Economic Performance of Bt Cotton Varieties in Pakistan

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Abstract

Farmers in Pakistan have been growing cotton that contains the first generation of Bt gene since 2002. The cultivation of these varieties, although formally unapproved and unregulated, increased rapidly after 2005. In 2007, nearly 60 percent of the cotton area was under BT varieties. This paper examines the economic performance of Bt cotton in Pakistan based on data collected through a structured questionnaire survey in January-February 2009 in two districts (Bahawalpur and Mirpur Khas). The extent of the impact of Bt cotton on costs of production and yield gains are different across the two districts with their diverse agro-climatic conditions and pest pressures. Seed expenditures increase in both districts, but a decline in the number of bollworm sprays and hence in the expenditure for pesticides is observed and total pesticide control costs (for bollworms and non bollworm pests) declines in both districts. Total production costs decline in Bahawalpur but rise in Mirpur Khas. The yield increases are higher in Mirpur Khas as well, resulting in total revenue and gross margins improving more than in Bahawalpur. The results are similar to other studies of Bt cotton in India and suggest gains for Pakistan from progressing to a regulated national market for Bt cotton technologies.

Key words: *Bt cotton, economic performance, Pakistan, Bahawalpur, Mirpur Khas*

1. Introduction

Cotton production is important to Pakistan's agriculture and to the overall economy. Nearly 26 percent of all farmers grow cotton, and over 15 percent of Pakistan's total cultivated area is devoted to this crop, with production concentrated in two provinces: Punjab (80%) and Sindh (20%) (Government of Pakistan, 2003). Cotton and its intermediate and final products (such as, yarn, textiles and apparel) contribute significantly to the gross domestic product (8%), total employment (17%), and foreign exchange earnings (54%) in Pakistan (Government of Pakistan, 2009a; 2009b). Pakistan is the fourth largest producer and the third largest consumer of cotton in the world. The cotton-textile sectors have important implications for national economic performance and poverty reduction (Cororaton and Orden, 2008).

Since the early 1990s cotton production in Pakistan, has been facing the challenge of large scale pest infestation contributing to unexpected fluctuations in cotton yield and significant economic losses. A wide range of pesticides has been introduced to control various cotton pests during the last 15 years, which has notably increased the cost of cotton production. Moreover, as the pests' developed resistance to these chemicals, their effectiveness declined over time.

Given the economic importance of this crop, cotton research has always received high priority in Pakistan. The primary objective of cotton research has been to develop new cotton varieties that are resistant to pests, heat, and drought, and have high yield potentials with desirable fiber characteristics. Despite various research efforts, Pakistan has been suffering from huge economic losses due to persistent pest attacks on the cotton crop. Estimated losses vary from 10-15 percent in a typical year to 30-40 percent in a bad crop year (Salam, 2008).

The introduction of genetically modified (GM) cotton offers significant promise for addressing the issue of crop loss by controlling some of the pest infestation. Pakistan started work on the development of GM cotton in 1997. Despite various administrative and research efforts[1] that are required to commercialize a GM crop, Pakistan had not commercially adopted Bt cotton by late 2009. This delay has resulted in the unregulated adoption of Bt-type cotton. Estimates show that about 60 percent of the cotton growing area was under these varieties in 2007; 50 percent in Punjab and 80 percent in Sindh. Nearly 40 varieties of Bt cotton were under cultivation (PARC, 2008).

A few studies have attempted to make preliminary comparisons of the performance of existing Bt type varieties with the recommended non-Bt varieties in Pakistan based on semi-structured questionnaires and informal interviews (Hayee, 2004; Sheikh *et al.*, 2008; Arshad *et al.*, 2009). These studies observe a relatively poor performance of existing Bt cotton compared to the recommended conventional varieties. In addition to these studies, the Pakistan Agricultural Research Council (PARC) conducted a detailed scientific survey on 126 locations in 21 districts in 2007. This survey examined the presence of Bt content in claimed Bt plants. The laboratory results indicate that about 10 percent of the sample in Punjab and 19 percent in Sindh were not positive for the 'Cry' protein[2]. However, to the best of our knowledge, existing studies do not provide an evaluation of the economic performance of unapproved Bt varieties compared to the conventional varieties in Pakistan. This paper provides an economic analysis to bridge this gap.

