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A RESOURCE USE EFFICIENCY ANALYSIS OF SMALL Bt COTTON FARMERS IN PUNJAB, PAKISTAN

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The paper examined the resource use efficiency of small Bt cotton farmers of Punjab province of Pakistan using the production function approach. Data for the study were obtained from 150 randomly selected Bt cotton farmers from Punjab province using a multistage sampling procedure and then categorized into small, medium and large farmers. Average farm size of small farmer was found to be 5 acres. Regression results indicated that Fertilizer, Spray Number, Irrigation acre inch and labour cost were significantly affecting Bt cotton production while farm size was found non significant. The resource use efficiency analysis showed that efficiency ratios i.e. MVP/MFC for inputs fertilizer (Kg), spray number, irrigation (acre inch) and labour cost (Rs) were found to be 1.5, 3.94, 3.01 and 1.27, respectively. All the efficiency ratios, more than unity indicated the under utilization of all the production inputs under consideration in case of small Bt cotton farmers. Bt cotton production for small Bt farmers had an increasing return to scale with elasticity of production 1.27. Opportunities still exists to increase Bt cotton output in the study area by increasing the level of above mentioned productive resources.
Keywords: small farmers, resource use efficiency, Bt cotton, farm size

INTRODUCTION

Cotton is the main cash crop of Pakistan. The cotton industry and cotton related services play the foremost role in Pakistan's economy and being a non-food cash crop contributes significantly in foreign exchange earning. It is second in terms of area to wheat, which is the country's staple food (SMEDA, 2010). Area annually planted under cotton is around 3 million hectares (Cororaton *et al.,* 2008). It accounts for 8.6 percent of the value added in agriculture and about 1.8 percent to GDP (GoP, 2010). Pakistan is the fourth largest producer of cotton after China, USA and India (Hanif and Jafri, 2008). Its Overall contribution to the world production of cotton in 2004–2006 was 8 percent (Cororaton *et al.,* 2008).

In view of its widespread forward and backward linkages, the cotton crop occupies a unique position in the rural economy of Pakistan. Its performance holds the key not only for the growth and development of agriculture sector but also for the healthy growth in the overall economy. It provides raw material to domestic cotton industry comprising of 503 textile mills, 1263 ginning factories, 8.1 million spindles and 2622 oil expelling units. It also yields 3.5 to 3.6 million tons of cotton seeds which contribute over 64 percent of the total domestic edible oil production (Pakistan Cotton Ginners Association, Textile Vision, 2005).

Cotton was sown on the area of 3106 thousand hectares in year 2009-10, 10.1 percent more than last year area of 2820 thousand hectares. The production was estimated at 12.7 million bales for year 2009-10, which was 7.4 percent higher than the last year's production of 11.8 million bales (GoP, 2010). However, the cotton production was 5.0 percent less than the target of 13.36 million bales mainly due to the shortage of irrigation water, high temperatures in the month of August resulting in excessive fruit shedding and flare up of sucking pest complexes (GoP, 2010). On the other hand per hectare yield has declined to 695 kg per hectares as compared to last year per hectare yield of 713 kgs (GoP, 2010) and Pakistan ranked 10th with respect to per hectare yield (Abdullah, 2010).

Small land holding is one of the main causes of low productivity of agriculture in Pakistan. More than 70 percent of the farmers in Punjab own less than 2 hectare of land (Garcia *et al.,* 2003). Despite their distinctive and critical position, small farmers belong to the poorest sector of population and therefore cannot invest on their farm. The vicious cycle of poverty has led to the unimpressive performance of the agricultural sector. Lack of access to extension services and information; lack of access to agricultural credit due to lack of collateral to satisfy credit institution; limited land area and inadequate resource distribution are some of the constraints for small farmers. Other factor contributing to low productivity other than small landholding are high prices of agriculture inputs (seeds, fertilizers, pesticides etc.); higher intensity of insects and pests attack; shortage of good quality, high-yielding, insect and pests resistant varieties of seeds; deficiency of irrigation water; lack of access to advance technologies like laser land leveling and watercourse lining etc., lack of awareness about good agricultural practices; and adulterations in pesticides, fertilizers and seeds.

