Determinants of Economic Analysis of BT Cotton V/S Non-BT Cotton in Tando Allahyar Sindh, Pakistan

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Keywords: BT Cotton, Conventional cotton, Technology, Resource, Efficiency, Sindh

Posted Date: October 18th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-965001/v1

Abstract

Adoption of certified and improved high-yielding varieties is a critical strategy for farmers in developing nations to increase agricultural productivity and living circumstances. The goal of this research was to investigate the factors that influence the adoption of improved cotton varieties by small-scale farmers in Tando Allahyar area of Sindh, Pakistan. In this study, Tando Allahyar area was selected, which is the main area of cotton cultivation. With the help of specially designed questionnaires, Bt cotton and non-Bt cotton data were collected from Better cotton registered farmers through personal interviews. Data were collected by simple random sampling. Descriptive and probabilistic regression models were used for data analysis. The empirical results showed that year of age (P≤ 0.000), House hold size (P≤ 0.092), farm machinery ownership (P≤ 0.000), distance to market (P≤0.005), access to market information (P≤0.003) and ground water quality (P≤ 0.000) had significantly positive influence on adoption of Bt cotton and non-Bt cotton verities, while age (P≤ 0.053) had significantly negative effect, while farming experience (P ≤-0.000), had significantly negative effect.

Introduction

Pakistan is the fourth-largest cotton producer in the world and Asia's third-largest spinning potential (after China and India) with thousands of ginning and spinning cotton textile mills. Estimated 1.5 million cotton-dependent smallholders (BCI, 2019). Cotton (*Gossypium: Hirsutum*), called "White Gold," is a significant source of economic viability of non-food cash crops and plays an important role in economic development. It is the largest source of raw materials for the basic agricultural textile industry. Pakistan is the world's fifth largest producer, fourth largest consumer, fourth largest fiber and third largest raw cotton exporter. Cotton provides 45% of labor employment and 60% of foreign exchange income, and it occupies more than 1.5 million agricultural households that contribute to the country’s exports in the form of raw cotton, yarn cotton and other by-products. The share of cotton crops in GDP is 1.0%, and its share in agricultural value-added is 5.5% (GOP, 2018).

Cotton production is an increasing number of diseases and insect attacks in Pakistan. Due to their inability to accept any financial risk, Pakistan's small farms are particularly susceptible to pests and diseases. Pesticides, which account for 33 percent of cotton production expenses, are critical inputs (Sarangdhar and Pawar, 2017). Cultivation of *Bacillus thorionensis* (Bt) cotton is resistant to common cotton bollworm pests and is regarded as the solution to recent challenges associated with the cotton bollworm.

Bt cotton badge incorporates the gene for soil bacteria *Bacillus thuringiensis*. This gene contains a natural toxin to many insects and pests, particularly bollworm pest. His backers also claim that using such cotton seed will reduce pesticide use and, in effect, have significant environmental effects. It indicates that countries such as the United States, Australia, China, Mexico, Argentina, South Africa and India, which allowed commercial cultivation of Bt cotton products, have lower pesticide consumption and costs in terms of success and profits (Fitt, 2003; Kranthi and Stone, 2020; Luttrell and Jackson, 2012;

Nava-Camberos et al., 2019; Qiao et al., 2017). Nevertheless, experiments indicate Bt cotton adopters overuse pesticides (Gong et al., 2016; Liu and Huang, 2013). It relates particularly to smallholders whose livelihoods are primarily dependent on cotton income.

Given the growing importance of Bt cotton to developing countries economies, particularly Pakistan's cotton planting system, our research tries to address three questions. (A) Will the use of Bt cotton minimize the use of pesticides in cotton production? (B) Are the costs and disadvantages of Bt cotton consumers greater than those of non-Bt cotton consumers? (C) Are fertilizer, labor and irrigation water input costs for Bt cotton higher than non-Bt cotton? This research aims to determine the average effect of adoption on growth, expense, and benefit.

(*Gossypium: Hirsutum*) cotton is a world's foremost fiber, along with natural crop covering one of the world's largest textile industries carry out yearly fiscal impact of at least $600 billion worldwide (Ashraf et al., 2018). Cotton is grown more than one hundred countries in the world, it's estimated that more than one hundred million farmers produce in the world, China, USA, India, Pakistan and Brazil are the top producing countries. Cotton production in Pakistan's marketing year 2018/19 to 2019/20 is estimated at 8.0 million 480 pounds bales, which will add 500,000 bales to the revised valuation. Rabi and kharif are the two crop seasons in Pakistan; kharif crops include rice, sugarcane, cotton and maize, maize, maize. A crucial non-food kharif crop, cotton is India's principal source of foreign exchange profits, while agriculture is the country's backbone and it's most important industry. Agriculture is directly responsible for 26 percent of the gross domestic product (Rehman et al., 2015). In global production Pakistan accounts for the fourth major share, forecast indicates in the future by 2027 Pakistan will produce 2.4 Mt of cotton. 1.4% annually Production will boost, as a result of area development and yield improvements. Similarly, Pakistan, India is estimated to realize more rapidly growth in the cotton area than in other crops (FAO, 2018). Cotton is usually developed in the two areas of Punjab and Sindh, with the previous representing for 74.7% and the latter for 24.6% of the nation's cotton growing land, it is moreover grown in Balochistan and Khyber Pakhtunkhwa (KPK) provinces. After China, India and the United States, as the world rankings have come to the forefront of 2017/18 Pakistan has won the fourth position, beating Brazil, Uzbekistan, Australia, Turkey, Argentina and Turkmenistan. The quantity of cotton produced in the country is important for economy growth; Pakistan's annual output has increased by 6.5+ million metric tons and has an area of 3.3 million hectares. During the kharif season, it covers 15% of Pakistan's cultivation in the land, during the monsoon months the kharif season is from May to August. Industrial crops are mainly cultivated in Punjab and Sindh. Since the demand for cotton is increasing especially in Bt cotton, its production in the country is also better as compared to past decades (RS News, 2018).