[1] The Biosafety Rules and Biosafety Guidelines were approved in 2005, the Pakistan Intellectual Property Right Organization was established in 2005. In addition, successful field trials of domestically developed Bt varieties have also been conducted (Rao, 2006).

[2] The Bt gene produces various proteins. Among them, the crystalline proteins, prefixed with 'Cry' are harmful for the larvae of moths and butterflies, beetles and flies and thus act as a natural pesticide.

The analysis is based on survey of cotton farmers, conducted during January-February 2009 in two districts of Pakistan.

Internationally, many studies have analyzed the impact of Bt cotton in developing countries (see for example, Pray *et al.,* 2001; Huang *et al.,* 2002; for China; Ismael *et al.,* 2002; Thirtle *et al.,* 2003; for South Africa; Qaim and de Janvry, 2003 for Argentina; Traxler *et al.,* 2003 for Mexico; and Qaim, 2003; Qaim and Zilberman, 2003; Orphal, 2005; Gandhi and Namboodiri, 2006; for India). Results from these studies suggest that these countries experienced a decline in pest infestation and enjoyed stable and higher yields and higher profits after the adoption of Bt cotton.

Despite encouraging performance reported in the studies cited above, the use of Bt cotton remains highly controversial in many developing countries. We focus on the experiences from India as those are most relevant for Pakistan. A large number of cotton farmers committed suicide in India during the period 2002-2006. Some groups argued the introduction of Bt cotton to be the main reason for these suicides. The farmers had allegedly accumulated debts to buy expensive Bt cotton seed and the subsequent crop failures[3] drove them to destitution. Some groups blamed Bt cotton as the cause of death of sheep flocks grazing on cotton fields[4]. Some activist groups challenged the effectiveness of Bt cotton in terms of higher cost of production

[3] Several news items and some studies conducted by the NGOs indicate that the Bt cotton is the main reason of farmers' suicide (Qayum and Sakkhari, 2005), whereas, the in-depth analysis based on the published data and empirical studies, Gruère *et al.* (2008) have not found any connection between farmer suicides and Bt cotton.

[4] "Mortality in Sheep Flocks after Grazing on Bt Cotton Fields – Warangal District, Andhra Pradesh". Report of the Preliminary Assessment April 2006, http://www.gmwatch.org/archive2.asp?arcid=6494

and lower yield than the non-Bt varieties (Qayum and Sakkhari, 2005)[5]. Due to close geographical proximity and similarities in production and cultural practices, the Indian experiences created controversies and apprehensions about the Bt cotton adoption in Pakistan[6].

The performance of Bt cotton depends on the agro-climatic conditions, genotype of the variety and cropping practices. A well-performing Bt variety in one area may not produce desired results if grown in a different agro-climatic zone. Therefore, only approved Bt varieties, which are tested for the local agro-climatic conditions, are recommended for use. A country has to follow bio-safety guidelines to approve a Bt variety for commercial use. In Pakistan, the Bt varieties were developed by various private sector plant breeders through crossing Bt material with local germ-plasm so that the Bt trait is transferred to locally developed cotton varieties[7]. These varieties are distributed without a formal regulatory framework which raises several concerns about seed quality, awareness among farmers, and the possible impacts on human and animal health, and biodiversity. Six of these varieties were approved for field trials in 2009 and expected to be released for commercial use in 2010. The lack of in-depth research about the economic performance of these Bt varieties relative to conventional varieties, and the Indian reports about farmers' suicide, death of sheep flocks and lower profitability raise apprehensions about the commercial adoption of Bt cotton in Pakistan. The civil society organizations and NGOs are holding demonstrations against the commercial adoption of Bt cotton by citing the Indian examples. Given these circumstances, this paper presents a much needed assessment of the

[5] Analysing the findings presented to support these claims and comparing with the results of empirical studies, Herring (2009) points out that the reports portraying the negative picture of Bt cotton are inconsistent with both farmers' behaviour and scientific studies.

