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Impact Assessment of Improved Technology of Mustard Production in Arid Region of Rajasthan: An Econometric Study

K.M. Gawaria* and B.L. Gajja

Central Arid Zone Research Institute, Jodhpur 342 003, India

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Abstract: The performance of modern technology of mustard cultivation and its impact on the farmer community of arid region of Rajasthan has been assessed through a survey of 40 farmers at Osian tehsil in Jodhpur District using production functions and decomposition analyses. The results suggested that the introduction of improved mustard technology exhibited constant effect in comparison to traditional technology. The total difference in the mustard productivity between modern and traditional technology was estimated to be about 50%. The major component of the productivity gap was due to the difference in varietal component contributing approximately 39%, while remaining 11% was shared by different inputs in terms of differences in their use levels between modern and traditional production technology in this crop. The study suggests that with the adoption of modern technology farmers could harvest better yields from their inputs.

Key words: Mustard, production function approach, yield decomposition model, nature of technology change.

Mustard (*Brassica* spp.) is the most important oil seed crop of India after soybean and plays a significant role in the oil economy by contributing about 27% of the total oil seed production. The species of *Brassica* viz., *B. juncea*, *B. napus*, *B. carinata* and *B. rapa*, yellow sarson and brown sarson are grown as oil seed crops in different parts of the country. Among these *B. juncea*, commonly known as Indian mustard or raya, is covering more than 80% of the total area under mustard cultivation due to its tolerance to biotic and abiotic stresses. The area, production and productivity of this crop during 2008-2009 was 6.18 Mha, 7.36 Mt and 1190 kg ha^{-1}, respectively. The crop is grown all over the country, but Rajasthan is the major mustard growing state occupying nearly 45% of the total area and contributes in the same proportion towards the production to the national oil seed pool (Yadava *et al.*, 2010). Agriculture is the backbone of Indian economy and is the main stay of the population, directly or indirectly, for seeking food, clothing, employment and perhaps everything. Poor farmers are less able to cope with shortfalls in crop production and as a consequence, diversify their activities as a precaution. This occurs more frequently in rainfed areas, where uncertainty of crop production is higher due to unpredictable environmental conditions (IRRI, 1995). New agricultural technologies implied for high yielding varieties, fertilizers, irrigation, market, infrastructure, etc. were introduced during the mid 60's, resulted into self-sufficiency of our country in the field of agriculture. The agricultural production increased from 180 Mt in 1980's to 200 Mt in 2004. The new technologies increased crop production and employment opportunities not only in agricultural sector, but in secondary sectors also. The usual approach in modeling technological relationship in production is based on mean levels of inputs and outputs. The random nature of agricultural production is the major constraint. Thus, variability in yield is not only explained by the non-controllable factors such as input and output price but, also by controllable factors such as varying the levels of outputs (Just and Pope, 1979; Antle, 1983).

An impact is a natural or man-induced changes in the bio-geophysical environment having both spatial and temporal components and can be described as the change in an environmental parameter, over a specified period and within a defined area resulting from a particular activity compared with the situation. Economic impact assessment is a process of measuring development objectives, such as increases in production, income and improvements in the sustainability of production

*E-mail: gawaria07@gmail.com

systems. The increasing population needs more food grains, but due to limited availability of land, it is not possible to provide grains in adequate quantity, and in this situation, adoption of new technology is the only option to cope up the scarcity.

The objective of the present study is to analyze the impact of new technology on economics of mustard crop with respect to the pattern of resources used in production process, output and income status in the Jodhpur District of Rajasthan.

Materials and Methods

Eighty farmers with 40 adopting traditional and 40 adopting modern technology were selected using simple random sampling method from a cluster of five IVLP villages spread across Osian tehsil of Jodhpur District during 2005-2006. For evaluating the objectives of the study requisite primary data pertaining to agricultural year 2005-06 were collected from the sampled farmers through personal interview. Variety 'Jai Kisan' of mustard was taken as a high yielding variety under modern technology.