The negative impact of GM crops in developing countries remains a controversial issue. Although previous studies have tested the direct loss of productivity of Bt cotton and specific genetically modified crops, there is insufficient understanding of the general socioeconomic results (Subramanian and Qaim, 2010). This is of exceptional monetary value in the agricultural and industrial activities in Pakistan, the lives of hundreds of thousands of farmers depend on the cotton crop, and millions more are employed in cotton. In addition, cotton seeds account for 35% of the total edible oil production (Arshad et al., 2007).

The quarterly of the crops worked correctly and showed an increase of 3.83 percent compared with the end of the year by 0.91 percent. The progress of sub-sectors, essential crops, different crops and ginning increased by 3.57%, 3.33% and 8.72% respectively, compared with 2.18%, -2.66% and 5.58% last year (GOP, 2018). However, cotton is an indispensable cash crop and a means of survival for the Pakistani textile industry. During the kharif period or the monsoons from April to June, cotton is grown on 15% of arable land. Two provinces were identified: Punjab is almost 75%, and Sindh is about 25%. Typically, cotton is produced by small-scale farmers cultivating less than 5 hectares of land, an expected that 1.6 million farmers grow cotton (USDA, 2019).

However, cotton crop production an important role in the economy of Pakistan because it contributes to foreign exchange reserves and the livelihood of the poor. Cotton is grown in 70 countries. The cotton-producing countries in Asia include Pakistan, China and India, but China is the world's biggest cotton producer. The world's cotton is produced by only four countries: China, the United States, India, and Pakistan. Chinese cotton production is 25% more than that of the United States, India, and Pakistan. About two-thirds of cotton used in three countries: China, India and Pakistan, accounting for 35%, 15% and 10%, respectively (Sabir et al., 2011). Now, any developed and developing country in the world has extensively planted it on an area of 7.2 million hectares on a large scale, and these countries have achieved extraordinary results in reducing pesticides, insects, bollworms, fertilizers and increasing yield per acre are being verified (James, 2011). Compared with non-Bt cotton varieties, Bt cotton has significant monetary benefits. Researchers have shown that using Bt cotton can reduce pesticide poisoning, labor costs and pest damage. Therefore, the expansion of these areas can promote the prosperity of farmers (Ghafoor Awan et al., 2015). As well as, a large number of researchers have studied and found that use of Bt Cotton can reduce pesticide and labor costs (Bakhsh, 2017; Sharma and Summarwar, 2017; Wang and Fok, 2018; Zhang et al., 2020). According to developing evidence from a farm survey, the usage of genetically modified Bt cotton in rural areas has reduced insect pests, increased yields and increased farm profits. Both China and India have high-quality Bt cotton varieties. However, in the past decade, no matter what administrative and research work has been done, Pakistan will no longer commercially approve any genetically modified cotton varieties until 2010. Extension of commercialization approval results in unregulated use of Bt cotton varieties in Pakistan (Abid et al., 2011). Cotton production in Pakistan depends on the production of competing crops, fertilizer costs and arable land area. Unfortunately, advertising in Pakistan collapsed. Unfortunately, advertising and marketing in Pakistan collapsed (Carpio and Ramirez, 2002). Effective promotion can stimulate cotton production at the farm level and provide some quality. In addition, more education, finance and improved vehicles can increase manufacturers' market participation. In addition, broader education, finance, and more transportation opportunities can further increase producers' participation in the market (Ali et al., 2017). In addition, education for producers, safe methods for plants, and the use of fertilizers and resources contributed toward expanded production of cotton (Ashraf et al., 2018).

Adoption of Bt cotton and its impact: an overview

Other countries use the estimated percent difference in the production and cost of Bt and non-Bt cotton. They provided a preliminary overview of the effects of Bt cotton in China, using field trials data supplemented by a general equilibrium model (Cabanilla et al., 2005). The cultivation costs of Bt cotton crops are considerably higher than non-Bt crops. Contrary to the Badge Company's claim, Bt Cotton did not reduce pesticide consumption. In fact, farmers who cultivated Bt cotton were spending more because of pesticides. However, found that the production capacity in Bt cotton is much higher than for non-Bt cotton varieties. In addition to cost efficiency, profit per hectare was also found in people who cultivated Bt cotton. Bt cotton variety have led to the need introduce different policies to maintain and improve indices of Bt cotton cultivation in India (Narayanamoorthy and Kalamkar, 2006).