[6] For example, in Financial Post, May 12, 2008, Najma Sadeque wrote "After a disastrous track record in 40 countries, Bt cotton is 'welcomed' in Pakistan". Actually only 10 countries adopted Bt cotton commercially by the end of 2008.

[7] Most of these Bt varieties contain the Cry1Ac gene, developed from Monsanto's transforming event MON531 (commonly known as Bollgard).

performance of unapproved Bt cotton varieties some of which have already been approved for field trials in 2010. This paper is divided in four sections. Section 2 describes the data collection methodology. The analysis of the economic performance of Bt cotton in Pakistan is presented in Section 3. Section 4 focuses on policy implications of the results and concludes the paper.

2. Data and Methods

To examine the economic impact of the adoption of unapproved Bt varieties on costs of production and yields, a questionnaire-based survey "Bt Cotton Survey 2009" was conducted during January-February 2009 in two cotton growing districts of Pakistan: Bahawalpur in province Punjab; and Mirpur Khas in province Sindh[8]. The selected sample is drawn from the existing sampling frame of the panel survey, the Pakistan Rural Household Survey (PRHS)[9]. Out of four cotton districts in the PRHS, Bt Cotton Survey 2009 was conducted in two districts where the number of cotton growers was sufficient in the sample. This survey covered 8 villages and 104 cotton growers in each district. This gives a total sample of 208 cotton growers in 16 villages of two districts. In each village 13 cotton growers were surveyed.

The cotton growing areas of Pakistan can be divided into six zones on the basis of rainfall and temperature. Because of weather differences, the pressure of pests is different in these zones (Soomro and Khaliq, 1996). The selected districts have different agro-climatic conditions in terms of rainfall, minimum and maximum temperature, and humidity. Because of these differences, the pest pressure on the cotton crop is also different. Low temperature and high

[8] The national statistics indicate that Bahawalpur produces 11 percent of Punjab's cotton and Mirpur Khas accounts for 11 percent of cotton produced in Sindh (Government of Pakistan, 2006). The Bt Cotton Survey 2009 received financial supported from Innovative Development Strategies, Islamabad and the Institute for Society, Culture and Environment, Virginia Tech, Alexandria, Virginia. PARC provided essential in-kind support for the field research.
[9] This survey was conducted jointly by the World Bank and Pakistan Institute of Development Economics (PIDE).

relative humidity cause an increase in the bollworm population and decline in the population of sucking pests. Bahawalpur has hot and dry climate and Mirpur Khas has hot and humid climatic conditions. Average rainfall is low in both districts. Approximately two-thirds of the Bahawalpur district is covered by desert. The quality of soil is mostly sandy in Bahawalpur and clay in Mirpur Khas. Canals are the main source of irrigation in both districts. The selected districts may not represent all cotton growing areas of Pakistan. However, an attempt is made to capture the diversity of cotton growing areas in terms of pest pressure through the selection of these districts.

The questionnaire was designed to collect relevant information on individual (age, education), household (household size, number of dependents), and farm (size of farm, type of tenure) characteristics. In addition, data on cost of inputs, cotton output, and revenue from cotton sale were collected. The sample was comprised of Bt adopters as well non-adopters. A comparative analysis of the economic performance of Bt and non-Bt cotton in Pakistan is developed from this data set.

3. Results

The data indicates that the majority of farmers are small. Nearly 81.6 percent of the surveyed farmers operate less than 12.5 acres of land. Most of them are concentrated in the category less than 5 acres in both districts. These districts differ in the type of land tenure. A majority of owner farmers is concentrated in Bahawalpur (77.9%) and most of the sharecroppers are in Mirpur Khas (73.1%). The land distribution in Pakistan, particularly in Sindh, is highly skewed. As a result, a large number of landless households and small owners are tied into sharecropping arrangements (World Bank, 2002). Such arrangements are based on the prior understanding

between the owner and the tenant about inputs and output. A majority of the sharecroppers in the present survey indicate that the landlord provides 50 percent of the inputs except labour and the sharecropper is responsible for 50 percent of the inputs and their timely use. Output is divided on 50-50 basis. Most of the surveyed farm families have been growing cotton for generations.

