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IS BT GENE COTTON ADOPTION PAYING OFF FARMERS IN PAKISTAN?

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ABSTRACT

Existing literature on impact of *Bacillus Thuringiensis* (Bt) cotton gene adoption in Pakistan is based on districts of one province and one or two years of data. This study contributes to literature in two aspects; we have conducted farm level survey in six districts (Rahim Yar Khan, Multan, Bahawalpur, Matiari, Shaheed Benazirabad and Sukkur) of two provinces (Punjab and Sindh) of Pakistan for three consecutive years (2014-15 to 2016-17) to assess the comparative advantage of Bt gene adoption over conventional cotton crop within and across provinces. Moreover, this study has assessed farmer's wellbeing by comparing per capita income of farmers with poverty line. Results of panel data indicate that net yield gain from Bt gene cotton per acre is 33 to 37.5 % higher than conventional cotton gene. However, Bt cotton yield per acre is 13% higher in districts of Punjab than yield in districts of Sindh, this has resulted in huge gap between per capita incomes of Bt farmers in these provinces. Furthermore, Bt gene growers have significantly low pesticide applications as compared to conventional cotton producers. The results obtained from Cobb-Douglas production specification establish that irrigation cost, seed cost and fertilizer quantity have significant positive impact on over all cotton yield. This study suggests that awareness programs regarding refuge area and specification of seeds might improve yield as well as per capita income of farmers in Pakistan.

Contribution/ Originality: This study contributes to literature in two aspects; we have conducted farm level survey in six districts (Rahim Yar Khan, Multan, Bahawalpur, Matiari, Shaheed Benazirabad and Sukkur) of two provinces (Punjab and Sindh) of Pakistan for three consecutive years (2014-15 to 2016-17) to assess the comparative advantage of Bt gene adoption over conventional cotton crop within and across provinces.

1. INTRODUCTION

Pakistan is fifth largest cotton growing country after China, India, United States and Brazil but ranked 21 in terms of yield. According to United States Department of Agriculture (2018)[1], Pakistan is producing 685 kg/ha which is definitely higher than world average yield (581 kg/ha) but 34 % lower than its potential. One of the leading reasons behind low yield is non- *Bacillus Thuringiensis* (Bt) cotton production in Pakistan. Many developed countries like China, Australia and USA adopted Bt gene to increase cotton yield in mid 1990s, Pakistan produced

1 Editorial, Reuters. "U.S. government to pay $4.7 billion in tariff-related aid to farmers". U.S. Retrieved 2018-08-28.

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its first Bt crop almost after a decade. Australia and China are among the highest cotton producers in terms of yield because more than 94 % of farmers are growing Bt gene for more yield and less crop losses.

The importance of high cotton yield and low crop losses are not restricted to farmers only, Pakistan's textile sector production and exports rely on per year cotton production. Low yield effects per capita income of 40 % of labor force associated to raw cotton production and textile sector in Pakistan. Though textile sector contributes almost 8.5 % to GDP and consist of 57 % of total exports of Pakistan, cotton crop adds around 45 % to Pakistan's agricultural output alone along with 1.4 % to GDP[2]. Moreover, cottonseed oil production also relies on cotton yield that is essential part of edible oil.

Since 2008, more than 80 % of cotton growers in India and China have adopted Bt cotton crop seed whereas more than 38 % of the farmers are still growing non-Bt cotton in Pakistan. In this study, we have conducted a farm level survey to assess the comparative advantage of Bt gene adoption over conventional cotton crop. There are several advantages of opting Bt cotton gene. Literature has highlighted that Bt cotton lint is bigger in size and better in color than conventional cotton lint, hence result in more commercial gains (i.e. (Zhao *et al.*, 2011). Moreover, Bt gene increases yield by increasing crop immunity to fight against weeds and bollworms attacks and reduces crop losses. Furthermore, production of toxic protein in Bt gene increases the immunity of crop and reduces pesticide applications (Zhao *et al.*, 2011; Wan *et al.*, 2017).

While many researchers have underlined yield benefits of Bt gene, others have analyzed comparative advantages of Bt over conventional cotton crop in terms of cost as well. For instance, Bennett *et al.* (2004) conducted a farm level survey, by included 9000 Bt and non-Bt adopters in analysis results maintain that Bt adopters bear 79 % less pesticide cost than non Bt growers in India. Similarly, Sadashivappa and Qaim (2009) have conducted a farm level survey in India, results derived from three rounds of observations show that Bt adopters applied 41 % less pest applications which reduced their pest cost significantly. Moreover, an ample literature has maintained that net gains for small scale Bt growers also increase considerably in Argentina, India and China, also confirm that Bt crop yield gains can be 80 % more than non-BT crop, pesticides costs also decrease by one-third. In addition, conventional crop requires around 8-11 sprays of insecticides whereas BT-crop requires 3-5 at max, the cost of cultivation reduces with reduction in insecticides applications (i.e. (Pray *et al.*, 2002; Qaim and De Janvry, 2002; Subramanian and Qaim, 2010)).