The first genetically modified seeds used in developed countries are expensive. However, in recent years, Bt cotton seeds are widely used in developing countries. The main reason for this is that Bt cotton has many distinct private benefits. Investigated by Huang et al. (2002) (Bennett et al., 2004); Qaim and Zilberman (2003) and Pray et al. (2002) recommended to use Bt cotton is believed to reduce pesticide spraying and increase seed costs and yield. The evidence provided suggests that planting Bt cotton not only reduces the spread of insecticide against cotton bollworm, but also reduces the number of cotton pests on other crops.

This study examines at the benefits of using Bt cottonseed in Sindh. This study uses a simplified form of a panel model to determine the average short-term impact of Bt cotton technology profit, yield and agricultural resources. Studies show that farmers increase Bt cotton due to the fact that it is resistant to infection with cotton seed moths and is more productive. On average, an economic assessment shows that farmers accepting Bt get 10 percent more crop per hectare, and reduce the use of pesticide by about 22 percent per hectare, use 8 percent irrigation per hectare as resulting in a change of 78% of the area cultivated area for Bt cotton (Bakhsh, 2013). Moreover, due to the low use of chemical pesticides at Bt cotton sites, significant health benefits in terms of high biodiversity of agricultural land and less severe pesticide poisoning and environmental benefits due to low pollution of soil and groundwater. Farmers themselves estimate the positive effects of $ 79 per acre, half of which is health and the other half are for improving the environment. The addition of an average gross profit increase of $ 204 leads to a cumulative gain of $ 283 per acre or $ 1.8 billion for the total area of cotton Bt in Pakistan (Kouser and Qaim, 2013).

However, the efficacy of Bt toxins is different depending on many technical limitations. In Pakistan, the proliferation of Bt cotton continues to occur despite weak regulatory systems and no seed quality control. There is really a problem with varieties sold for Bt. Only farmers' trust affects cotton yields in the traditional development model, which does not adequately handle Bt as damage reduction. Biophysical indicators have the greatest impact, and official approval is the weakest. Results are important for measuring exposure (Ma et al., 2017).

However, perceptions of Bt cotton are not always optimistic. Some studies show that Bt cotton did not significantly increase production and income, and hawks continue to grow (Hayee, 2004)((Huang et al.,

2002; Ismael et al., 2001). These studies have identified various failure factors for Bt cotton, including the lack of knowledge on the use of this technology, black market outbreaks of unimproved Bt cotton varieties, climate change and other disasters. Many concern about the effects of small farmers' incomes and the change of Bt cotton, and they may be compelled to buy all the seeds of the crop from foreign monopolies (Qaim and Zilberman, 2003). For example, comparison of Bt cotton varieties with local cotton varieties in Pakistan shows that small farmers use Bt cotton in anticipation of lower costs, but in reality they can afford higher costs due to higher seed prices and higher fertilizer requirements and irrigation (Ali and Abdulai, 2010; Nazli, 2010; Sheikh et al., 2008), which shows that the overall result of taking Bt cotton is positive for all types of farms, but to varying degrees.

Material And Methods

Our research was conducted in the area of cotton cultivation in Tando Allahyar district of Sindh Province. Tando Allahyar is divided into two parts, one is the irrigated area and the other is the non-irrigated area. We are concentrated in the irrigated area, where 80% of the cotton growing area is concentrated. In our research, we divided cotton cultivation into three Talukas including Taluka Jhando Marri, Taluka Tando Allahyar, Taluka Chamber (Figure 1) with soil quality and rainfall levels. First growing cotton area when conducting this study, farmers usually use Bt and non-Bt cotton seeds in these talukas.

The list is organized in alphabetical order by the name of each Taluka village. This list symbolizes our target population in each chosen area. In the sampling phase, a simple random sampling technique was used to identify respondents from the list of cotton growers. Therefore, we identified 80 responses from each selected taluka.

Based on the aforementioned techniques, the overall sample size in chosen three fields is 240. We conducted a crop season-based interview (2018) Better cotton registered farmers to collect data on cotton planting input, production, and other characteristics. We found some Bt adapters growing conventional crops (non-Bt cotton), so we asked the same questions about Bt and non-Bt cotton.

We interviewed farmers twice in the sample for data on farming methods, Bt cotton adoption, economic and economic characteristics, and related information. Collected through farmer's Bt and non-Bt plot information. This includes the input and output of the form and the corresponding price. As farmers apply new technologies to better plot strategies, having information about plot properties will produce interesting results.

The study was conducted to a comparative analysis of Bt cotton v/s regular cotton production in Tando Allahyar District. This study focuses on factors affecting cotton production and comparing the financial benefits of two types of cotton (non-cotton and Bt cotton).