The adoption of Bt cotton increased rapidly during 2006-2008 in both districts. In 2006, the adoption rate in Bahawalpur was higher (36%) than Mirpur Khas (32%). However, in 2008, about 87 percent of the farmers in Mirpur Khas cultivated Bt cotton whereas this proportion was 74 percent Bahawalpur.

The Bt Cotton Survey 2009 asked some qualitative questions about the performance of Bt cotton. A large number of sampled farmers indicate that because of higher price of seed and higher use of fertilizer and water, the cost of production is higher for Bt varieties relative to non-Bt varieties. However, the decline in the intensity of bollworms increased the yield and they are able to earn larger profits. The level of awareness about Bt technology and its use is extremely low in both districts. Most of the farmers in both districts do not know the name of seed variety or the seed company. Most of the farmers do not have any knowledge about the importance of seed quality and the refuge area[10]. To examine the performance of Bt and non-Bt cotton, this section compares the differences in cost of production, yield and gross margin for both varieties. To evaluate the significance of the differences in the mean values of these variables, two-group mean-comparison tests are performed.

[10] Farmers are encouraged to plant a certain fraction of their cotton area with conventional varieties or with some other crop. This area is called refuge area. On these non-Bt refuges, Bt-susceptible insects remain unharmed, so they can mate with the resistant insects that survive on the nearby Bt plot and produce non-resistant insects. The refuge area is especially important in the regions where most of the cultivated area is covered by one crop.

3.1 Impact on pesticide, seed and other expenditures

Pesticide expenditure

Farmers adopt Bt cotton because of its resistance against pests. About 92.9 percent of the respondents who are not using Bt cotton reported the infestation of bollworms. Among them, 58.9 percent indicate the high intensity of this infestation. Nearly 35.9 percent of Bt adopters also report the infestation of bollworms. However, the infestation intensity was moderate to low. A majority of farmers report the attack of cotton leave curl virus (CLCV) and mealy bug irrespective of the variety they used. As mentioned earlier that the laboratory tests of the samples of Bt cotton grown in Pakistan indicates the presence of Cry 1Ab/Ac in most of the samples. However, the intensity varies from low to high, indicating the possibility of seed mixing (PARC, 2008). In the Bt Cotton Survey 2009, the possibility of spurious seed, as identified by the key informants, cannot be ruled out as one of the reasons why in 35.9 percent of the cases, the Bt variety is not effective for bollworms.

Table 1 reports the means and standard deviations of the number of pesticide sprays and pesticide expenditure per acre by pest groups on Bt and non-Bt cotton in Bahawalpur and Mirpur Khas. Pests are divided in two groups: bollworms, includes spotted, pink, American and armyworm; and non-bollworms, includes all other pests, such as, white fly, mealy bug, aphids, jassids and others. This table shows a significant difference in the number of sprays on bollworms in both districts. In Bahawalpur, farmers spray 1.5 times on Bt varieties against 2.6 times on non-Bt varieties. This number is 1.18 and 2.67 for Bt and non-Bt varieties in Mirpur Khas. As a result, the bollworm pesticide expenditure for Bt varieties is significantly lower for Bt varieties as compared to non-Bt varieties in both districts. No significant difference in the

number of sprays or non-bollworm pesticide expenditure has been found in both districts. Because of the much lower expenditure on bollworms, total pesticide expenditure appeared significantly lower on Bt varieties (2,555 Rs/acre in Bahawalpur and 1,929 Rs/acre in Mirpur Khas) than on non-Bt varieties (3,238 Rs/acre in Bahawalpur and 2,636 Rs/acre in Mirpur Khas). However, the difference in the total number of sprays is statistically insignificant in both districts. The quantity of pesticide used per spray can reflect a better picture of the expenditure on pesticide. This survey, however, has not collected this information.