However, the scenario has been changed with the adoption of Bt cotton in the world. *Bacillus thuringiensis*, usually known as Bt is a bacterium that occurs naturally in soil. Bt has been used as a biological pesticide for more than 50 years (Qaim and Zilberman, 2003). First generation of transgenic cotton included plants with single insecticidal Bt genes (Ferry *et al.,* 2006). Several Bt transgenic crops including tomato, canola, potato, chickpea, egg plant and cotton have been field tested in USA, Argentina, Canada, India and Australia. Cotton crop has been transformed with different forms of Bt gene producing crystal protein toxin. Bt genes commercialized in more than 18 cotton producing countries (Forrester, 2008). Bt cotton was first commercially grown in 1996. More than 50% of the global cotton area is now under genetically modified (GM) cotton (James, 2008; 2009). In India, area under Bt cotton has increased to 8.4 million hectares in 2009 exceeding that of China's 3.4 million hectares (James, 2009).

Bt varieties are being cultivated on about 200,000 hectares in Punjab and Sindh Province (Addison, K., 2007). Non recommended Bt is being grown on 30 percent of the total cotton area of Pakistan (Rao, 2008). Bt cotton is being grown with different names. Of all these genotypes Bt-121 occupied more than 40 percent and was considered relatively better than other Bt cotton as regard to uniformity (Rao, 2008).

These Bt varieties are from exotic sources which are given to farmers for cultivation without validating its purity, performance and without providing production technologies based on research conducted according to local environment. (GoP, 2010). Farmers which are mostly small farmers are not so much aware about the harmful effect of these illegal untested varieties on their health and soils.

The process of adopting original Bt seed is very slow in Pakistan. In Pakistan during 2005-06 season pre-commercial planting of Bt cotton have been carried out in Punjab and Sindh with some indigenously developed Bt cotton verities- "IR-NIBGE-2" and IR-FH-901". But these verities were unable to give better results in term of adoption and resistant to pest. There is great demand for improved genetically modified verities (Rao, 2008). However it is appreciating that recently Government of Pakistan has approved various varieties under the bio safety rules and regulations designed by federal and provincial governments (GoP, 2010).

However, still there is huge potential to increase overall cotton production. Therefore, to increase cotton productivity, sound macro and micro-economic farm policies are needed. These require a knowledge of aggregate farm level resource availability and differences in the productivities of these resources in different farm sizes. This paper tries to provide some useful information in policies towards increasing Bt cotton production.

The study, therefore, examines resource use efficiency pattern, returns to scale in Bt cotton production on small scale farms, to report evidence related to resource use and farm productivity.

MATERIALS AND METHODS

In order to meet the objective of study Punjab was selected as study area, which is the largest cotton producing province with 80 % share in total cotton production in Pakistan (Osakwe, 2009). Despite its dry climate, extensive irrigation makes Punjab province a rich agricultural region. Wheat and cotton are the largest crops. Other crops include rice, sugarcane, millet, corn, oilseeds, pulses, vegetables, and fruits such as Kinnow.

Sampling Framework and Data Collection: The study used a multi-stage sampling technique. In first stage Punjab province was divided into three categories/zones on the basis of contribution to overall cotton production in the province. Zone-I with high contribution to overall cotton production (> 8 percent) included districts; Rahim Yar Khan (13.9 % to total cotton production), Bhawalpur (13.0 %), Vehari (10.4 %), Bhawalnagar (8.7%), and Lodhran (8.6 %). Zone-II with medium contribution to overall cotton production (4.1% to 8%) in the province included districts; Khanewal (8 %), Muzafargarh (6.8 %), Multan (6.4 %), Rajan Pur (7.2 %) and D.G. Khan (4.8 %). Zone-III with lowest contribution in overall production (0.1 % to 4 %) included districts; Pakpattan (2.2 %), Sahiwal (2.7 %), Okara (1.2 %), Jhang (1.7 %), Toba Tek Singh (1.3 %), Layyah (1.1 %), Mianwali (0.8 %). From these three categories one district was randomly selected from each zone. District Rahim Yar Khan from Zone-I, District Multan from Zone-II and District Mianwali from Zone-III were selected randomly as sample districts.