Study Area and Sample selection

Field surveys were collected by using personal interviews with 240 farmers. Large farmers were selected from each of the three Tehsil so that the sample could represent all types of farmers. Total of 240 sample sizes were selected from Bt cotton and non-cotton district Tando Allahyar, for each growing system, 20 farmers were selected, and four villages (80 samples) from each crop system selected from each taluka. One village (20 samples) was selected by random sampling from each village. Sample size was determined at 10 percent sample error rate using the "Selecting a sample from a given population"

The sample size was determined by the cotton producers, and the farmers were asked additional questions through face-to-face interviews, this provided a very detailed picture of cotton production in district Tando Allahyar. Interviews for cotton growers were conducted during the harvest season 2018, each interview took 30 minutes

Analytical framework

Probit regression model is commonly used to test the functional relationship between likelihood of *adoption* and its determinants (such as work, farm size, property ownership, and social status). Binary econometric simulations can help evaluate farmers using emerging technologies (Mariano et al., 2012; Muzari et al., 2012; Zhou et al., 2008). This empirical approach provides more comprehensive knowledge on farmers' traits that tend to suit similar technologies. Because of its good properties, assuming normal distribution, probit regression model is preferred over others (Wooldridge, 2010). For this research, we used probit regression model to classify variables impacting Bt cotton and non-Bt cotton for Tando Allahyar, Sindh, Pakistan. Our methodological equations are economically, are given.

$$ACV = \beta_0 + \sum_{i=1}^{12} \beta_i x_i + \mu$$

β_0, estimated coefficients; βi, estimated parameters; x_i, determination value; μ, stochastic error term.

Result

Table 1 provides descriptive figures of certain socioeconomic features of the 240 Bt farmers and non-Bt farmers. All respondents averaged 35.5 years. The average household members were 6.4. The mean experience was 12.7 years. In comparison, 61 per cent of respondents had good soil quality in the sample region and 67.1 percent owned agricultural machinery. As observed, the average distance from the study area to the nearest market is about 11 kilometers. In contrast, 74% of respondents visited market information. In addition, an average of 59% of respondents received credit; in the previous year, the contact rate of respondents with agricultural extension workers was 7%.

Table 1
Descriptive statistics of variables (n = 240).

Variables	Description	Min	Max	Mean±SD
X1=Age (Years)	Age of the cotton growers, measured in year	21.0	72.0	35.537±9.307
X_2 =Edu (Years)	Education of the respondent	1.0	5.0	3.687±1.058
X3=Household size	Number of overall family members	3.0	14.00	6.412±1.934
X_4 =Experience (year)	Farming experience of the respondent	3.00	45.00	12.775±7.009
X_5 =Landholding Size	Farm size, measured in acres	15.36	80.97	31.062±12.323
X_6 =Soil Quality	(1 if good soil quality; 0, otherwise)	1.00	2.00	1.150±.357
X_7 =Farm Machinery	Agricultural equipment ownership (1 if household owns a tractor or tube well; 0, otherwise)	0.00	1.00	0.729±.445
X_8 = Distance (km)	Distance to markets	1.00	22.00	11.625±6.176
X_9 = Market Information	(1, if have access market information; 0, otherwise)	1.00	2.00	1.020±.143
X_{10} = Credit Accessibility	(1, if the household has access to credit; 0, otherwise)	1.00	2.00	1.041±.200
X_{11} = Extension Contact	Number of extension agent contacts with farmers	0.00	2.00	0.095±.334
X_{12}=Ground Water Quality	Ground water Quality 1, if good water quality; 0, otherwise	1.00	3.00	2.058±0.889
SD, Standard deviation.				

Table 2 reports the results of the difference between the characteristic mean values of Bt farmers and non-Bt farmers. There seems to be a significant difference in land area, agricultural machinery ownership and soil quality between Bt farmers and non-Bt farmers. However, most Bt farmers have access to market knowledge, groundwater quality and extension services compared to non-Bt farmers. Some there were no significant variations in age, family size, agricultural experience, and market distance between the two groups.

Table 2
Differences between adapter and non-adapter in Tando Allahyar, Sindh, Pakistan.

Variables	Adopter	Non-adopter	Difference	t- value
Age (Year)	35.53	33.67	1.80	-0.007
Edu (Year)	3.68	3.65	0.03	1.534
Household size	6.41	6.32	0.08	1.724
Experience (year)	12.77	10.49	2.28	-0.631
Landholding Size	31.06	29.28	1.77	45.050***
Soil Quality	1.15	1.15	0.00	-1.236**
Farm Machinery	0.7292	0.58	0.14	-1.706**
Distance (km)	11.62	12.25	-0.62	-0.111
Market Information	1.02	1.00	0.02	-1.459**
Credit Accessibility	1.04	1.05	-0.02	0.666
Extension Contact	0.09	0.11	-0.02	-1.052**
Ground Water Quality	2.05	2.05	-3.30	-1.877**
***, P < 0.1; **, P < 0.05; ***, P < 0.01.**				

Determinants To The Acv In Sindh, Pakistan

Table 3 presents estimated probit regression model results. Empirical predictions were made using Maximum likelihood process, model highly important at 1%. The results of x^2 Tests show that likelihood ratio statistics are also significant (P > x^2 0.0000), It shows that the model has strong explanatory power. The empirical results of the probabilistic econometric model show that age, family size, farming experience, farming machinery, market information, market distance and groundwater quality are significant positive determinants of ACV.