Most of the available studies on Bt cotton advantages or its impact on farmer's health, poverty level and per capita income are based on Bt adoption in India and China. There are very few studies available on Pakistan economy which either carter large sample of farmers or examined longitudinal data to assess Bt gene performance in cotton crop. This study is contributing in debate on gains from Bt cotton adoption in Pakistan. Previously, Ali *et al.* (2012) have conducted survey from 325 farmers from different districts of Punjab and conclude that rural poverty has decreased among Bt cotton growers in 2007. Considering that results derived from different districts of same province with small sample may not be generalized, we have increased sample size by adding farmers from six different districts selected from two provinces of Pakistan (Punjab and Sindh) to assess farmers wellbeing across provinces. Kouser and Qaim (2015) also add to literature by examining financial gains derived from Bt cotton adoption. They have conducted a farm level survey from 352 farmers (Bt adopter and Non-adopters) from 32 villages of Punjab and maintain that income earned from Bt adoption have significant positive impact on health expenditures and overall wellbeing of the farmers.

1.1. Significance of the Study

An ample literature has highlighted the positive yield gains and increase in farmer's profitability from Bt adoption in India, Argentina and China, it is important add into literature to know the impact of Bt adoption on

[2] Source: Economic Survey of Pakistan (2016-17).

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farmer's wellbeing and satisfaction in Pakistan. To best of our knowledge, existing studies on Pakistan have not compared agro-economic benefits across provinces. Moreover, existing studies have considered very small sample as well as one-year financial benefits only. Cotton is leading cash crop in provinces of Punjab and Sindh so that huge labor force's livelihood also depends on profitability derived from yield of cotton crop. The motivation of this study is based on the fact that even after Bt-adoption, rural poverty and farmer's per capita income is falling below than poverty line in Pakistan. This study has highlighted disparities in per capita income of farmers, cotton yield and cost of production across two cotton-producing provinces of Pakistan.

1.2. Contribution of the Study and Objectives

This study is contributing to the existing literature in man terms. This study is based on longitudinal panel data collected from (small to large scale) farmers from two provinces of Pakistan by adding six districts Rahim Yar Khan, Multan, Bahawalpur, Matiari, Shaheed Benazirabad and Sukkur in analysis. Survey based questionnaires have been filled to gather information regarding use of raw material, insecticide sprays and yield from conventional cotton crop growers and different varieties of Bt crop growers for three consecutive years. Data of average family size has been utilized to find per capita income of farmers and their families.

Our research adds to existing literature on Pakistan agriculture in two ways. First, by three consecutive years (2014-15 to 2016-17) panel data collection, we have analyzed the yield gains from Bt and non-BT crop within and across provinces of Pakistan. Second, through Cobb-Douglas production specification we have assessed impact of raw materials cost and consumption on over all cotton yield and find net yield gains of Bt gene crop.

This study is organized as follows. The second section is providing an overview on the history and current situation of BT adoption in Pakistan and related issues. In third section, structure of interview based farm survey. Results derived from survey and net yield gain analysis obtained from Cobb-Douglas production specification are presented in fourth part of this article followed by conclusion and policy implications.

2. BT COTTON SEED AVAILABILITY, ADOPTION AND ISSUES IN PAKISTAN

Cotton is cash crop of Pakistan. It is Kharif (Monsoon) period crop and grows mostly in the two provinces of Pakistan; Punjab (79%) and Sindh (20 %). Ministry of environment allowed the release of Bt seeds for different crops in 1997 but Bt seed of cotton trials continued till mid-2000s. After various quality and safety tests, a few varieties were provided to farmers for further investigation over performance of the seeds so that first successful trial of Bt cotton seed can be traced back to 2002-03 in Sindh. In 2005-06, three best approved qualities of BT cotton seed were grown over 7800 acres of land in Punjab region. During this trial it had been analyzed that BT cotton caught less bollworms and weeds as compared to non-BT cotton crop in the same climatic region of Punjab. Moreover, cost of production also declined as farmers used nearly 50 percent less pesticide sprays in Bt crop fields. Finally, official commercialization of Bt seed took place in 2009-10 after these successful trials. Pakistan's agriculture sector has 73 different varieties of BT cotton seed. After the legal approval of commercialized use of BT seed in 2009-10, many Pakistani research institutes have come up with new varieties. For instance, Sindh Seed Council (SSC) have introduced nine new BT cottonseed varieties in 2017 and claimed that these varieties will increase yield gains because of high quality cotton lint. Central cotton research institute (CCRI), Multan has introduced three varieties of BT cottonseed in 2016-17. Research institute claimed that newly introduced varieties have higher yield and more resistance to bollworms and cotton leaf curl virus. Institute also recommended farmers to enforce refuge strategies for better results.