Seed usage and expenditure

The conventional varieties of cotton require 8 to 10 kg of cotton seed per acre. This requirement is lower for Bt seed[11]. However, our survey data shows that the quantity of seed used is not significantly different for both varieties. This may be due to the fact that most of the farmers are receiving seed without proper instructions. The survey results reported in Table 2 show that in Mirpur Khas, farmers, in general, use a lower amount of seed (5.9 kg/acre of Bt and 6.1 kg/acre of non-Bt), whereas in Bahawalpur, this amount is close to the recommended amount of conventional varieties (7.6 kg/acre for Bt and 7.7 kg/acre for non-Bt). Low values of standard deviation indicate little variation in the use of seed in both districts. The survey finds that Bt seed is more expensive than the non-Bt seed. In Bahawalpur, the reported average price of Bt seed was Rs 180.9/kg, that is significantly higher than the price of non-Bt seed (Rs 107.7/kg). This price difference is higher in Mirpur Khas (Rs 195.3s/kg for Bt and Rs 110/kg for non-Bt). Both types of seeds are expensive in Mirpur Khas as compared to Bahawalpur (see Table 2). The difference in price is reflected in the expenditure on seed. Because of the lower use of seed in Mirpur Khas, the seed expenditure in this district is less than the expenditure in Bahawalpur.

[11] For example, the seed requirement for a recently approved (not commercialized) variety, AS-803 is 5-7 kg/acre.

However, the expenditure on Bt seed in both districts is significantly higher than that on the conventional varieties. As stated earlier the results of Bt Cotton Survey 2009 may not be comparable across districts, but within districts, they show a consistent pattern.

Other expenditures

Table 3 provides the comparative information on the expenditure on fertilizer, cotton picking and other items, such as, land preparation, sowing, irrigation and other labour charges of Bt and Non-Bt cotton across both districts. The table indicates that the expenditure on fertilizer and cotton picking is higher for Bt varieties in both districts. This difference is significant for fertilizer in Bahawalpur and for cotton picking in Mirpur Khas. Farmers in Bahawalpur spent 358 Rs/acre more on fertilizer for Bt varieties.

The flowering of the cotton plant generally starts one and half month after its planting. Blooming continues regularly for several weeks. It takes about two months between the blooming of the flower and the first opening of bolls. Cotton picking starts with the opening of bolls. The planting period of cotton in Pakistan is from April to June. Picking starts in August and continues until December. In Pakistan, cotton is picked manually; mostly by women and children. Cotton pickers are hired and payments are generally made in kind. Pickers are usually paid $1/16^{th}$ share of the harvest, i.e., 2.5 kg per 40 kg of the harvest. Some of the farmers make cash payment that is equivalent to the share of harvest mentioned above.

In the Bt Cotton Survey 2009, a majority of the farmers in Mirpur Khas planted cotton in April and picking started in early August. In Bahawalpur cotton was sown in May and picking started

by September. The number of pickings differs between the districts. Cotton was picked two to three times in Bahawalpur and three to five times in Mirpur Khas. This survey collected information on the price of cotton received after the sale of each picking. To compute the picking expenditure, the average price of all pickings is used to calculate the value of $1/16^{th}$ share of total harvest. The surveyed farmers indicated more bolls per plant for Bt varieties than non-Bt varieties. This is reflected in the higher expenditure on the picking of Bt cotton than non-Bt cotton. The difference in picking expenditure is statistically insignificant in Bahawalpur and significantly higher in Mirpur Khas[12]. All other expenditures include expenditure on land preparation, sowing, irrigation, labour cost for different operations, etc. No significant difference across Bt and non-Bt varieties in both districts has been observed for these expenditures.