Production function approach

The production function model was used to process the data. The log-linear function (Cobb-Douglas version) of the following specification was considered for both the technologies. Several other workers (Fufa and Hassan, 2003; Raza *et al.,* 2008; Singh *et al*., 2009) widely used functional form of Cobb-Douglas version and found it appropriate for the input-output relationship in agricultural economics due to its ease in manipulation and interpretation of the results.

$$\text{Ln } Y = \text{Ln } A + a_1 \text{ Ln } X_1 + a_2 \text{ Ln } X_2 + a_3 \text{ Ln } X_3 + a_4 \text{ Ln } X_4 + a_5 \text{ Ln } X_5 + a_6 \text{ Ln } X_6 + U_1 \quad \text{............(1)}$$

where, Y = Production (q)

X_1 = Area under the crop (ha)

X_2 = Total expenditure on seed (Rs.)

X_3 = Total expenditure on fertilizers and FYM (Rs.)

X_4 = Total expenditure on irrigation (Rs.)

X_5 = Total labor used (man-days)

X_6 = Other expenditure included the value of machinery used, insecticide/pesticides, depreciation and other charges (Rs.)

U = Random disturbance term

A = Scale parameters and 'a_i' are slope parameters of the regression function.

To examine whether the parameters of the production function of modern technology were different from those of traditional technology, the analysis of covariance test (Chow, 1960) was applied. Since Chow's F-statistics was found significant, an attempt was made to test whether the structural difference in production relationships was due to intercept or slope or both. This was done by introducing in equation (1) dummy variables for intercept slope and for both and then testing the significant levels of the dummy variables so obtained from the equations were estimated separately.

Yield decomposition model

The separate crop production functions based on per hectare basis were estimated for modern and traditional technologies. The production function approach has been widely used to decompose total change in output (Bisaliah, 1977; Thakur and Kumar, 1984; Kiresur *et al.,* 1995). The specification of production functions used in decomposition analysis is as follows:

$$\text{Ln } Y_t = \text{Ln } A_t + a_1 \text{ Ln } X_{1t} + a_2 \text{ Ln } X_{2t} + a_3 \text{ Ln } X_3t + a_4 \text{ Ln } X_{4t} + a_5 \text{Ln } X+_t + U_1 \quad \text{..........……(2)}$$

$$\text{Ln } Y_m = \text{Ln } A_m + b_1 \text{ Ln } X_{1m} + b_2 \text{ Ln } X_{2m} + b_3 \text{ Ln } X_{3t} + b_4 \text{ Ln } X_{4m} + b_5 \text{ Ln } X_{5m} + U_2 \quad \text{.............(3)}$$

where,

Y = Crop yield (q ha^{-1})

X_1 = Quantity of seed applied (kg ha^{-1}).

X_2 = Exp. on fertilizers and FYM (Rs. ha^{-1})

X_3 = Total expenditure on irrigation (Rs. ha^{-1})

X_4 = Total human labor (man-days ha^{-1})

X_5 = Other expenses include value of seeds, depreciation on machine, bullock, etc. (Rs. ha^{-1})

Subscripts t and m indicate traditional and modern technology systems, respectively.

In addition to fitting crop production functions for traditional and modern technologies, a pooled function was also fitted using dummy variable for variety. Taking the difference between the equations (2) and (3) and performing a slight algebraic manipulation and rearrangement of some terms, the following decomposition model was developed:

$$Ln\ Y_m - Ln\ Y_t = (Ln\ A_m - Ln\ A_t) + [(b_1 - a_1)\ Ln\ X_{1t} + (b_2 - a_2)\ Ln\ X_{2t} + (b_3 - a_3)\ Ln\ X_{4t} + (b_4 - a_4)\ Ln\ X_{4t}) + (b_5 - a_5)\ Ln\ X_{5t}] + [(b_1\ (Ln\ X_{1m} - Ln\ X_{1t}) + b_2\ (Ln\ X_{2m} - Ln\ X_{2t}) + b_3\ (Ln\ X_{3m} - Ln\ _{3t}) + (b_4 - a_4)\ Ln\ X_{4m} + (b_5 - a_5)\ Ln\ X_{5m}] + (U_2 - U_1) \quad ......(4)$$