2.1. Issues and Challenges Faced By Farmers

Pakistani farmers are facing many challenges and issues. Most of the farmers prefer to grow two major crops a year. Due to low profitability from previous crop, farmers seek loans from microfinance banks or local

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moneylenders for next crop. Literature establishes that farmer's access to financial markets increases income and crop yield (i.e. (Barrett *et al.*, 2001; Quisumbing and Pandolfelli, 2010)). Surprisingly, survey conducted for this study highlighted that 67 % farmers take loans on 80 to 100% interest rate from local moneylenders because they do not want to go through the lengthy scrutiny process of commercial and agricultural banks. Moreover, they do not own big area of land to offer collateral to banks. Historically banks are also reluctant to extend loans to small landowners because of high-anticipated transaction cost. However, 63 % of farmers from Sindh reported that they do not have access to banks even as 70% of banking branches are located in urban areas of Pakistan. In this situation farmers cannot afford to grow better quality (expansive) and high yield seed. Similarly, farmers cannot afford more fertilizer and required quantity of insecticides to increase yield. This unavailability or inaccessibility to financial resources may result in low quality cotton crop so as low returns. Hence, farmers stay trapped in vicious circle of poverty. Among many other issues and challenges low access to education due to income constraint and more dependents also play vital role in determining farmer's income in Pakistan. According to Jamison and Lau (1982) schooling and family size are primary elements in determining farmer's income in developing countries. This survey has witnessed that big family sizes (average family size: 6.9) and low education attainment (average schooling: 5 years) are leading factors behind poverty among the farmers in Pakistan. Literature establishes that farmer's education and awareness significantly affects its income (Meijer *et al.*, 2015; Panda, 2015). Unfortunately, demographical and socio-economic data of our survey have identified that nearly 80 % of farmers are unaware of names, quality and legalization of Bt cotton seeds they are using. Farmers were also unaware of existence of approved seeds list formed to guide seed buyers regarding seeds selection as per climate and soil properties of their area of cultivation. Most of the farmers reported that they buy seeds from local retailers and do not know the name, brand or variety they are using. While, according to the Ministry of Agriculture, they have provided list of legal, tested and approved Bt cottonseeds varieties, all varieties are as per local agro-climatic conditions. Here, we can anticipate that this unawareness can be due to low schooling and results in low crop yield. Almost 29 % of Bt adopters reported that they are using as much fertilizer and insecticide sprays as non-Bt adopters, this reflects unawareness due to education exposure. Furthermore, results of survey show that big family sizes are creating disguised labor problem (though more in Sindh than Punjab), in case of any climate, change (flood or drought) or insect attack family income may get significant shock.

Currently, almost 74 % of framers are growing BT crop in Sindh and Punjab region but they are lacking knowledge about properties of Bt seeds. Researches maintain that expansive Bt seed, appropriate water and fertilizer consumption (referred to PH of soil) and availability of refuge area have positive impact on cotton yield and reduces probability of crop loss[3]. Our survey identified that farmers have misperception that price and quality of seed do not significantly affect crop yield. Moreover, only 0.001% of cotton cultivation plots have refuge areas in Pakistan. The purpose of the refuge area is to prevent pests from developing resistance to the technology. Indian agriculture sector introduced refuge area concept among farmers in 2002-03 and this technology reduced 18- 22% yield loss (due to insect attacks) in first year of adoption.

3. FARM LEVEL SURVEY AND DISTRICT SELECTION CRITERIA

This study is based on micro-level data collected from six districts of cotton production fields in Punjab and Sindh, Pakistan. We carried out three rounds of panel survey for data collection. First round of survey was conducted in 2014-15, total 380 farmers were interviewed, through stratified random sampling procedure we shortlisted only 350 farmers to run analysis. Farm level interviews have conducted with the help of natives because of language and trust barriers. Unfortunately, we could manage to interview only 340 farmers during second round (2015-16) and selected 300 for analysis. In order to maintain unbiased and random sample survey, we added new

[3] i.e. Constable, Rochester and Daniells, (1992). Hu, Hu, Jing, Meng and Chen, (2009).

