficiency model would be estimated simultaneously using the maximum likelihood estimation (MLE) method by Frontier 4.1 program, which estimates the variance parameters of the likelihood function.

RESULTS AND DISCUSSION

Sample Characteristics

The characteristics of 105 farms are shown in Table 1. Average total own land was 0.77 hectares, net cultivated land 0.75 hectares and area under mustard was 0.16 hectare. Major cropping patterns followed in mustard land were Fellow - *Tori7* - BR 28/29/8/16/30/HB (65%) and *Pajam* - *Tori-7*- BR-28/16/29 (25%). Soil is mainly clay to loam. Sowing started from last week of October and continued up to 3rd week of November. Harvesting started from last January and ended in mid February.

Table 1. Summary data on sample characteristics

Average total own land (ha)	0.77
Average net cultivated land (ha)	0.75
Average area under mustard (ha)	0.16
Cropping pattern in mustard land: (i) Fellow-Tori7-BR 28/29/8/16/30/HB : (ii) Pajam-Tori-7-BR-28/16/29 : (iii)BR11-Tori 7-BR 28/26 : (iv)Other(BR12/8/Daincha/Jute/Local))-Tori-7-BR-28/16/29 :	 65% 25% 5% 5%
Land type: (i) High : (ii) Medium high : (iii) Medium :	 9% 59% 32%
Soil type (i) Clay : (ii) Clay Loam : (iii) Loam :	 1% 97% 2%
Transplanting	4th week October to 3rd week of November
Harvesting	4th week January to 2nd week of February

Input Use

Data presented in Table 2 shows the input use for cultivation of mustard in one hectare of land. Power tiller with 1 to 3 ploughing did land preparation. The average power tiller cost was Tk 2915. The average human labour required in one hectare of land was 43 man-days of which 26 percent was provided from the farmers' own family. They used seed at the rate of 13 kg per hectare.

Table 2. Use of different inputs to cultivate mustard per hectare of land

Particulars	Mustard (*Tori-7*)		
	Own	**Hired**	**Total**
Power tiller (Tk)	-	2915	2915
Human labour (man-days)	11	32	43
Seed (kg)	8	5	13
Fertilizer			
Urea (kg)	-	202	202
TSP (kg)	-	17	17
MP (kg)	-	42	42
Gypsum (kg)	-	2	2
DAP (kg)	-	109	109

Farmers did not used any manure in mustard field On average, in one hectare of land 202 kg of Urea, 17 kg of TSP, 42 kg of MP, 2 kg of Gypsum and 109 kg DAP were used by the farmers. That is farmers used N, P, K and S at the rate of 115 kg, 25kg, 21 kg and 1 kg per hectare in their mustard field. Their use of N (Urea) was much higher than the recommended dose, but did not use any Zn or B. For Tori-7 variety, the doses of N, P, K, S, Zn and B were 63 kg, 19 kg, 33 kg, 21 kg, 2.1 kg and 0.4 kg per hectare, respectively (BARC 1997, p. 61). Farmers used 38% of Urea and all other fertilizer as basal. They used remaining Urea (59%) as first top dress after 15 to 21 days of sowing and some of them used second top dress (3% Urea) after 30 days of sowing. They did not spend any money for controlling pest and insect.

Cost and Return

For *Tori-7* variety of mustard average total variable cost of production and total cost of production per hectare of land were Tk 10,742/- and Tk 13,742/-, respectively (Table 3).

Table 3. Cost and return for cultivating mustard in per hectare of land

Particulars	All		
	Own	**Hired**	**Total**
Power tiller (Tk)	-	2915	2915
Human labour (Tk)	692	1981	2673
Seed (Tk)	235	155	390
Fertilizer	-		
Urea (kg)	-	1239	1239
TSP (kg)	-	305	305
MP (kg)	-	593	593
Gypsum (kg)	-	8	8
DAP (kg)	-	2498	2498
Int. on op. capital (Tk)			121
Total variable Cost (Tk)			10742
Rental value of land (Tk)			3000
Total cost (Tk)			13742
Gross yield (kg)			856
Av. Price of mustard (Tk/kg)			16.54
Return from mustard (Tk/ha)			14162
By-Product (kg)			1095
Av. Price of by-product (Tk/kg)			1.00
Return from by-product (Tk/ha)			1095
Gross return (Tk)			15258
Gross margin (Tk)			4516
Net return (Tk)			1516
BCR			1.11
BCR (TVC basis)			1.42

The total yield of mustard seed was 856 kg per hectare and by-product was 1,095 kg. The gross return was Tk 15,258/-. For cultivating *Tori-7* variety of mustard in one hectare of land, gross margin obtained was only Tk 4,516/- and the net return or profit was Tk 1,516/-, and undiscounted benefit cost ratio (BCR) was 1.11.

Reasons to cultivate Tori-7 variety of mustard

All of the farmers told that they cultivate only *Tori-7* variety because they have no alternative to this variety. Variety other than *Tori-7* does not permit boro cultivation timely. *Boro* is their most preferred crop. Along with this reason 70 per cent farmers also reported that they have no idea about short duration high yielding varieties of mustard and 30 per cent reported that seed is not available for short duration mustard variety other than *Tori-7* (Table 4).