The decomposition equation (4) approximately measures the per cent change in output with the introduction of HYV's (modern technology) of mustard. The first bracketed expression on the right hand side is a measure of per cent change in output due to shift in scale parameter (A) of the production function. The second bracketed expression measures, the effect of change in slope parameters, and these two terms sum up to the total effect of modern technology. The third bracketed term measures the contribution of change in input use. The difference between the resources required to produce the per hectare modern technology level of the output (Ym) by traditional technology and the resources actually used to produce the output with modern technology indicates the value of input saved due to higher level of production efficiency. The value of inputs saved (Is) under modern technology over traditional technologies are treated as the benefit of modern technology.

Results and Discussion

Production function

All the estimated production functions were significant and the adjusted coefficient of determinant (R^2) was high ranging from 90.57 in case of traditional technology to 94.51 in case of modern technology, indicating that variation in yield was adequately explained by the explanatory variables included in the model viz., farm size (X_1), expenditure on seed (X_2), expenditure on fertilizer and farm yard manure (X_3), expenditure on irrigation (X_4), total labor used (X_6) and expenditure on other expenses including on machinery and pesticides used, interest on working capital and depreciation (X_5) (Table 1). Using the same model similar observations were recorded by Kiresur *et al.* (1995) in sorghum, and Jankowski *et al.* (2007) in cabbage.

The perusal of the production function estimate revealed that the coefficient of all the explanatory variables were positive and

Table 1. Estimated regression parameters of farm production functions of mustard crop

Particular	Mustard technology			
	Modern	Traditional	Pooled	Pooled with dummy variable
Constant	2.6129 -	2.2301 -	2.6129 -	0.6972 (0.0956)
Farm size (X_1)	0.1507**** (0.0695)	0.1347*** (0.0631)	0.1507**** (0.0695)	0.2993***
Seed (X_2)	0.1474** (0.0911)	0.1167 (0.0833)	0.1474** (0.0911)	0.1309**
Fertilizer and FYM (X_3)	0.1371*** (0.0509)	0.1108** (0.0657)	0.1371*** (0.0509)	0.1253***
Irrigation (X_4)	0.2883*** (0.1052)	0.2503**** (0.1107)	0.2883*** (0.1052)	0.0571***
Total labor used (X_5)	0.3059**** (0.1096)	0.2701**** (0.1139)	0.3059**** (0.1096)	0.2495****
Other expenses (X_6)	0.1307 (0.0792)	0.1109 (0.0815)	0.1307 (0.0792)	0.2981****
R^2	0.9451	0.9057	0.9451	0.0997**
No. of observations	40	40	40	80
F- value	2.6129	2.2301	2.6129	34.4395

****, *** and ** significant at 1, 5 and 10% level of significance. Figures in parenthesis are the standard errors.

significant at varying degree of significance indicating a substantial impact on mustard production with the only exception to 'other expenses variable' (X_6) in case of both modern and traditional technologies, which was positive, but non-significant. The value of estimated regression coefficients of modern technology were more than estimated value of regression coefficient of traditional technology indicates that modern technology is more responsive due to its judicious usage especially to farm size (X_1) as well as labor (X_5) and suggests that with the increase in area and in labor enhanced the production of mustard crop. It could be noticed that the production elasticity of the inputs were invariably less than unity indicating diminishing marginal productivity with respect to each of the inputs. The production elasticity of all the inputs were relatively higher in case of modern technology as compared to that of traditional technology resulting in higher efficiency levels, owing to the diminishing marginal production productivity (MPP) of the production function.

Structural break and nature of technological change

The existence of structural break was examined by conducting tests for the equality of regression equations. Chow's F-statistics were computed for the equality regression coefficients including the intercept term obtained as 3.92, which at 7 and 64 degree of freedom was significant at 5% level, indicating the structural break in the production response and shifted the mustard production function in the process of technological change by the introduction of modern technology in the crop.