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farmers from same areas to maintain sample size for analysis so we interviewed 370 farmers in third round (2016-17) and selected 350 for analysis. We generated two sub samples for analysis; Bt crop grower and Conventional crop grower. The purpose of creating sub groups was to assess yield differences and cost-benefit analysis between both types of crop growers.

Table-1. Selected sample for analysis from six districts of Sindh and Punjab.

Years	Punjab		Sindh		Total
	BT	Conventional	BT	Conventional	
2014-15	110	80	90	70	350
2015-16	120	60	60	60	300
2016-17	140	80	80	50	350

Data collected from survey clearly reveals that over the three years of survey time (2014-2017) many farmers have adopted Bt seed to grow cotton. One of the main reasons can be Kissan Package (2014-15) announced by government which supplied approved commercialized BT cottonseed on relatively subsidize rates (Ma *et al.*, 2017). Another reason can be expected higher yield of BT crop over conventional crop.

In this study, we have selected districts of Bahawalpur, Multan and Rahimyar Khan from Punjab and districts of Matiari, Sukkur and Shaheed Benazir-Abad from Sindh for analysis. There are two main reasons behind short listing of six districts from two provinces. First, all of them have almost same climate, soil quality and water PH to avoid any yield related advantage.[4] Second, most of the existing studies have either taken districts for Punjab or Sindh but we have taken samples from both provinces to analyze across provinces yield and per capita differences.

4. IMPACT OF BT COTTON ADOPTION ON PROFITABILITY AND PER CAPITA INCOME OF FARMERS

This section presents province-wise as well as combine results of farm-level survey. This section has served three objectives; we have presented comparative advantage of Bt gene production over conventional crop within sample provinces (Sindh and Punjab). Moreover, we have provided per capita income differences within and across provinces to measure wellbeing of farmers. Furthermore, net productivity effects of Bt gene crop have been measured through Cobb-Douglas production specifications in 4.3 of this section.

4.1. Comparative Advantage of BT Gene over Conventional Cotton in Sindh

The results provided in Table 2a presents survey result of Sindh province. Sample districts [Matiari, Sukkur and Shaheed Benazirabad (SB)] are located in interior Sindh and densely populated areas (rural-urban population ratio 66.5%: 33.5%) with lush agricultural region. Indus River flows on left bank of SB and Sukkur, it irrigates 83% of agricultural area of these regions. Mainly irrigation system of Matiari and Sukkur is based on canals and tube wells system. Like many other cities and towns of Sindh, Matiari and SB are also facing water shortage. Unfortunately, these areas face drought every 4 out of 10 years since 1989 (Tagar and Shah, 2013). According to Agriculture Statistics of Pakistan (2016-17), crop water requirement is significantly as high as five times the mean seasoned rainfall in SB and Matiari. The survey based results Table 2a show that average area per famer is quite small in Sindh. Small-scale farmers do not own cultivation and harvesting equipment so that manure and harvesting costs are high among small landholders. They keep only necessary equipment and borrow others when needed as machines as if fertilizer applicator, tractors, seed sowing, cotton drill, picking machine etc are expansive to buy as well as maintain. Survey registered that only 21.5 % of the farmers in Sindh possess all necessary and

[4] For instance, underground water used for irrigation in Multan has mean PH of 6.9 (standard deviation of 0.6) and contains high content of arsenic. Similarly, underground water of Rahimyar khan and Bahawalpur have mean water PH of 6.3 and 6.6, respectively. These reported PH levels are very much similar so it is feasible to compare the yield as crop yield get effected if irrigation water PH differ Khattak, Ahmed, Qazi, Izhar, Ilyas, Chaudhary, Khan, Iqbal and Waheed, (2012).

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required machines and equipment. We have presented comparative advantage of Bt adoption over conventional crop in Table 2b, survey results show that apart from low pesticide cost, a major impact of Bt adoption is on yield of cotton crop. By having 46 % (average of three years' sample) more yield, Bt farmers have 183% more per capita income than that of non-Bt adopters. BT crop growers have 47.6 % more yield than conventional crop adopters in 2014-15, this yield gap remained significantly high in next two years, too. Though the cost of seed is considerably higher for BT gene, the profitability of the BT adopters has also been significantly higher than non-BT growers. Average profitability of Bt grower over non-Bt grower is 180% in Sindh and per capita income of Bt farmer is US $ 1.28 per day.

Table-2(a). Agro-economic effects of BT crop on farmers (three districts of Sindh).