In second stage tehsils were selected among three districts for survey randomly. From district Rahim Yar Khan out of four tehsils, two tehsils; Khan Pur and Liaqat Pur were selected randomly. From district Multan out of three, two tehsils; Shujaabad and Jalalpur Jattan were selected randomly. From Mianwali district out of three tehsils one tehsil Piplan was selected randomly. In the third stage 150 farmers were selected for interview randomly. 50 farmers were interviewed from each district with considering small, medium and large farmers. Then 150 farmers were categorized into small, medium and large Bt cotton farmers on the basis of their farm size.

The Data used for the analysis was collected for cotton season 2008-09 and it included: total Bt cotton produced in kg as output while the input included the farming experience in years, area under Bt cotton in acres, quantity of fertilizer used in kg; sprays applied in numbers and total labour cost in rupees which included family and hired labour cost per each respondents for different farm activities. Other variables included the demographic variables such as farmer's age, farming experience, years of schooling and family size.

Data was collected through personal interviews: for this purpose a questionnaire was constructed to obtain desired information the respondents. To test the workability of the questionnaire a test survey was conducted on ten respondents of the village chak number 23 P (tehsil khan Pur, district Rahim Yar Khan). In the light of the results some revisions were made in the questionnaire.

***Theoretical Background*:** The discipline of economics is related to the maximization of well-being in the face of unlimited wants and limited resources. The primary focus of economics is to allocate resources in such a way that enhance the community well-being. Achieving an optimal allocation of resources, the allocation that maximizes well-being, needs attention to the three fundamental economic questions i.e.

i) What to produce which is commonly known as allocative efficiency?
ii) How to produce?
iii) To whom should goods and services be distributed?

The current research considered only first fundamental economic equation.

Efficiency measurement is crucial because it leads to a substantial resource savings (Bravo- Ureta and Rieger, 1991). One of the strategies for increasing agricultural production is a combination of different measures designed to increase the level of farm resources as well as make efficient use of the resources already committed to the farm. Technical inefficiency arises when less than maximum output is obtained from a given bundle of factors while allocative inefficiency arises when factors are used in proportions, which do not lead to profit maximization i.e. underutilization of resource. Efficient use and allocation of resources imply that a redistribution or re-allocation of resources achieves optimal level of production.

Productivity is considered as a measure of the efficiency of all resources employ in any farming operation. It is defined as an indicator of the resource efficiency to its mean increase in optimal allocation and combination of farm resources (Olayide and Heady, 1982). Productivity could as well be measured in terms of marginal physical product (MPP) in which case, the interest is in the addition to total product resulting exclusively from a unit increase in the use of that input i.e., total factor productivity growth. It therefore sufficient to say that productivity or resource use efficiency can only be measure and ascertained from farm-level efficiency (Udoh and Oluwatoyin, 2006). Hence in this study, resource-use productivity or efficiency was evaluated by estimating the marginal physical productivities of the inputs used by the Bt cotton farmers in the study area.

Economic efficiency combines both the technical and allocative efficiency. It occurs when a firm chooses resources and enterprises in such manner as to attain economic optimum (Adesina and Djato, 1997). The analysis of efficiency is generally associated with the possibility of farms to produce a certain optimal level of output from a given bundle of resources or certain level of output at least cost.

Umoh and Yusuf (1997) identified two measures of productivity namely, partial productivity and total factor productivity (TFP). Partial productivity is calculated as the ratio of output to a single input. The ratio of output to all inputs combined is called the total factor productivity. Generally, two approaches are used in measuring TFP. These are the growth accounting or index number approach and the parametric or econometric method (Goni *et al.,* 2007). The econometric method is based on an econometric estimation of the production function or the fundamental cost or profit function. In this study, the Cobb Douglas production function was used to measure the productivity (or resources use efficiency) of the Bt cotton farmers. From the production function, the conventional neoclassical test of economic efficiency was derived. The rule of this test is that the shape of the production function (MPP) should be equal to the inverse ratio of input price to output price at the profit maximization point.

