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An economic evaluation of impact of soil quality on Bt (*Bacillus thuringiensis*) cotton productivity

***Muhammad Abid*[*1], *Muhammad Ashfaq*[1], *Imran Khalid*[2] *and Usman Ishaq*[1]**
[1]Department of Agricultural Economics, University of Agriculture, Faisalabad
[2] Soil Scientist, Irrigation and Power Department, Government of Punjab, Lahore

Abstract

The study was conducted with the aim to determine the impact of soil quality on the Bt cotton productivity. A sample of 150 farmers was selected by using multi-stage sampling technique from three districts i.e. Rahim Yar Khan, Multan and Mianwali. A Cobb Douglas production function was employed to assess the effect of various agronomic and demographic variables on the Bt cotton productivity. Results of the analysis indicated that land preparation cost, seed cost, fertilizer cost, labour cost and dummy variable of soil quality were significant and positively contributing towards higher Bt cotton yield. While the spray cost and irrigation cost variable were found positive but non-significant. Findings of the study suggested that focusing on maintaining and improving the quality of soils is necessary to obtain higher crop yields. All this needs attention of agricultural extension department to provide information about advance techniques to farmers for improving soil quality.

Key words: Soil quality, Bt cotton, productivity, economic evaluation

Introduction

Agriculture is the resource core of Pakistan's economy. The sector accounts for 21 percent of the GDP and employs 45 percent of the total labour force (GoP, 2010). Agriculture contributes to economic growth as a supplier of raw materials to industry as well as a market for industrial products. In addition, agriculture contributes roughly 66 percent in the export earnings of Pakistan through cotton related products (AgroNews, 2009). About 62 percent of the country's population lives in rural areas that are directly linked with agriculture sector for their livelihood. The agricultural sector grew at an average rate of 3.2 percent per annum during the decade of the 2000s. During the year 2009-10, the overall performance of agriculture sector has been weaker than the projected target. Against a target of 3.8 percent, and previous year's performance of 4.0 percent, agriculture is estimated to have grown by 2.0 percent in 2009-10 (GoP, 2010).

Cotton, the White Gold, occupies a pivotal position in Pakistan's economy (Ibrahim *et al.,* 2007). It account for 1.8 percent to GDP and 8.6 percent of the value addition in agriculture. Cotton is grown on around 3 million hectares annually in the country (GoP, 2010). It is second in terms of area after wheat crop (SMEDA, 2010). Mostly it is grown in Punjab and Sind. Punjab accounts for about 80 percent of total cotton crop area and total cotton production in the country, while the province Sind accounts for about 20 percent. The other two provinces i.e. Khyber Pakhtunkhwa (KP) and Balochistan have a joint share of less than 1 percent (Cororaton *et al*., 2008). In view of the leading shares of Punjab in area and production of cotton, its production performance has a major bearing on the overall situation in the country. Hence in current study, Punjab province was taken as study area.

Different cotton varieties are grown in the country ranging from generic cotton verities to *Bacillus thuringiensis* (Bt) verities. Bt cotton has gained popularity in Pakistan during the last few years. In Sind and Punjab, almost 80% of cotton growing area has become prominent under Bt Cotton with different names (GoP, 2010). The performance of these locally grown non-recommended Bt verities is quite ambiguous because of its poor resistance against some pests. The Bt cotton varieties including Bt hybrids which are currently grown in Pakistan, are from exotic sources imported illegally and have not been tested so far according to standard rules and regulations set by Government agencies at Federal and Provincial levels (GoP, 2010).

Actually, *Bacillus thuringiensis* (Bt) is a bacterium that produces crystal protein, which are poisonous to many pests. Plants have been modified with little sequences of genes from Bt to express the crystal protein Bt being made since 1996. Now Bt genes are commercialized in more than 18 cotton producing countries (Forrester, 2008). Since 2009 Pakistan was the only major exporter that had not adopted Bt cotton (USAID, 2009). However, recently, Government of Pakistan approved seven local genetically modified verities. Ministry of Food, Agriculture and Livestock (MINFAL) is negotiating with Monsanto to introduce Bt

*Email: abiduaf@googlemail.com

cotton variety and Bt Hybrid in Pakistan (GoP, 2010).

Various factors i.e. environmental, soil, agronomic, policy related and economic factors affect crop productivity. Each factor has its own impact on crop yield but soil is the main anchorage for crop production. Poor soil quality results in low crop yield. In Pakistan, most of the soils are nutrient deficient. Due to financial constraint, high prices of fertilizers and less availability of organic matter, soil quality remains poor in most parts of country. Soil degradation is another dilemma of the present age, which leads towards soil erosion and poor soil quality. The fertility and quality of soil is affected by various physical, chemical and biological properties of soil. The soil physical properties mainly soil texture and chemical properties such as pH, electrical conductivity (EC), lime and organic matter (OM) content and concentrations of macro/micronutrients mainly determine the soil fertility and its productivity (Khattak and Hussain, 2007). However, the good quality soil is positively related to yield. Masterson (2007) found that there is significant positive impact of better soil quality on the crop yield.