	2014-15		**2015-16**		**2016-17**	
	BT	**Conventional**	**BT**	**Conventional**	**BT**	**Conventiona**
	n=90	**n=70**	**n=60**	**n=60**	**n=80**	**n=50**
		Mean (SD)		**Mean (SD)**		**Mean (SD)**
Average seed (kg/acre)	20	20	20	20	20	20
Number of Insecticide Sprays	6.03***	8.92	5.21***	8.21	5.08***	7.02
	(1.23)	(2.91)	(1.88)	(2.44)	(2.19)	(3.21)
Insecticide Use (liter/acre)	6.36**	9.55	6.02**	9.37	6.01**	9.01
	(1.97)	(2.99)	(2.30)	(4.71)	(2.77)	(2.96)
Yield (kg/acre) raw cotton(lint+seed)	636***	430	632***	440	641***	440
	(180)	(191)	(129)	(184)	(166)	(178)
Yield (kg/acre) raw cotton (only lint)	232**	185	285**	201	274**	202
	(40)	(32)	(39)	(58)	(46)	(44)
Output Price (Rs./kg) Raw cotton(lint only)	110	130	110	130	119	135
	(10.01)	(10.82)	(9.81)	(9.55)	(7.63)	(7.91)
Output Price (Rs./kg) raw cotton (lint+seed)	59.1	61	66	65	68	66
	(9.18)	(6.10)	(5.97)	(4.55)	(6.77)	(4.18)
Average area per farmer (acres)	15	16	15	15.1	16.4	14.1
	(3.92)	(3.98)	(3.61)	(3.99)	(3.99)	(3.87)
Farmer family size	6.8	6.8	6.77	6.71	6.7	6.7
	(1.26)	(1.23)	(1.39)	(1.29)	(1.33)	(1.34)
Refuge area/acre	0	0	0	0	0	0
Seed Cost (Rs./acre)	600***	220	609***	240	611***	230
	(110)	(160)	(131)	(140)	(128)	(121)
Insecticide Cost (Rs./acre)	3369***	6000	3589***	6500	3800***	6900
	(750)	(787)	(860)	(971)	(855)	(977)
Fertilizer Cost (Rs./acre)	4155*	3699	4822*	3886	4956*	3900
	(1025)	(1008)	(986)	(1003)	(869)	(1069)
Manure Cost(Rs./acre)	1730	1456	1882	1560	2011	1700
	(307)	(289)	(318)	(271)	(398)	(400)
Operational Cost and Other Cost (including water)Rs./acre	6025*	5260	6699	5950	7789*	6800
	(1009)	(1018)	(1325)	(1371)	(1271)	(1276)
Harvesting Cost(Rs./acre)	2890*	2114	3126*	2489	3369*	2650
	(489)	(478)	(423)	(407)	(409)	(446)
Total Variable Cost TVC (Rs./acre)	18769	18749	20727	20625	22536	22180
	(2369)	(2456)	(2391)	(2401)	(3003)	(2690)
Gross Revenue (Rs./acre) raw cotton (lint+seed)	37587***	26230	41712***	28600	43588***	29040
	(4021)	(4511)	(4125)	(4223)	(3986)	(4078)
Profit (Rs./acre)	18818***	7481	20985***	7975	21052***	6860
	(3562)	(2337)	(3196)	(3012)	(3969)	(3378)

Note: *,**,*** mean values are significantly different from those on conventional plot at 10%,5% and 1% level of significance.

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Table-2(b). Comparative advantage of BT over conventional cotton (percentage).

	2014-15	2015-16	2016-17
Insecticide Use (%)	-33.4	-35.8	-33.3
Yield (%)	47.9	43.6	45.7
Seed Cost (%)	172.7	153.8	165.7
TVC (%)	0.1	0.5	1.6
Gross Revenue (%)	43.3	45.8	50.1
Profit (%)	151.6	163.1	206.9
Per Capita Income (%)	135.8	159.1	256.9

Our findings are in line with finding of Qaim and De Janvry (2003); Sadashivappa and Qaim (2009) and Kouser and Qaim (2015) Bt farmers have low number of pest application so as low cost. Insecticide spray cost is the major part of total variable cost; BT gene growers bear 34 % less insecticide cost on average than conventional gene growers. Moreover, average profitability of Bt grower over non-Bt grower is 180% in Sindh and per capita income of Bt farmer is US $ 1.28 per day. Unfortunately, non Bt growers are living in depth of poverty in big districts of Sindh province as per capita income of non-Bt grower is nearly US $ 0.45 per day[5]. According to definition of poverty (World Bank), a person consuming less than 1.5 $ a day is living below poverty line. However, even after having comparative advantage BT farmer is receiving 14 % less income than poverty line benchmarks whereas non Bt growers are earning as low as 66 % less than poverty line benchmark.