***Descriptive and Econometric Analysis of Data*:** The descriptive analysis was used to describe the socio demographic characteristics of Bt farming households and the Bt farming system in the study area. The data thus collected was tabulated in the form of tables. Mean values were Calculated by using the formula

Simple arithmetic mean, A.M. = X/N

Where: X = summation of all values

N = total number of items

The analytical procedure employed was production function analysis. This was used to obtain the parameters for the measurement of resource use efficiency of the Bt cotton farmers. Number of studies (Khan and Young, 1979; Othman, 1985; Gani and Omonona, 2009; Fasasi, 2006; Alene, 2002 and Anene, *et al.,* 2010) used Cobb Douglas production function to measure resource use efficiency.

The general production function can be presented by the following equation:

$$\mathbf{Y = f (X_1, X_2, X_3, X_4, X_5, X_6, Ui)..... (1)}$$

Where;

Y = Cotton output measured in Kg

X_1 = Farm experience measured in years

X_2 = Area under Bt cotton was taken in acres

X_3 = Fertilizer quantity is measured in Kg

X_4 = Spray numbers

X_5 = Irrigation measured in acre inch

X_6 = Labour cost is measured in Pakistan Rs.

U_i = Error term which included unknown factors affecting the Bt cotton output of farmers in sampled area

Irrigation was measured in acre inch by the formula given below

Acre inch for cotton = (Irr*3 acre inch) + 1 acre inch

Where Irr = Number of irrigations

In this formula, each irrigation included 3 acre inch water for cotton crop on average while first irrigation had 4 acre inch water which commonly known as rouni in local language. So author multiplied 3 acre inch to numbers of irrigation and than add 1 acre inch in the answer to find total acre inch for Bt cotton crop for specific farm.

Data were fitted to four functional forms using ordinary least square (OLS) techniques. The estimated functions were evaluated vis-à-vis the economic, econometric and statistical criteria including plausible signs and magnitudes of the coefficients and standard errors, the magnitude of R^2, T-statistics, F-statistics (Umoh and Yusuf, 1997). Having tested the effects of all the regressors on the regressand, the Cobb-Douglas production function was chosen as the lead equation, which is implicitly represented by equation (2) given below.

$$\mathbf{Y = aX_1^{\,b1} X_2^{\,b2} X_3^{\,b3} X_4^{\,b4} X_5^{\,b5} X_6^{\,b6} u_i \text{ .... } (2)}$$

The Cobb-Douglas production function in the form expressed above was linearised into a double logarithmic function with a view to getting a form amenable to practical purposes as expressed below.

$$\mathbf{\ln Y = \ln a + b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6 + \ln U_i \text{ .... } (3)}$$ Where,

ln = Natural logarithm

a = constant

$\mathbf{U_i}$ = error term

Y, X_1, X_2 … X_6, is as defined in equation (1).

***Determining the Resource Use Efficiency and Returns to Scale*:** The resource use efficiency was obtained from the estimated equation by comparing the Marginal Value Product (MVP) of a particular input with the Marginal Factor Cost (MFC) of that input. The following ratio i.e. r = MVP/MFC, was used to estimate the relative efficiency of resource use. Where:

MVP = value added to Bt cotton output due to the use of an additional unit of input, calculated by multiplying the MPP by the price of Bt cotton i.e. MPP_{Xi}•Py

MFC = cost of one unit of a particular resource.

Decision rule for resource use efficiency was;

If r = 1; it shows the resource is efficiently used, that is optimum utilization of resource hence the point of profit maximization

If r < 1; resource is excessively used or over utilized hence decreasing the quantity use of that resource increases profits.

If r > 1; resource is under used or being underutilized hence increasing its rate of use will increase profit level.

Economic optimum takes place where

MVP = MFC. If r is not equal to 1, it suggests that resources are not efficiently utilized. Adjustments could be therefore, be made in the quantity of inputs used and costs in the production process to restore r = 1

Elasticity of production (E_p) is the measure of response of output to changes in the variable input. Based on the function of best fit, the elasticity of various inputs was determined by this formula.

$$\mathbf{E_P = dy/dxi * X\hat{} / Y\hat{} \text{ or } MPP/APP}$$

Where Y is the Bt cotton output

X's are the various input used in production X^ and Y^ are the averages of input and output respectively.

MPP = marginal physical product

APP = average physical product

Since the Cobb-Douglas production function gave the best fit, the regression coefficient are still the elasticities and used to measure the rate of return to scale which is a measure of a firm's success in producing maximum output from a set of input.