3.2 Impact on total expenditure, yield, revenue and gross margin

The comparison of per acre total expenditure, yield, revenue and gross margin is reported in Table 4. The revenue is computed by using the quantity sold and the price prevailing at the time of sale as reported by the farmer. The sample includes a large number of sharecroppers who share the harvest and input expenditure with the landlord on a 50-50 basis. Total expenditure and revenue for this group is calculated on the basis of their shares of production costs and output revenue. Table 4 reports the expenditure and revenue adjusted for the sharecroppers. Gross margin is the difference between adjusted revenue and adjusted total expenditure. Table 4 shows that the expenditure on Bt and non-Bt cotton are not statistically significant. However, these differences are statistically significant between districts (not shown in Table 4).

[12] Since expenditure on cotton picking is paid as a fraction of yield. Higher the yield, higher will be the $1/16^{th}$ share that will be paid as picking expenditure.

This table shows that total expenditure, yield per acre, revenue and gross margins are significantly higher for Bt varieties in Mirpur Khas whereas in Bahawalpur no significant difference has been observed. The Bt Cotton Survey 2009 has not found any difference in the price of Bt and non-Bt cotton. However, the higher yield of Bt cotton gave higher revenue in both districts. Resultantly, Bt varieties appeared more profitable.

3.3 Performance of Bt versus non-Bt cotton

Table 5 summarizes the results of tables 1 to 4. These results show a relatively better performance of the existing unapproved varieties of Bt cotton that contain the first generation of the Bt gene. The number of bollworm sprays declined by 1.2 on average; 1.1 in Bahawalpur and 1.5 in Mirpur Khas. Because of the higher number of sprays for non-bollworms, total number of sprays decline by 0.3 only. The total pesticide expenditure declined by 21.1 percent in Bahawalpur, and 26.8 percent in Mirpur Khas. This decline is mainly driven by a substantial decline in the expenditure on bollworms sprays. This indicates the effectiveness of existing Bt varieties in controlling the bollworms. This result is comparable with Bennet *et al.* (2006a) who found a similar decline in Maharashtra, India. The results show that Mirpur Khas experienced a much higher increase in yield per acre from Bt varieties as compared to non-Bt varieties (39.3%) than Bahawalpur (5.9%). Table 4 indicates that the yield increase in Bahawalpur is not statistically significant. Sheikh *et al.* (2008) also found no significant difference in the yield of Bt and non-Bt varieties in Punjab. Despite higher expenditure on seed, fertilizer and cotton picking, the total expenditure on Bt varieties was 5.3 percent lower than non-Bt varieties in Bahawalpur. Whereas in Mirpur Khas, Bt varieties incur higher expenditure. A higher yield and the same

price for both varieties resulted in a higher gross margin that is Rs 2,224/acre higher in Bahawalpur and Rs 5,777/acre higher in Mirpur Khas.

It is useful to compare the results for Pakistan with other countries. Table 6 provides a comparison of the performance of unapproved Bt varieties in Pakistan with the performance of approved Bt varieties in India and China. This table shows that the difference in pesticide expenditure, yield and gross margins in Pakistan is comparable with both these countries. Like Pakistan, India also exhibits regional differences in the performance of Bt cotton. However, the difference in seed price of Bt and non-Bt varieties is much lower in Pakistan as compared to India and China. This may be attributed to the difference in approved and unapproved varieties.

4. Conclusions

This paper examines the performance of unapproved Bt varieties in Pakistan. The analysis is based on the data collected through structured questionnaires in January-February 2009 in two cotton growing districts of Pakistan; Bahawalpur and Mirpur Khas. This survey covers 208 cotton growers in sixteen villages in these districts. The agro-climatic conditions of these districts are different; Mirpur Khas is hot and humid and Bahawalpur is hot and dry. This survey finds high adoption of available Bt varieties in both districts. A majority of surveyed farmers, both sharecroppers and owner operators, are using this technology.