Bt cotton is quite new technology in Pakistan. Various studies have been conducted on the different aspects of Bt cotton, but as such no study has been done to find out the extent of possible impact of soil quality on the Bt cotton productivity. Keeping in view the importance of soil quality for crop productivity, study in hand was undertaken with the aim to find out any positive impact of soil quality on the productivity of Bt cotton.

Material and Methods

Sampling and data collection

The current study used a multi-stage sampling method. In the first stage of sampling, Punjab province which have 80 percent share in total cotton production of the country (Cororaton *et al*., 2008), was selected as study area and divided into three 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 the districts; Rahim Yar Khan having 13.9 percent contribution to total cotton production; Bahawalpur (13.0 percent), Vehari (10.4 percent), Bhawal Nagar (8.7 percent), and Lodhran (8.6 percent). Zone-II with medium contribution to overall cotton production in Punjab (4.1 to 8 percent) included districts; Khanewal with 8 percent contribution to total province cotton production, Muzafargarh (6.8 percent), Multan (6.4 percent), Rajan Pur (7.2 percent) and D.G Khan (4.8 percent). Zone-III with lowest contribution to overall cotton production (0.1 to 4 percent) included districts; Pakpattan with 2.2 percent contribution to the total cotton production in the province, Sahiwal (2.7 percent), Okara (1.2 percent), Jhang (1.7 percent), Toba Tek Singh (1.3 percent), Layyah (1.1 percent), and Mianwali (0.8 percent) (Cororaton *et al.,* 2008). From these three zones, one district was randomly selected from each zone i.e. District Rahim Yar Khan from Zone-I, District Multan from Zone-II and District Mianwali from Zone-III as sample districts.

In second stage, tehsils were selected randomly from three districts for survey. From district Rahim Yar Khan, out of four 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. Fifty farmers were interviewed from each district.

The data used for the analysis was collected for cotton season 2008-09 through personal interviews from the Bt cotton growers. For this purpose, a questionnaire was constructed and tested with pilot survey conducted on ten respondents of the village number 23 P (tehsil Khan Pur, district Rahim Yar Khan). In the light of the results, questionnaire was restructured by making certain additions and deletions.

Econometric Analysis of Data

Cobb Douglas production function was used to estimate the impact of soil quality on the productivity of Bt cotton. Various researchers e.g., Ahmad *et al*., 1999; Bakhsh, 2006; Bashir *et al.,* 2007; Masterson, 2007 and Raza *et al.,* 2009 have also used similar kind of production functions in such type of studies.

Generalized form of Cobb-Douglas production function for estimation of Bt cotton productivity is given as:

lnay = $\beta_0 + \beta_1$ lnlpcost+ β_2 lnscost + β_3 lnfcost + β_4 lnspcost+ β_5 lnircost + β_6 lnlcost + β_7 lnedu + $\beta_8 D_1 + \mu$

Where:

β_0 = Constant

lnay = Natural log of average yield of Bt cotton in sample area measured in maunds per acre.

lnlpcost = Natural log of cost of land preparation (leveling, planking and rotavator) for Bt cotton crop in sample area measured in Rs. per acre.

lnscost = Natural log of seed cost of for Bt cotton crop in sample area measured in Rs. per acre.

lnfcost = Natural log of fertilizer cost for Bt cotton crop in sample area measured in Rs. per acre.

lnspcost = Natural log of spray cost for Bt cotton crop in sample area measured in Rs. per acre.

lnircost = Natural log of irrigation cost for Bt cotton crop in sample area measured in Rs. per acre.

lnlcost = Natural log of cost of labour operations for Bt cotton crop in sample area measured in Rs. per acre.

lnedu = Natural log of years of schooling of the farmer growing Bt cotton in sample area.

D_1 = Dummy variable for the soil quality. If D_1=1 then it represents soil quality is good otherwise if D_0 = 0, it represents worse or medium soil quality.

M= Error term

$\beta_1, \beta_2, \beta_3, ..., \beta_8$ are the regression coefficients to be estimated through multiple regression analysis.

In this model, soil quality dummy variable was based upon the different soil quality parameters. Soil quality was judged through physical and chemical characteristics i.e. pH, electric conductivity (EC), sodium adsorption ratio (SAR) and soil texture. Electric conductivity and pH were determined by conductivity and pH meter (Mclean, 1982; Richards, 1954). While the SAR was determined by the following equation

$$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{½}$$ (Maas and Chapman, 2005)

The soil texture was determined by Hydrometer method (Koehler *et al*., 1984). In this study, good quality soil means, a soil having pH ranges from 5.5 - 8.2, EC between 1.5 and 2 dS m^{-1}, SAR within range 0-10 (mmol L^{-1} (Das, 1996; Maas and Chapman, 2005). Value "1" was assigned to the farms that had good quality soils based on the above mentioned criteria and value "0" was assigned to the farms which did not match with the mentioned criteria.