Criteria for return to scale is

$\Sigma E_P = 1$: constant return to scale

$\Sigma E_P < 1$: decreasing return to scale

$\Sigma E_P > 1$: increasing return to scale

RESULTS AND DISCUSSION

The summary statistics of a small Bt farmers household in Punjab is presented in Table 1. The table showed that average family size of small Bt cotton farmers was found 8.22. Besides, an average age of small Bt cotton farmer was about 45.02 years with 16 years of average experience in cotton production. Average education of the small Bt farmer was found to be 8 years. Average farm size of small Bt cotton farmers was found to be 5 acres.

Table 1. Summary statistics of small Bt cotton farmers in Punjab

Indicator	Average
Family size	8.22
Age (years)	45.02
Farming experience (years)	20.06
Education (years)	8
Farm size (acres)	5

The estimated form of the unrestricted Cobb-Douglas production function for small farmers is given in Table 2. The value of R^2 was 0.76, which indicated that 76% of the variations in the Bt cotton output is being explained by the explanatory variables included in the model.

Table 2. Estimated Cobb Douglas production function for small Bt farmers in Punjab

Model	Coefficients	t-value
(Constant)	2.54 *	2.63
Ln Farm Experience (X_1)	0.12 **	1.84
Ln Area under BT (X_2)	0.05 ^{ns}	0.28
Ln Fertilizer Quantity Kg (X_3)	0.20 **	1.86
Ln Spray Number (X_4)	0.29 **	1.80
Ln Irrigation acre inch (X_5)	0.20 ***	1.36
Ln Labour Cost (X_6)	0.30 *	3.32

*Significant at less than 5 % level; **Significant at less than 10 % level; ***Significant at less than 20 % level and ns = non significant

Farming experience is an important factor affecting the productivity of any crop. The experienced farmers could manage various farm practices in a better way. In the current study farm experience for small Bt cotton farmers was significant at 7 percent significance level and significantly affecting Bt cotton output. As farm experience increases by one percent then cotton output (Kg) will increase by 0.12 percent (Table 2). Same positive impact of farming experience on the crop productivity was reported by Koye, *et al.,* 2008.

Area under Bt cotton for small Bt cotton farmers is highly non significant with 78 percent significance level (Table 2). Which shows that cotton output is independent of any change in area under Bt cotton.

Fertilizer is another important factor contributing higher cotton productivity. Cotton growth and yield is affected by application of fertilizer. In the current study fertilizer quantity for small Bt cotton farmers was found significant at 7 percent level of significance. This implies that a one percent increase in the fertilizer quantity will lead to 0.20 percent increase in Bt cotton output (Table 2). Bakhsh, *et al.,* 2005 reported positive impact of fertilizer (N and P) on the productivity of cotton in Sargodha district.

The incidence of weeds, pests and disease on cotton crop is a growing problem in all cotton growing areas of Pakistan and adoption of chemical control methods are increasingly becoming popular among the cotton growers in Pakistan (Bakhsh *et al.,* 2005). In the current study sign of number of sprays for small Bt cotton farmers was positive and significant at 8 percent significance level showing that one percent increase in spray numbers will lead to 0.29 percent increase in Bt cotton output (Table 2). Although Bt cotton is assumed to be resistant against various pests but unfortunately in Pakistan, but still no such pure Bt cotton variety is available to farmers. Currently sowing Bt is vulnerable to all type of sucking pests and some boll worms, which needs more use of pesticide.

Agricultural production is directly depends upon the availability and effective use of water which is a major input for any crop production. In the current study sign of irrigation for small Bt cotton farmers was found positive. As far irrigation acre inch increases by one percent then there will be 0.20 percent increase in cotton output at 18 percent level of significance (Table 2).

Sign of labour cost for small Bt cotton farmers was found positive and highly significant at 0.02 percent level of significance. This implies that with one percent increase in labour cost, cotton output will increase by 0.30 percent (Table 2).

Elasticity of production was found to be 1.16 which shows increasing returns to scale for small Bt cotton farmers. This indicated that if inputs are doubled than out will be increased more than double.