Contrary to the findings of earlier studies (Hayee, 2004; Sheikh *et al.,* 2008; Arshad *et al.,* 2009), the results of this study show a relatively better performance of the existing unapproved varieties of Bt cotton that contain the first generation of Bt gene compared to conventional (non Bt)

varieties. A decline in the number of bollworm sprays hence in the expenditure of pesticides has been observed. Both districts experienced a decline in pesticide expenditure and an increase in expenditure on seed, fertilizer, and picking. An increase in yield is observed in both districts that resulted in a higher gross margin for Bt varieties. The extent of the impact of Bt cotton on cost of production and yield are different across districts. For example, the number of non-bollworm sprays increased in Bahawalpur whereas it declined in Mirpur Khas. Total expenditures declined in Bahawalpur by 5.3 percent and increased in Mirpur Khas by 37.5 percent. Bahawalpur experienced a yield increase by 5.9 percent and Mirpur Khas by 39.3 percent. This resulted in differences in total revenue and gross margins.

Farmers' knowledge about the use Bt seed is extremely limited. They do not know about the quality of seed or the importance of refuge areas. The increased incidence of secondary pests, such as, CLCV and mealy bug, in last five year may be the result of using Bt varieties without leaving a refuge area, improper use of inputs by farmers, the use of non-CLCV resistant varieties to transfer the Bt gene, etc. These findings are consistent with the results from other developing countries. To control the crop losses and spread of secondary pests, there is an urgent to commercialize the approved varieties.

Despite a small sample, this paper captures the agro-climatic diversity in the selected districts and points out different effects of Bt cotton in different intensities of pest pressure. Due to high diversity of cotton growing areas, more location-specific information and larger sample size is required to capture the impact of Bt technology in the cotton growing areas of Pakistan.

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Table 1: Number of pesticide sprays and pesticide expenditure on Bt and non-Bt varieties

	Bahawalpur			Mirpur Khas		
	Bt	**Non-Bt**	**t-values**	**Bt**	**Non-Bt**	**t-values**
Bollworm sprays	1.54	2.60	-6.26***	1.18	2.67	-7.42***
	(0.91)	(0.70)		(0.39)	(0.78)	
Bollworm pesticide expenditure (Rs/acre)	1,846	3,488	-6.56***	1,259	2,667	-2.74***
	(1,211)	(1,226)		(1,099)	(1,917)	
Non-bollworm sprays	4.04	3.88	0.63	3.12	3.50	-0.95
	(1.33)	(1.24)		(1.32)	(1.09)	
Non-bollworm pesticide expenditure (Rs/acre)	3,073	2,993	0.22	2,093	2,605	-0.87
	(1,989)	(1,717)		(1,975)	(1,242)	
Total sprays	2.98	3.25	-1.24	2.74	3.08	-1.12
	(1.70)	(1.19)		(1.43)	(1.02)	
Total pesticide expenditure (Rs/acre)	2,555	3,238	-2.88***	1,929	2,636	-1.73*
	(1,804)	(1,507)		(1,862)	(1,580)	

Note: Bollworm pesticide refers to pesticides that are used to control bollworm, while non-bollworm pesticides are used for other pests, such as, white fly, mealy bug, aphids, jassids, etc.
Results are means. Figures in parentheses are standard deviations.
***, **, * denote statistical significance at the one percent, five percent and 10 percent levels, respectively.

Table 2: Quantity, price and expenditure of Bt and non-Bt seed

	Bahawalpur			Mirpur Khas		
	Bt	**Non-Bt**	**t-values**	**Bt**	**Non-Bt**	**t-values**
Quantity (kg/acre)	7.6	7.7	-1.023	5.9	6.1	-0.281
	(1.3)	(1.5)		(2.3)	(1.9)	
Price (Rs/kg)	180.9	107.7	5.771***	195.3	110.0	6.017***
	(75.3)	(47.0)		(48.4)	(43.9)	
Expenditure (Rs/acre)	1,318	838	5.097***	1,149	652	2.954***
	(536)	(406)		(593)	(330)	

Note: Results are means. Figures in parentheses are standard deviations.
***, **, * denote statistical significance at the one percent, five percent and 10 percent levels, respectively.