Results and Discussion

Table 1 shows important agronomic characteristics of the selected variables. The descriptive statistics of the variables that were included in the econometric analysis along with information regarding the average cost per acre in Pak. rupees are also given in Table 1.

In order to determine the impact of soil quality on Bt cotton productivity, Ordinary Least Square (OLS) model was estimated. Bt cotton yield (lny) measured in kg per acre was taken as dependent variable in the model. Different combinations of inputs and socio economic variables were analysed by using Cobb-Douglas production function. The Cobb-Douglas production function was found suitable because it can handle multiple inputs in its generalized form (Raza *et al.,* 2009).

Results of estimated model were also more or less according to *a priori* expectations. R^2 and adjusted R^2 were also in satisfactory range and indicated that about 58 percent variation in Bt cotton yield is due to the explanatory variables included in the model. While F-value (26.99) indicated that, overall results of model were also significant (Table 2).

Table 1: Descriptive statistics of the important variables in Bt cotton production

Variable	Mean	Std. Deviation
Land preparation cost (Rs.)	2168	1217
Seed cost (Rs.)	1037	739
Fertilizer cost (Rs.)	4405	2309.42
Spray cost (Rs.)	2709	1653.8
Irrigation cost (Rs.)	2112	1912
Labour cost (Rs.)	7344	2236
Average yield (kg)	1114.27	284.95

Table 2: Estimated regression results of Cobb- Douglass production function

Variable	Parameter	t-statistics	Sign. Level(P)
Constant	-0.30	-0.60	0.55^{NS}
lnlpcost	0.10	3.32	0.00^{***}
lnscost	0.06	1.86	0.07^{*}
lnfcost	0.11	3.29	0.00^{***}
lnspcost	0.05	1.50	0.13^{NS}
lnircost	0.02	1.35	0.18^{NS}
lnlcost	0.10	2.02	0.05^{**}
lnedu	0.03	2.88	0.00^{***}
D_1	0.17	5.06	0.00^{***}
R^2	0.61		
Adjusted - R^2	0.58		
F- value	26.99		

*Significant (P = 0.10), **Significant (P = 0.05), *** highly significant (P = 0.01)

Results suggested that out of eight variables, six variables were significant at significance level $P \leq 0.10$. According to the results, coefficient for land preparation cost was positive and significant at significance level ($P \leq 0.05$). The value of coefficient implies that one percent increase in expenditure on land preparation will lead to 0.10 percent increase in Bt cotton yield. Coefficient for seed cost (0.06) was found positive and significant at ($P \leq 0.10$), which implies that Bt cotton yield will increase by 0.06 percent with one percent increase in expenditures on seed (Table 2).

The coefficient of fertilizer cost was significant at the same significance level and indicated that one percent increase in the expenditures on fertilizer will lead to 0.11 percent increase in the Bt cotton yield. The coefficient for spray and irrigation variable were positive but significant at 13 percent and 18 percent level of significance, respectively. The non significance of spray variable may be due to the attack of Cotton Leaf Curl Virus (CLCV) and milly bug in cotton crop. Coefficient for labour cost was positive and significant at 5 percent level of significance

which implies that one percent increase in expenditures on labour operation will lead to 0.10 percent increase in Bt cotton yield. The coefficient for education was 0.03 with a significance level of less than 1 percent which implies that one percent increase in education of farmers will lead to 0.03 percent increase in Bt cotton productivity (Table 2).

The coefficient of dummy variable for soil quality was highly significant at less than 1 percent significance level indicating that Bt cotton productivity as explained by the explanatory variables increased by 0.17 percent due to good quality soil for the sampled farmers (Table 2). Same results were found by Masterson (2007) who estimated that crop yields were significantly greater with better soil quality and higher soil quality was estimated to significantly increase land productivity.

Conclusions

Most of the factors studied were found contributing positively towards higher Bt cotton yield. However, effects of education, fertilizer cost, land preparation cost, labour cost, seed cost and soil quality were substantially significant. The dummy variable for soil quality was also found as another important factor contributing towards higher Bt cotton yield which showed the importance of soil quality and fertility for achieving higher crop production.

This is suggested that farmer should take interest in managing soil quality of land to get higher yield. Government should also play its role in maintaining soil quality of lands in the country by providing easy access to farm inputs especially gypsum, fertilizer and organic matter which help in maintaining the soil quality. Extension system established by government should emphasize to educate the farmers about scientific and practical methods to improve quality of their soils for better agricultural productivity. Field visits and demonstration by extension department could be right steps in this way.

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