Table 3, shows the MVP and MFC of the individual input used. From Table 3 it is observed that all the ratios of MVP to MFC were greater than unity which implies that inputs were not utilized to optimum economic advantage. There is the need for adjustment in the marginal value product (MVP) of all the inputs to ensure optimal use.

Table 3. Marginal Value Product (MVP) and Marginal Factor Cost (MFC) of production inputs in Bt cotton production in Punjab, Pakistan

Inputs	MVP	MFC	Efficiency ratio
Fertilizer	44	29.4	1.50
Spray Number	9515	2418	3.94
Irrigation acre inch	1271	423	3.01
Labour cost	1.27	---	1.27

Fertilizer is very important input in cotton production. Most of the soils are nitrogen deficient. There is always need to add fertilizers in soil to fulfill nutrients deficiency to get maximum production. A balanced used of fertilizer with desire level of nutrients is very necessary if one wants to get maximum production. Results in table 3 showed that small Bt cotton farmers were under utilizing the fertilizer resource because ratio of MVP to MFC for small farmers was greater than unity i.e. 1.5 for fertilizer. Therefore farmers have an opportunity to increase their profit by using more fertilizer in their fields.

Unfortunately Pakistan is lagged behind in the development of transgenic varieties having resistance against all type of pests. Most of the varieties in Pakistan have high risk of pest attack. Bt cotton grown in Pakistan is not registered and there is no surety about the resistance of Bt cotton against pests. Farmers in sample area growing cotton have reduced pesticide use on the perception that varieties that they are going to grow would have resistance against pests. But because of less quality and attach of pests leads to less production of cotton. Results of resource use efficiency analysis showed that small Bt cotton farmers are under utilizing spray numbers. The ratio of MVP to MFC for small Bt farmers was estimated as 3.94 which was greater than unity (Table 3). Hence small Bt cotton farmers have an opportunity to increase their profit by applying more number of sprays at their Bt cotton fields to equate MVP to MFC or ratio of MVP to MFC equal to unity.

Punjab in Pakistan does cultivate Bt cotton in about 35 percent of the total area under cotton. There is no such large difference in the productivity of currently growing Bt cotton as compared to the non-genetically modified cotton. Also, another important factor that is not at all being considered is that the water requirement of Bt cotton increases manifold in case of the transgenic crop. For a country like Pakistan, where cotton is traditionally grown as a rain-fed crop, the requirement of water will remain a major factor in its productivity and growth. Production of Bt cotton can be increased by providing water to crop at desired level. Results of resource use efficiency analysis (Table 3) indicated that small farmers were under utilizing water resource because ratio of MVP to MFC greater than unity (3.01) showed that there is potential for small Bt farmers to increase their profit by increasing the use of water in Bt cotton crop. Labour is very important resource in cotton production. The results of resource use efficiency analysis (Table 3) showed that ratio of MVP to MFC for small Bt cotton farmers was 1.27 (greater than unity) i.e. resource was being underutilized and there is need to use more labour in different farm activities to increase profit by equating MVP to MFC.

CONCLUSION AND RECOMMENDATIONS

This study has measured the efficiency of resource-use and return-to-scale among small Bt cotton farmers in Punjab. The result showed that Bt cotton production has an increasing return to- scale with elasticity of production i.e. 1.16 in case of small farmers. In addition, all the production inputs i.e. fertilizer, spray, irrigation and labour were being under-utilized because the ratios of MVP to MFC were greater than unity which implies that small farmers can increase Bt cotton output by increasing the level of all these inputs up to optimal point.

From the discussion above, it was concluded that there was a dire need to fulfill the shortage of resources to enhance Bt cotton production. If the inputs are properly arranged and timely provided to the farmers, the cotton production can be further enhanced. Water is a scarce commodity throughout the world. The sensible use of the available water is, however, a management issue and, therefore, requires motivation among farmers in using water at required time in required quantity. The study showed that the small farmers, who are already deficient in resource use, cannot bear the burden of increasing cost of inputs. To address this issue, government should provide subsidized inputs to small farmers along with proper extension services, which will help not only to enhance cotton productivity and profitability but will also improve the living standards of the small farmers. In addition subsidized credit facilities to small farmers may catalyze this process. To do all this requires effective agricultural policies with strong implementation and follow up on the behalf of government.

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