Table 3
Probit analysis on determinants of ACV in northern Sindh, Pakistan (n = 240).

Variables	Coef.	Std. Err.	T	P>|t|	[95% Conf. Interval]
Age (Year)	0.81239***	0.02645	30.71	0.000	(0.7602, 0.8 451)
Edu (Year)	-1.106	0.752	-1.47	0.142	(-2.587, 2.587)
Household size	0.38926**	0.23117	1.68	0.092	(-0.0638, 0.8423)
Experience (year)	-3.77336***	0.60418	-6.25	0.000	(-4.9635, 2.5831)
Farm Size	-0.25664	0.36479	-0.70	0.482	(-0.9752, 0.4619)
Soil Quality	0.37574	2.23232	0.17	0.866	(-4.0218, 4.7733)
Farm Machinery	3.7254***	1.06807	3.49	0.000	(1.6320, 5.8187)
Distance (km)	0.23748***	0.08514	2.79	0.005	(0.0705, 0 .4043)
Market Information	16.23924***	5.48106	2.96	0.003	(5.4416, 27.0368)
Credit Accessibility	0.25140	3.98915	0.06	0.950	(-7.6071, 8.1099)
Extension Contact	-3.78701	2.37300	-1.60	0.112	(-8.4617, 0.8877)
Ground Water Quality	-1.83686***	0.49077	-3.74	0.000	(-2.7987, 0.8749)
Constant	77.33424**	39.74659	1.95	0.053	(-0.9833, 155.6518)
LR X^2 (12) 58.61 Prob > X^2 0.0000 Pseudo R^2 0.705 Log likelihood-53.83283					
***, P < 0.1; **, P < 0.05; ***, P < 0.01.**					

Determining Acv In Sindh, Pakistan (Marginal Effect)

Bt and Non-Bt may be affected by many socio-economic factors in rural households. There is evidence that the age of the previous year, farming experience, agricultural machinery and groundwater quality had a significant and positive impact on the use of Bt cotton and non-Bt cotton Table 4. The estimated marginal age coefficient is negative but significant (β2) was -1.62, which means if -1.62% increase in formal age, the probability of Bt and Non-Bt will lead to -1.62% increase. Likewise, Farming experience coefficient is negative but significance (β 4) was -3.64, the Bt farmers and non-Bt farmers would increase by -3.64%. Furthermore, the coefficient of farm machinery is negative and significance (β 6) was -3.77, the adopting of rice farmers' probability would increase -3.77%. Finally, it is found that the groundwater

quality coefficient is significant and positive, and the probability of Bt farmers and non-Bt farmers will increase by 37.78%, respectively.

Table 4
Analysis of marginal effects on determinants of better ACV varieties in Tando Allahyar, Sindh, Pakistan (n=240).

Variables	Margin	Std. Err.	t	P>|t|	[95% Conf. Interval]
Age (Year)	-1.62072***	0.4795162	-3.38	0.001	(-2.198233, 0.3206432)
Edu (Year)	-0.86827	0.8288028	-1.05	0.296	(-2.501003, 0.7644498)
Household size	-2.60746	2.320474	-1.12	0.262	-(7.17876, 1.963824)
Experience (year)	-3.64556***	0.596918	-6.11	0.000	(-4.821485, 2.46965)
Landholding Size	-0.25664	0.3647969	-0.70	0.482	(-0.9752876, 0.4619988)
Soil Quality	10.78431	12.55745	0.86	0.391	(-13.95363, 35.52226)
Farm Machinery	-3.77336***	0.6041816	-6.25	0.000	-4.963595, 2.583142)
Distance (km)	-0.53530	0.7278349	-0.74	0.463	(-1.969129, 0.8985136)
Market Information	-37.07234	31.3508	-1.18	0.238	(-98.83284, 24.68816)
Credit Accessibility	0.10434	22.47376	0.00	0.996	(-44.16854, 44.37723)
Extension Contact	9.23651	13.42669	0.69	0.492	(-17.21382, 35.68685)
Ground Water Quality	37.78804 ***	8.013304	4.72	0.000	(22.00198, 53.5741)
***, P < 0.1; **, P < 0.05; ***, P < 0.01.**					

Discussions

The yield of any crop depends on soil structure, climatic conditions, social organization, resource availability, quality input, and favorable sales conditions in the factor market and product market. Therefore, it is considered that the area and production level of Bt have been briefly discussed. And the production potential of conventional cotton in various regions of Pakistan and the research overview, and then explain the survey results. Farmers with low soil quality are more likely to adopt, despite greater rates of adoption. Bt cotton is more suitable for plant-contaminated areas than rice and other crops. Therefore, Bt cotton spread is expected to grow in relatively small farms and fertile areas. Irrigation prices include electricity / fuel and canal charges. In Haryana and Punjab, almost all cotton is cultivated through irrigation. One of the reasons for the increase in usage may be that Bt cotton seeds are more expensive than non-Bt cotton, so Bt cotton farmers pay close attention to crop management (Qaim et al., 2006). The higher production costs of Bt growers are compensated by higher yields. The total income and profit of Bt growers are 33% and 50% higher than non-Bt cotton respectively (Mal et al., 2011; Qaim et al., 2006).