The nature of technological change was examined by testing the homogeneity of regression coefficients of various inputs expressed in the form of explanatory variables while the intercept terms (constant) in the two production functions (production function of modern technology and traditional technology) were allowed to differ (Alshi *et al*., 1983). The computed F-ratio of 1.08 at 6 and 68 degree of freedom found to be non-significant implying that shift in the production was due to intercept and not due to slope. It could be seen that intercept for modern technology was higher by 29.93% as compared to traditional technology in mustard as inferred by the intercept dummy variable value (Table 1). Thus, as a result of introduction of modern technology of mustard the technological change was of neutral type.

The analysis of covariance test also indicated that the structural break (shift in production function) was due to significant change in intercept rather than the slope. However, to know the complete structural relationship in the parameters of the production functions for the two technologies, the logs linear production function (Cobb-Douglas production function) was estimated with both intercept and slope dummies. The estimated regression coefficients are presented in Table 2.

The model was significant at 5% level of significance and had high coefficient of determinant (R^2). None of the slope dummies turned to be significant indicating that the complete structural break through was due to shift in intercept in production function. The positive sign of the dummies for all the explanatory variables used in the production function indicated that production of the crops was higher with the use of inputs in case of modern technology.

Table 2. Testing of complete structural relationship between production function of modern and traditional technologies of mustard crop

Variables	Regression coefficient with dummy variables
Intercept	0.5994
Intercept dummy	0.0735***
Farm size (ha) (X_1)	0.1274**
Seed (X_2)	0.1903**
Fertilizer and FYM (X_3)	0.1169***
Irrigation (X_4)	0.2779****
Total labor used (X_5)	0.3011****
Other expenses (X_6)	0.1207
Dummy variable for	
Farm size (ha) (X_1)	0.0963
Seed (X_2)	0.1055
Fertilizer and FYM (X_3)	0.1193
Irrigation (X_4)	0.0907
Total labor used (X_5)	0.1006
Other expenses (X_6)	0.1214
R^2	0.9587
No. of observations	80
F- value	41.5011

****, *** and ** significant at 1, 5 and 10% level of significance.

Yield decomposition

The productivity difference between modern and traditional technologies was disaggregated into its constituents, i.e. sources of technological and inputs components used with the help of the decomposition model as suggested by Bisalliah (1977). The per hectare log - linear production functions as specified in equation (2) and (3) and the geometric mean levels of inputs used for both technologies were used for decomposition of yield.

The per hectare Cobb-Douglas production functions for modern, traditional, pooled (both modern and traditional) and pooled with intercept (constant term) dummy were estimated and results are presented in Table 3. The estimated production functions were significant at 5% level of significance as indicated by F-value. The coefficient of determinant (R^2) was 85.03 and 94.88 for traditional technology and pooled with intercept dummy, respectively. Estimated regression coefficients were significant at varying degree of freedom except other expense variable (X_5) under both modern and traditional technology.

The Chow's F-test was also carried out to find out the existence of any significant difference between two production functions (modern and traditional technologies) in terms of their parameters. The production functions as well as pooled functions with intercept dummy were also fitted. The pooled production function showed a positive and significant value for all the explanatory variables. The significant (Chow's 'F' value) indicated a difference in production parameters between modern and traditional technology, while estimated regression coefficients were significant at varying degree of freedom except other expense variable (X_5) under traditional technology.

The constant term of modern technology was higher than that of traditional technology, indicating that the shift in production function was due to technological change. It also indicated that at a given level of inputs, more yield could be obtained under modern technology as compared to traditional technology.