Table 4. Reasons to cultivate Tori-7 variety of mustard

Reasons	Per cent of farmer respond
(a) Variety other than Tori-7 does not permit boro cultivation timely. Boro is their most preferred crop.	100
(b) No idea about short duration high yielding variety of mustard.	70
(c) Seed is not available for short duration mustard variety other than Tori-7.	30

Problems to cultivate mustard

According to the farmers' opinion, lack of short duration high yielding varieties of mustard is their major problem. After that they mentioned lack of knowledge about modern cultivation technique and mustard cultivation is not possible due to timely *boro* cultivation, which is their preferred crop (Table 5).

Table 5 Problems to cultivate mustard

Problems	Per cent of farmer respond
(a) Lack of short duration high yielding variety of mustard	100
(b) Mustard cultivation is not possible due to timely boro cultivation, which is their preferred crop.	12
(c) Lack of knowledge about modern cultivation technique.	36

Yield Differences with Experimental Plot

Currently, no short duration variety is available like farmers' *Tori-7* (72 to 76 days). Short duration high yielding varieties take more 4/5 days than farmers' *Tori-7*, but farmers do not want to sacrifice this only 4/5 days as they prefer *boro* rice too much. Actually delayed *boro* planting by this 4/5 days will not affect much in *boro's* yield. Farmers do not spray any insecticide or pesticide in their mustard field, as a result forced maturity is occurred with the infestation of insect and pest.Per hectare yield of Nap-0519, Nap-0567, Nap-0559, Nap-0538 and Nap-0545 were 1999, 1925, 1851, 1629 and 1629 ton, respectively (Fig. 1)

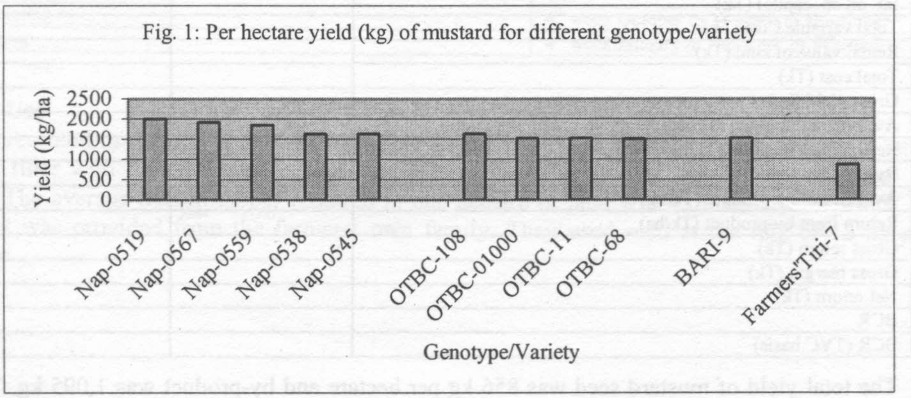


Fig. 1: Per hectare yield (kg) of mustard for different genotype/variety

Though yield of B. napus in experimental field is more than double compare to *Tori-7* of farmers' field, farmers do not prefer napus. Reasons behind that are shattering problem of napus, black colour of seed for which market price is low and napus is very much sensitive to boron, and seed will not be form in boron deficient field. In *B campestris* group where *Tori-7* also included, shattering problem, black colour of seed, boron sensitivity problem like napus group is not present. But it also takes more 4/5 days than farmers' *Tori-7*, which create problem for adoption. Unavailability of seed in the market is the major problem for the mustard variety (BARI-9, BARI-12 and TS-12) of *B campestris* group. Per hectare yield were 1629, 1518, 1516, 1502 and 1521 kg for genotypes OTBC-108, OTBC-01000, OTBC-11, OTBC-68 and BARI-9, respectively in regional yield trial at RARS, Jamalpur. Strong extension work is needed for the adoption of the variety like BARI-9.

Maximum-likelihood estimates of the Cobb-Douglas production function

The maximum-likelihood estimates for parameters of the Cobb-Douglas stochastic production frontier model and those in the technical inefficiency model for mustard are presented in Table 6. All of the slope coefficients or output elasticities of inputs were positive and most of the parameters were statistically significant. Human labour, power tiller cost and fertilizer were found to act as important factors and had positive impact on mustard production. The coefficients associated with human labour and fertilizer was found to be highly significant, coefficient of power tiller cost was found significant and this associated with seed was not significant. In this study, output elasticity of inputs was the highest for human labour (0.249), followed by fertilizer ((0.182) and power tiller (0.097). Sum of the quantity of Urea, TSP, MP, Gypsum and DAP was taken as the variable fertilizer. By taking Urea, TSP, MP, Gypsum and DAP as individual variables, multicollinearity problem arose among these variables.