Table 3: Expenditures on fertilizer, irrigation, picking and other items of Bt and non-Bt cotton

	Bahawalpur			Mirpur Khas		
	Bt	**Non-Bt**	**t-values**	**Bt**	**Non-Bt**	**t-values**
Fertilizer expenditure (Rs/acre)	3,020	2,663	2.535***	2,819	2,532	1.022
	(749)	(717)		(977)	(716)	
Picking expenditure (Rs/acre)	1,811	1,711	0.864	1,965	1,411	4.145***
	(629)	(566)		(461)	(367)	
All other expenditures (Rs/acre)	3,166	2,929	1.094	2,182	2,224	-0.010
	(1,280)	(857)		(836)	(1,133)	

Note: Results are means. Figures in parentheses are standard deviations.
***, **, * denote statistical significance at the one percent, five percent and 10 percent levels, respectively.

Table 4: Total expenditure, yield, revenue and gross margin of Bt and non-Bt cotton

	Bahawalpur			Mirpur Khas		
	Bt	**Non-Bt**	**t-values**	**Bt**	**Non-Bt**	**t-values**
Total expenditure (Rs/acre)	13,557	14,157	-0.775	6,812	6,519	0.278
	(4,327)	(3,491)		(3,742)	(1,644)	
Yield (kg/acre)	808	763	0.864	877	629	4.145***
	(281)	(253)		(206)	(164)	
Revenue (Rs/acre)	28,192	26,568	0.811	20,022	13,953	2.695***
	(10,256)	(10,823)		(7,963)	(3,903)	
Gross margin (Rs/acre)	14,634	12,411	1.212	13,210	7,433	3.428***
	(9,525)	(9,705)		(5,909)	(3,631)	

Note: Results are means. Figures in parentheses are standard deviations.
Expenditures, revenue and gross margin are in Rs/acre and yield is in kg/acre.
***, **, * denote statistical significance at the one percent, five percent and 10 percent levels, respectively

Table 5: Comparison of costs, yield, revenue and gross margin between Bt and non-Bt varieties in Pakistan

	Bahawalpur	Mirpur Khas	Average
Number of boll worm sprays	-1.1	-1.5	-1.3
Number of non-bollworm sprays	0.2	-0.4	-0.1
Number of total sprays	-0.9	-1.9	-1.4
Expenditure on bollworm pesticide (%)	-47.1	-52.8	-49.3
Expenditure on non-bollworm pesticide (%)	2.7	-19.7	-12.8
Expenditure on pesticides (%)	-21.1	-26.8	-27.1
Expenditure on seed (%)	64.9	76.3	29.0
Total expenditure (%)	-4.2	4.5	-7.1
Yield (%)	5.9	39.3	15.6
Revenue (%)	6.1	43.5	0.04
Gross margin (Rs/acre)	2,224	5,777	3,617

Note: Number of sprays and gross margin are in simple difference. Expenditure figures are percentage differences.

Table 6: Comparison of Pakistan's unapproved Bt varieties with China and India's approved Bt Varieties

		Percentage difference in Bt and non-Bt varieties				Gross margin (US$/ha)	
	# of sprays	Pesticide cost	Seed cost	Total cost	Yield	Bt	Non Bt
China (2001)	--	-58.1	333.3	-27.5	10.9	277	-225
India (2006)							
Gujrat	--	--	136.8	13.7	35.4	715	407
Maharashtra	-1.9	-21.3	192.4	36.5	46.3	504	319
Andhra Pradesh	-3.8	-25.8	173.1	5.6	44.6	420	121
Tamil Nadu	-2.0	-54.5	237.0	13.7	28.5	340	129
Pakistan (2009)							
Bahawalpur	-0.9	-21.1	64.9	-4.2	5.9	452	384
Mirpur Khas	-1.9	-26.8	76.3	4.5	39.3	408	230

Source: Huang *et al.* (2002) for China, Gandhi and Namboodiri (2006) for India, and Bt Cotton Survey 2009 for Pakistan.