Aziz et al. (2011) analyzed Bt comparative performance of Cotton has some outstanding traditional, arid and semi-arid cotton varieties. To evaluate superior genotypes, four cotton varieties CIM-496, BH-162, VH-144 and Bt-121 grown on sandy loam soil were studied for comparative growth and yield efficiency. The results showed that the plant height, plant height, boll number 1 and boll weight 1 growth parameters of Bt and non-Bt cotton varieties were significantly different ($P < 0.05$). The yield and fiber quality parameters of seed cotton, such as percentage of maturity, value of small parts, short fiber length and fiber strength, and percentage of virus infection are also important. Bt-121 seed cotton has the highest boll-1 weight and maturity percentage. Compared with all other varieties, the yield of Bt-121 cotton increased by 26%. In addition, compared with other varieties, cotton curl leaf virus infection has also been reduced by 58%. The fiber produced by BH-162 has the largest length and denier but seems to be the most vulnerable to virus attack. The conclusion is that Bt-121 performs best than other varieties in most of the traits studied and may be recommended for use in areas with arid to semi-arid climates. The weight of each boll of cotton seed cotton plays a key role in determining the final yield of cotton varieties. Under the main environmental conditions, the final yield of cotton varieties is directly or indirectly affected by the growth conditions and heritability. In the cotton genotype, the weight change per boll may be caused by the change in photosynthesis capacity and the distribution of these assimilates in various parts of the plant. Compared with non-Bt-121, the loss of young fruit form caused by insect diseases of Bt-121 is less. Bt-121 may form bolls earlier than male buds, which helps increase biomass and seed cotton yield. These results are consistent with the findings of Hebbar et al. (2007), they found that compared with non-Bt cotton varieties, Bt cotton has a larger boll weight.

Conclusions

This research applied a probabilistic econometric model. Empirical findings indicate that the level of education, farming expertise, soil quality, market information, ownership of agricultural machinery, and extension ties have major effects on cotton Bt and non-Bt. Education has a Positive impact on the use of Bt cotton and non-Bt cotton. In addition, Credit is really necessary in the agricultural sector, which can increase agricultural productivity and improve the lives of rural families. In this study, credit availability promoted the development of Bt cotton and non-Bt cotton. However, this variable is not important. Based on the survey results, this research recommends that ZTB Co., Ltd., commercial banks and other credit sources should provide timely and convenient Pakistani agriculture. Most Bt cotton and non-Bt cotton growers cannot obtain loans. Due to the high prices of certified and improved cotton varieties, farmers still use the seeds of traditional cotton varieties, so the cotton productivity per acre in Sindh, Pakistan is very low. Therefore, our research recommends that the public and private sectors provide Bt cotton and non-Bt cotton seeds at affordable prices. Central and provincial governments should also provide service providers with an enabling environment, including private seed suppliers, agricultural input distributors, and private extension services.

In this article, we advocate the use of Bt cotton and non-Bt cotton because it is the most likely option to increase cotton production and farm profits. The policy of the Pakistani government also follows this approach. However, in addition to potential profits, Bt cotton and non-Bt cotton have also caused

controversy. Academia, policymakers, non-governmental organizations and civil society organizations have expressed concern about the potential threats of Bt cotton and non-Bt cotton. Solving all these problems is beyond the scope of this research. When designing policies, the ecological impact of Bt cotton and non-Bt cotton must be considered. Therefore, commendable research considers the economic and environmental aspects of Pakistan's Bt and non-Bt cotton.

Declarations

Acknowledgments

I would like to thank and highly appreciate to my respectable supervisor Yin Qi from the College of Management, Sichuan Agriculture University for support me and partial funding of this research and all co-authors revised this manuscript for publication.

Authors' contributions

Rashid Usman Shar collected the data and drafted the manuscript. Yin Qi A participated in the study. Absar Mithal Jiskani edited manuscript. All authors read and approved the final manuscript.

Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Authors declare that they have no conflict of interest for the publication of the manuscript.

References

1. Abid M, Ashfaq M, Hassan S, Fatima N. A resource use efficiency analysis of small Bt cotton farmers in Punjab, Pakistan. Pakistan Journal of Agriculture Sciences. 2011;48(1):65–71.
2. Ali A, Abdulai A. The Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan. J Agric Econ. 2010;61(1):175–92.
3. Ali A, Abdulai A, Rahut DB. Farmers' Access to Markets: The Case of Cotton in Pakistan. Asian Econ J. 2017;31(2):211–32.