4.2. Comparative Advantage of BT Gene over Conventional Cotton in Punjab

We have conducted farm level survey from three districts of Punjab. Most of the farmers are interviewed from District Rahim Yar Khan (RYK) as this district contributes 16.2 % into total cotton production of Punjab. District RYK is located in very fertile region of southern Punjab. Nearly 82% of rural population of RYK is dependent on profitability of agriculture sector and farm (plot) sizes are 29 % bigger than any other cotton producing districts of Punjab and Sindh both. RYK is blessed with abundant water resources and farmers receive almost uninterrupted water from canals throughout the years that facilitates on time cultivation process. Survey has registered that more than 80% of farmers prefer growing two crops a year in RYK; wheat and cotton. In terms of cotton, yield RYK district is winner of whole Punjab region[6].

We have also interviewed farmers from district Multan and Bahawalpur (Bwp) for this analysis. Both of these districts have more Bt crop plots than conventional crop. Unfortunately, number of insect (bollworms) attacks and pesticide usage are higher in districts of Multan and Bwp than in RYK. Survey enumerated that farmers of RYK are wealthier than farmers of Multan and Bwp as 73 % of RYK farmers grow their crop on net. However, 72 % farmers of Multan and 69 % of Bwp grow crops after taking loans from local moneylenders (80-150 % interest rate) or microfinance banks. There are three main reasons behind this borrowing rate. First, small landholders have low profitability so that they can partially finance next season crop. Second, average family size including other dependents (like parents) in Multan (8.2) and Bwp (7.5) are higher than that of RYK (6.1), due to health, education and food expanses farmers left with low income to finance crop. Third, due to high probability of weeds and bollworms attacks total variable cost is higher in districts of Multan and Bwp.

Table 3a shows that Bt gene yield is significantly higher than conventional gene yield in districts of Punjab. Farm sizes are also bigger so that profitability of farmers in Punjab is higher than that in Sindh. There is a notable difference in pesticide application in Bt and non-Bt fields, results provided in Table 3b imply that Bt farmers are able to reduce 41.5% pesticide applications as compared to conventional gene growers. Moreover, there is significant difference in profitability and per capita income of Bt and non Bt farmers. Results show that average per capita income of Bt farmers in Punjab is US$ 2.5 per day whereas non-Bt growers have just US$ 0.57 per capita

[5] Calculated by adjusting for family size and per crop profit, compared with poverty line US $1.5 at US $= Pkr99.5 (average of 2014-15 to 2016-17)

[6] Awan and Sheikh (2015).

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income per day. Accessibility to banks is better in Punjab so only 39 % farmers reported that they are availing loans from local moneylender but most of the farmers' avail loan services from microfinance banks by pledging their lands with banks. Due to low interest payment pressure, farmers are able to divert their finances to buy better quality expansive seeds. Punjab government provided pesticides and fertilizer on subsidize prices to farmers in 2015 to 2017 which can be attributed to more cotton yield, low cost of production thus high profitability.

Table-3(a). Agro-economic effects of BT crop on farmers (three districts of Punjab).