Table 6. Maximum-likelihood estimates for the Cobb-Douglas production function of mustard cultivation

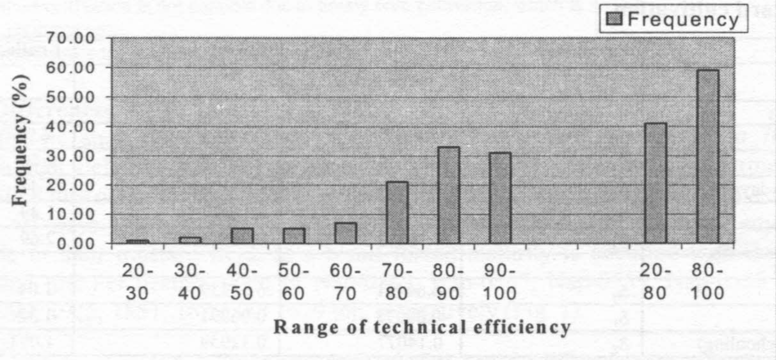
Variable	Parameter	Coefficient	Std.-error	t-ratio
Stochastic Frontier:				
Constant	β_0	3.78177	0.54616	6.92
Power tiller (Tk/ha)	β_1	0.09659	0.03718	2.60
Human labour (man-days/ha)	β_2	0.24889	0.07228	3.44
Seed (kg/ha)	β_3	0.16842	0.11312	1.49
Fertilizer (kg/ha)	β_4	0.18225	0.06776	2.69
Inefficiency Model:				
Constant	δ_0	-6.64481	6.38239	-1.04
Age (years)	δ_1	-0.09078	0.06891	-1.32
Education (year of schooling)	δ_2	0.14077	0.12939	1.09
Variance Parameters:				
Sigma-Sq.	σ^2	2.59101	2.10158	1.23
Gamma	γ	0.99699	0.00264	376.76
Log-likelihood		9.05		
LR test of the one-sided error		42.71		
Mean efficiency	μ_i	0.80		
Minimum Efficiency		0.20		
Maximum Efficiency		0.97		

The estimated δ-coefficient in Table 6 associated with the explanatory variables in the model for the inefficiency effects are worthy of particular discussion. It was observed that education of the farmers had not significant effect upon the inefficiency effects for mustard production. The sign of the coefficients of age of the farmers is negative, but not significant.

An important result for the present study from Table 6 is that the variance ratio parameter γ is quite high and strongly significant. This implies that about 100 per cent of the difference between the observed output and the maximum production frontier output is caused by differences in farmers' levels of technical efficiency as opposed to the conventional random variability. The magnitude and significance of the estimate for the variance parameter γ also supported the results from the likelihood-ratio tests. The value of general likelihood ratio (LR) test was 42.71 and the critical value of this test was $\chi^2_{0.05(4)} = 8.76$ (Kodde and Palm 1986, p.1246). The significant value of LR test reveals that there was technical inefficiency effect in the production of mustard. The results indicate that the farm-specific variables involved in the technical inefficiency model contribute significantly as a group to the explanation of the technical inefficiency effects in mustard production. Although, based on asymptotic t-ratios, slope coefficients were not significant individually. In view of a low validity of asymptotic t-statistic under the maximum likelihood estimation procedure the effects of farm-specific variables on technical efficiency were also tested using the generalized likelihood-ratio tests.

While mean technical efficiency measures, no doubt, have their own importance, from the policy perspective it becomes necessary to estimate technical efficiencies for individual units. Appropriate agricultural programmes can then be implemented to help the farmers realize technically efficient output. As indicated earlier, the farm-specific technical efficiency for individual sample farmers was estimated using equation (5), and presented in Fig. 2. These results show a wide variation in the level of technical efficiencies across sample farms, ranging from 0.1986 to 0.9682. A careful examination of the results reveals that about 61 percent of sample participants were obtaining outputs which were very close to maximum output estimated through the frontier, and the rest were far below the frontier.

Fig 2: Frequency Distribution of Technical Efficiency



It is apparent from the study that cultivation of mustard was profitable in Jamalpur district but not at satisfactory level. Human labour, power tiller cost and fertilizer were identified as important factors for the increase of mustard production. All of the farmers were found to have produced outputs with their mean technical efficiency was 80% (efficiency levels varying from 20% to 97%). The results indicate that there is substantial inefficiency in mustard production in Jamalpur district. Given the existing technology, the sample mustard growing farms could increase their production by 20 per cent by using their existing resources more efficiently. In other words, mustard producers in the sample would be able to increase average mustard yield from 856 kg/ha to 1070 kg/ha by operating at full efficiency. However, the predicted frontier production is still less than per hectare mustard production in research field for high yielding varieties. Thus, Jamalpur area has potential for shifting its production frontier upward by introducing high yielding varieties like BARI-9 to the farmers' field.

The results show that technical efficiency in mustard production can be improved by increasing the input levels, especially human labour and fertilizer. Similarly some of the ways to increase mustard production through technological advancement including development of short duration high yielding varieties of mustard. However the realization of these potentials depends greatly on continuous efforts of the government in ensuring timely and adequate supply of quality seed, chemical fertilizer, market and infrastructure development, research, training and extension in order to exploit full potential for increased mustard production.

Due to the lack of data, this paper is limited to technical efficiency only. Research on other aspects of productive efficiencies for mustard production, especially allocative scale and economic efficiencies can be carried out if appropriate data are collected in the future.

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