4. Arshad M, Suhail A, Asghar M, Tayyib M, Hafeez F. 2007. Factors influencing the adoption of Bt cotton in the Punjab, Pakistan. Young (up to 30 years), 11(16): 19.
5. Ashraf J, et al. Recent insights into cotton functional genomics: progress and future perspectives. Plant biotechnology journal. 2018;16(3):699–713.
6. Aziz A, et al. Comparative performance of Bt cotton with some elite conventional cotton cultivars under arid to semi-arid conditions. Afr J Agric Res. 2011;6(6):1600–6.
7. Bakhsh K. Economic and environmental impacts of Bt cotton: Evidence from Pakistan. SANDEE; 2013.
8. Bakhsh K. Impacts of Bt cotton on profitability, productivity and farm inputs in Pakistan: use of panel models. Environment Development Economics. 2017;22(4):373–91.
9. BCI. Better Cotton Initiative. Better Cotton Initiative; 2019.
10. Bennett R, Ismael Y, Morse S, Shankar B. Reductions in insecticide use from adoption of Bt cotton in South Africa: impacts on economic performance and toxic load to the environment. The Journal of Agricultural Science. 2004;142(6):665–74.
11. Cabanilla LS, Abdoulaye T, Sanders JH. Economic cost of non-adoption of Bt-cotton in West Africa: with special reference to Mali. Int J Biotechnol. 2005;7(1-3):46–61.
12. Carpio CE, Ramirez OA. 2002. Forecasting foreign cotton production: The case of India, Pakistan and Australia, The Proceedings of The 2002 Beltwide Cotton Conference. Citeseer, Atlanta, Georgia.
13. FAO. OECD-FAO agricultural outlook 2018–2027. OECD; 2018.
14. Fitt GP. Deployment and impact of transgenic Bt cotton in Australia, The economic and environmental impacts of Agbiotech. Springer; 2003. pp. 141–64.
15. Ghafoor Awan A, Nadeem N, Nawaz MA. 2015. Analysis of Profitability of BT Cotton Growers in District Multan-Pakistan. Journal of Resources Development and Management, 5.
16. Gong Y, Baylis K, Kozak R, Bull G. Farmers' risk preferences and pesticide use decisions: evidence from field experiments in China. Agric Econ. 2016;47(4):411–21.
17. GOP. Economic Survey of Pakistan 2018–19, Agricultural Statistics of Pakistan. Islamabad: Ministry of Food Agriculture and Livestock Division; 2018.
18. Hayee A. Cultivation of Bt cotton-Pakistan's experience. Islamabad: Action Aid Pakistan; 2004.
19. Hebbar KB, Perumal NK, Khadi BM. Photosynthesis and plant growth response of transgenic Bt cotton (Gossypium hirsutum L.) hybrids under field condition. Photosynthetica. 2007;45(2):254–8.
20. Huang J, Rozelle S, Pray C, Wang Q. Plant biotechnology in China. Science. 2002;295(5555):674–6.
21. Ismael Y, Bennett R, Morse S. 2001. Biotechnology in Africa: The adoption and economic impacts of Bt cotton in the Makhathini Flats, Republic of South Africa, Biotechnology Conference for Sub-Saharan Africa, Johannesburg, SA, pp. 26-27.
22. James C. 2011. Global status of commercialized biotech/GM crops, 2011, 44. isaaa Ithaca, NY.
23. Kouser S, Qaim M. Valuing financial, health, and environmental benefits of Bt cotton in Pakistan. Agric Econ. 2013;44(3):323–35.

24. Kranthi KR, Stone GD. Long-term impacts of Bt cotton in India. Nature plants. 2020;6(3):188–96.
25. Liu EM, Huang J. Risk preferences and pesticide use by cotton farmers in China. J Dev Econ. 2013;103:202–15.
26. Luttrell RG, Jackson RE. Helicoverpa zea and Bt cotton in the United States. GM crops food. 2012;3(3):213–27.
27. Ma X, et al. A question of integrity: variants of bt cotton, pesticides and productivity in Pakistan. J Agric Econ. 2017;68(2):366–85.
28. Mal P, Manjunatha AV, Bauer S, Ahmed MN. Technical efficiency and environmental impact of Bt cotton and non-Bt cotton in North India. AgBioForum. 2011;14(3):164–70.
29. Mariano MJ, Villano R, Fleming E. Factors influencing farmers' adoption of modern rice technologies and good management practices in the Philippines. Agric Syst. 2012;110:41–53.
30. Muzari W, Gatsi W, Muvhunzi S. The impacts of technology adoption on smallholder agricultural productivity in sub-Saharan Africa: A review. Journal of Sustainable Development. 2012;5(8):69.
31. Narayanamoorthy A, Kalamkar SS. 2006. Is Bt cotton cultivation economically viable for Indian farmers? An empirical analysis. Economic and Political Weekly: 2716-2724.
32. Nava-Camberos U, et al. Agronomic and environmental impacts of Bt cotton in Mexico. Journal of Integrated Pest Management. 2019;10(1):15.
33. Nazli H. Impact of Bt cotton adoption on farmers' wellbeing in Pakistan. University of Guelph, University of Guelph. Department of Agricultural, Economics Business; 2010.
34. Pray CE, Huang J, Hu R, Rozelle S. Five years of Bt cotton in China–the benefits continue. Plant J. 2002;31(4):423–30.
35. Qaim M, Subramanian A, Naik G, Zilberman D. Adoption of Bt cotton and impact variability: Insights from India. Applied Economic Perspectives Policy. 2006;28(1):48–58.
36. Qaim M, Zilberman D. Yield effects of genetically modified crops in developing countries. Science. 2003;299(5608):900–2.
37. Qiao F, Huang J, Wang X. Fifteen Years of Bt Cotton in China: Results from Household Surveys. World Dev. 2017;98:351–9.
38. Rehman A, et al. Economic perspectives of major field crops of Pakistan: An empirical study. Pacific Science Review B: Humanities Social Sciences. 2015;1(3):145–58.
39. News RS. 2018.
40. Sabir HM, Tahir SH, Khan MB. Bt cotton and its impact on cropping pattern in Punjab. Pakistan Journal of Social Sciences. 2011;31(1):127–34.
41. Sarangdhar AA, Pawar VR. Machine learning regression technique for cotton leaf disease detection and controlling using IoT. IEEE; 2017. pp. 449–54.
42. Sharma R, Summarwar S. Appraisal of Bollworm complex damage of Bt cotton by Integrated pest management (IPM). International Journal of Advanced Education Research. 2017;2(4):136–8.