	2014-15		2015-16		2016-17	
	BT	Conventional	BT	Conventional	BT	Conventional
	n=110	n=80	n=120	n=60	n=140	n=80
		Mean (SD)		Mean (SD)		Mean (SD)
Average seed (Kg/acre)	20	20	20	20	20	20
Number of Insecticide Sprays per acre	4.23	7.1	4.59	7.66	4.87	7.51
	(2.97)	(3.21)	(3.12)	(3.98)	(2.99)	(3.11)
Insecticide Use (liter/acre)	6	10.5	6	10	5.8	10
	(1.87)	(1.90)	(2.11)	(1.93)	(1.97)	(1.91)
Yield (Kg/acre) Raw cotton(lint+seed)	700	500	710	522	710	520
	(90)	(92)	(109)	(104)	(96)	(88)
Yield (Kg/acre) raw cotton (only lint)	277	122	285	130	288	136
	(40)	(32)	(39)	(58)	(46)	(44)
Output Price (Rs./kg) Raw cotton(lint+seed)	65	60.5	71.5	65.7	75.5	71
	(4.93)	(8.82)	(9.81)	(9.55)	(7.63)	(7.91)
Output Price (Rs./kg) raw cotton (only lint)	120.36	130.56	123.97	148.2	145.2	153.7
	(22.73)	(23.22)	(22.91)	(22.87)	(22.73)	(23.61)
Average area per farmer (acres)	22	15	22	14	23	14
	(2.12)	(2.28)	(3.61)	(1.99)	(2.29)	(2.27)
Farmer family size	6.8	6.8	6.9	6.8	6.8	6.8
	(1.26)	(1.23)	(1.39)	(1.29)	(1.33)	(1.34)
Refuge Area per acre	0	0	0.001	0	0.001	0
Seed Cost (Rs./acre)	550	230	560	250	565	250
	(110)	(160)	(131)	(140)	(128)	(121)
Insecticide Cost (Rs./acre)	4088	6895	4500	6950	4710	7261
	(750)	(787)	(860)	(971)	(855)	(977)
Fertilizer Cost (Rs./acre)	4611	3699	4822	3886	4956	4125
	(1005)	(1088)	(1016)	(1003)	(1069)	(1001)
Manure Cost (Rs./acre)	2200	2015	2689	2500	2800	2700
	(355)	(249)	(384)	(261)	(318)	(220)
Operational Cost and Other Cost (including water)	6000	5600	6250	5866	6500	5800
	(1019)	(1077)	(1025)	(1071)	(1051)	(1106)
Harvesting Cost (Rs/acre)	2900	2556	3207	2945	3510	3265
	(489)	(478)	(423)	(407)	(409)	(446)
Total Variable Cost TVC(Rs./acre)	20349	20995	22028	22397	23041	23401
	(2369)	(2456)	(2391)	(2401)	(3003)	(2690)
Gross Revenue (Rs./acre) raw cotton (lint+seed)	45500	30250	50765	34295.4	53605	36920
	(4101)	(4061)	(4155)	(4255)	(4086)	(4108)
Profit (Rs/acre)	25151	9255	28737	11898.4	30564	13519
	(3102)	(2817)	(3120)	(3112)	(3219)	(3118)

Note: *,**,*** mean values are significantly different from those on conventional plot at 10%,5% and 1% level of significance.

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Table-3(b). Comparative advantage of BT over conventional cotton.

Variables	2014-15	2015-16	2016-17
Insecticide Use (%)	-43	-40	-42
Yield (%)	40.0	36.0	36.5
Seed Cost (%)	139.1	124.0	126.0
TVC (%)	-3.1	-1.6	-1.5
Gross Revenue (%)	50.4	48.0	45.2
Profit (%)	171.8	141.5	126.1
Per Capita Income (%)	298.6	274.0	271.4

Comparing results derived from both provinces, we can conclude that both Bt and non Bt farmers of Punjab are better off than farmers in Sindh in terms of yield, pesticide application and profitability. Even per capita income of Punjab farmer is higher than that of Sindh based farmer.

4.3. Net Productivity Effects of BT gene

In previous sub section, we compared the comparative advantages of BT crop over conventional crop in two provinces, separately. However, here we are presenting an overall impact of BT and conventional gene production. By analyzing results provided in Table 4 a & b we can draw a comparison that Punjab has comparative advantage in Bt gene production in terms of yield and revenue generation over Bt gene productivity in Sindh. Moreover, per capita income of Bt gene growers of Punjab is significantly higher than per capita income of farmers of Sindh from same gene. To assess the overall performance of productivity in both provinces, we have constructed Cobb-Douglas production function. The specifications of Cobb-Douglas production function are as follows: cotton yield per care (expressed in natural log terms) used as a dependent variable, dependent variables are fertilizer, pesticides, labor, seed cost and irrigation. We have added one dummy in production function: BT dummy as a treatment variable implies that value of dummy is 1 if BT gene used and 0 otherwise. We have estimated production function for all three seasons with different specifications. In first model, we have estimated net effects of BT crop through OLS for whole sample. In second model, net yield effects of BT crop for BT adopter only. The basic composition of Cobb-Douglas production function is:

$$ln(Yc) = \beta_o + \beta_1 ln(Fsize) + \beta_2 ln(Scost) + \beta_3 ln(Fquant) + \beta_4 ln(Ircost) + \beta_5 ln(Lcost) + \beta_6 ln(Pest\_use) + \beta_7 Dummy + \varepsilon$$

Where

ln (Yc) = natural log of Cotton Yield measured in Rs. Per acre.

ln (Fsize) = natural log of Farm Size measured in acres.

ln (Scost) = natural log of Seed Cost measured in Rs. Per acre.

ln (Fquant) = natural log of Fertilizer quantity measured in Kg. Per acre.

ln (Ircost) = natural log of Irrigation Cost measured in Rs. Per acre.

ln (Lcost) = natural log of Labor Cost measured in Rs. Per acre.

ln (Pest_use) = natural log of Pesticide use measured in Liter. Per acre.