Mean geometric levels of inputs used

In addition to estimated parameters of production functions (Table 3), the decomposition analysis required geometric mean values of different explanatory variables (inputs) in model are given in Table 4. The data revealed that the geometric mean values of various inputs used on the modern technology were higher in comparison to those used on traditional technology. The total difference

Table 3. Estimated regression coefficients per hectare for mustard production functions

Particulars	Regression coefficients			
	MT	TT	Pooled	Pooled with dummy
Intercept	-0.0832	-0.0521	-0.0556	-0.4079
Intercept dummy	-	-	-	0.2407**** (0.1034)
Seed (X_1)	0.0413*** (0.0183)	0.0329**** (0.0153)	0.0380**** (0.0176)	0.0357*** (0.0131)
Fertilizer and FYM (X_2)	0.0217*** (0.0087)	0.0194** (0.0092)	0.0239*** (0.0108)	0.0208** (0.0074)
Irrigation (X_3)	0.2106*** (0.0904)	0.1921** (0. 0705)	0.1997*** (0.0762)	0.1287*** (0.0387)
Total labor used (X_4)	0.2516**** (0.0998)	0.2391*** (0.1007)	0.2433*** (0.1119)	0.3189*** (0.1309)
Other expenses (X_5)	0.0289 (0.0396)	0.0227 (0.0179)	0.0349*** (0.0087)	0.0407 (0.0271)
R^2	0.8952	0.8503	0.9543	0.9488
F- Value	18.7906	22.0311	29.1856	27.6609
No. of observations	40.0000	40.0000	80.0000	80.0000
Chow's F - value	2.8499***			

****, *** and ** significant at 1, 5 and 10% level of significance.

Table 4. Geometric mean levels of inputs used per hectare for mustard crop

Crop/input level	Technology	
	Modern	Traditional
Seed (X_1) (Rs. ha^{-1})	61.07	49.53
Fertilizer and FYM (X_2) (Rs. ha^{-1})	287.57	207.56
Irrigation (X_3) (Rs. ha^{-1})	708.58	559.89
Total labour used (X_4) (man-days ha^{-1})	29.71	21.07
Other expenses (X_5)	596.57	541.03

in the productivity was decomposed into technical change and its explanatory variables (inputs used) in the model. The results of the decomposition analysis are presented in Table 5.

The total estimated changes due to technology and inputs used was of the order of 52.99%, whereas, the technological component alone contributed 39.14%. This indicated that with the present levels of inputs used by traditional technology users, the production of mustard could be increased by 39.14% merely by adoption or switching over to modern technology. In other words, it can be stated that with no increase in levels of inputs, the existing production could be increased by adoption of modern technology to the extent of 39.14%. Such increase in the yield was exclusively due to technological improvement through a shift in the scale (intercept) and/or slope parameters of the production function. The yield of mustard can further be increased by 13.85% by increasing the inputs to the levels as that under modern technology. There was a slight difference in estimation of productivity change, i.e. observed change was 49.47%, where as estimated change was 52.99%. This discrepancy was attributed to random error in the model that may be due to some omitted variable. Such discrepancy of varying degree in decomposition model was also reported by various other workers (Bisaliah, 1977; Joshi and Jha, 1992; Singh and Gajja, 2004). However, in the present study, discrepancy was of a very low order, satisfying the decomposition analysis.

Table 5. Decomposition of yield of mustard crop between modern and traditional technologies

Source of change	Per cent attribute
Total observed change	49.47
Due to difference in technology	39.14
Due to technology	16.11
Seed (X_1) (Rs. ha^{-1})	3.28
Fertilizer and FYM (X_2) (Rs. ha^{-1})	1.49
Irrigation (X_3) (Rs. ha^{-1})	9.55
Total labor used (X_4) (man-day ha^{-1})	3.81
Other expenses (X_5)	3.90
Due to change in complementary inputs	13.85
Seed (X_1) (Rs. ha^{-1})	0.87
Fertilizer and FYM (X_2) (Rs. ha^{-1})	0.71
Irrigation (X_3) (Rs. ha^{-1})	3.34
Total labour used (X_4) (man-day ha^{-1})	8.65
Other expenses (X_5)	0.28
Total estimated change due to difference in technology	52.99

Conclusions

The large gap in the per hectare input levels between modern and traditional technologies indicated that at a given level of inputs, more yield could be obtained under modern technology as compared to traditional technology. It is not possible for farmers adopting traditional technologies to switch over to modern technologies due to poor financial resources. However, adoption of modern technologies may lead to better monetary returns due to efficient utilization of inputs.

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