43. Sheikh AD, Mahmood MA, Hussain A, Bashir A, Saeed R. Bt-cotton situation in Punjab. Technology Transfer Institute. Faisalabad; 2008.
44. Subramanian A, Qaim M. The impact of Bt cotton on poor households in rural India. J Dev Stud. 2010;46(2):295–311.
45. USDA. 2019. Cotton and product annual Islamabad.
46. Wang G, Fok M. Managing pests after 15 years of Bt cotton: Farmers' practices, performance and opinions in northern China. Crop Prot. 2018;110:251–60.
47. Wooldridge JM. Econometric analysis of cross section and panel data. MIT press; 2010.
48. Zhang X, Zhang Z, Zhou R, Wang Q, Wang L. 2020. Ratooning Annual Cotton (Gossypium spp.) for Perennial Utilization of Heterosis. Frontiers in Plant Science, 11: 1939.
49. Zhou S, Herzfeld T, Glauben T, Zhang Y, Hu B. Factors affecting Chinese farmers' decisions to adopt a water-saving technology. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie. 2008;56(1):51–61.

Figures

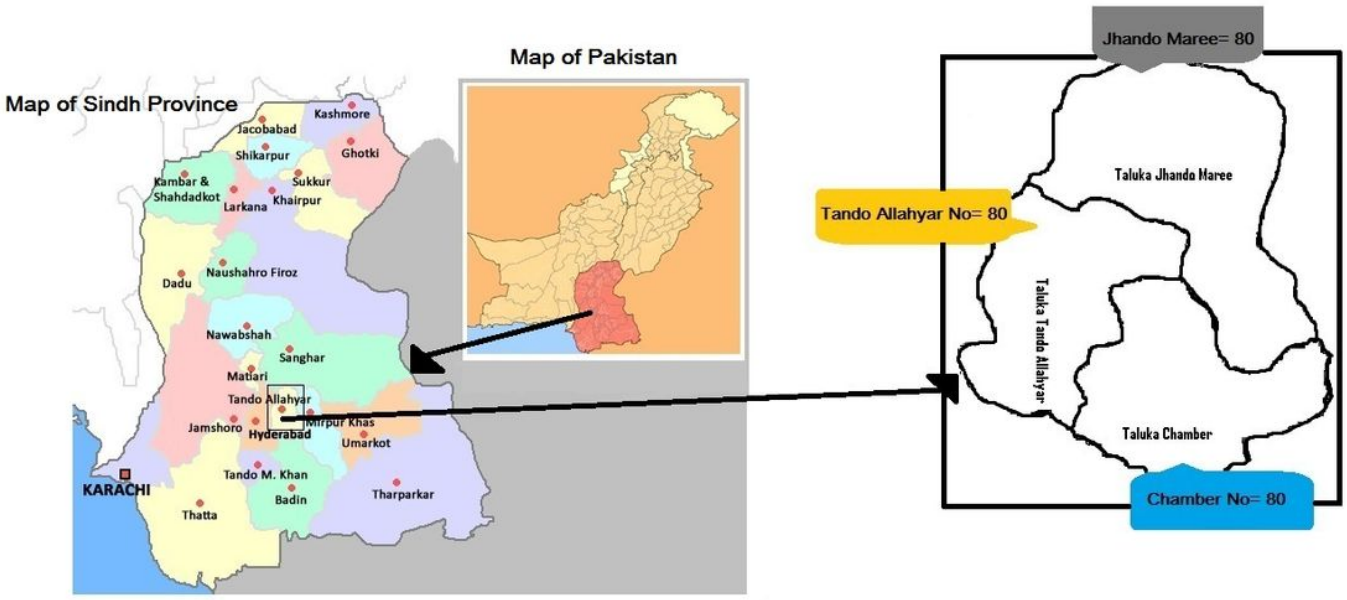

Figure 1

Map of Tando Allahyar District, Sindh province and study locations