We have estimated multiple regression equations, model 1 of analysis is for overall sample including dummy for BT technology. While model 2 in analysis is for sample of only BT adopters to explore the net yield, gains of cotton crop over three years of analysis. Results presented in Table 4 a & b are self-explanatory, seed cost has significant positive impact on cotton yield with and without technology, both. It means that better quality seed (expansive) can help in yield increment. Moreover, higher pest application helps in reducing yield loss so overall yield has positive association with pest usage. However, pest application has weak association with Bt gene cotton yield throughout the sample period. Higher the fertilizer consumption better the yield (Herring and Rao, 2012) also

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remain applicable for our sample. Our results maintain that Bt gene adoption has significant impact on cotton yield in Pakistan and net yield gains are also remarkable.

Table-4 (a). Estimated regression results of cobb-douglas production function (dependent Variable: Cotton Yield).

	2014-15		2015-16		2016-17	
	Cobb-Douglas specification		Cobb-Douglas specification		Cobb-Douglas specification	
	Model 1: Whole Sample	Model 2: BT adopters	Model 1: Whole Sample	Model 2: BT adopters	Model 1: Whole Sample	Model 2: BT adopters
Variables	Coefficients	Coefficients	Coefficients	Coefficients	Coefficients	Coefficients
Constant	-0.336	-0.401	-0.301	-0.325	-0.369	-0.301
	(-0.69)	(-1.20)	(-1.09)	(-0.97)	(-1.20)	(-0.89)
Lnlrcost	0.182	0.231	0.255	0.195	0.241	0.201
	(3.22)	(2.07)	(2.87)	(2.77)	(2.78)	(2.33)
Lnscost	0.102	0.388	0.367	0.379	0.371	0.402
	(4.06)	(4.11)	(3.94)	(4.06)	(3.98)	(3.74)
LnFquant	0.326	0.302	0.322	0.362	0.327	0.369
	(3.78)	(3.55)	(3.21)	(3.69)	(3.41)	(3.77)
lnPest-use	0.236	0.099	0.141	0.104	0.114	0.119
	(2.87)	(1.97)	(2.17)	(2.03)	(2.09)	(2.02)
LnFsize	0.336	0.413	0.341	0.396	0.417	0.391
	(3.78)	(3.97)	(3.81)	(3.74)	(3.97)	(3.88)
Lnlcost	0.107	0.121	0.112	0.117	0.135	0.123
	(1.89)	(2.01)	(1.93)	(1.99)	(2.03)	(2.01)
Dummy	0.233		0.356		0.399	
	(2.77)		(3.69)		(3.87)	
R-Square	0.771	0.812	0.791	0.822	0.795	0.819
Adj-R Square	0.748	0.783	0.763	0.793	0.768	0.791
D.W test	1.97	2.08	2.01	2.04	2.02	2.04
F-value	36.99	42.66	38.45	43.99	39.01	42.89
Note: value of t-stats in parenthesis.						

Table-4(b). Estimated regression results of cobb-douglas production function (Dependent Variable: Cotton Yield).

	2014-15		2015-16		2016-17	
	Model 1: Whole sample	Model 2: BT adopters	Model 1: Whole sample	Model 2: BT adopters	Model 1: Whole sample	Model 2: BT adopters
Net yield gain	38.69%	37.10%	36.56%	35.14%	41.20%	40.23%

5. CONCLUSION AND POLICY IMPLICATIONS

This study is contributing in existing literature by increasing assessment sample period. Moreover, we have provided a comparative advantage framework of Bt adopter over non adopters for six districts of two provinces of Pakistan. This study has highlighted that Punjab Bt cotton growers are better off than Bt cotton growers in Sindh as there are substantial differences in their per capita income, farm sizes and access to irrigation resources. By employing Cobb-Douglas production function, we have established that fertilizer quantity, seed cost and land preparation cost help in boosting overall yield in Pakistan. Furthermore, the net gain yield from Bt adoption remained significantly high during all three years of analysis so that profitability gap between adopters and non-adopters have also increased over the time. This study suggests that government may intervene in market to control the increasing prices of Bt cotton seed so most of the farmers will be able to afford better quality seed to attain good yield. We also suggest that banks may encourage farmers to get small loans from them rather being exploited by local money landers. Similarly, monetary policy framework of Pakistan may allow schedule banks to

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make loan services accessible to the farmers of Sindh. Finally yet importantly, awareness programs related to seed quality, importance of refuge area and pesticide utilization might increase overall cotton yield in Pakistan.

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