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The Impact of Better Management Practices (BMPs) Among Cotton Farmers in Punjab, Pakistan

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Abstract

Better management practices (BMPs) as a sustainable approach made it attractive for growers to control the provision of pollutants from agricultural activities as well as enhance the financial return. The experiments of cotton production were conducted in four different regions of Punjab in cotton-growing years 2017-2019. The objective of the study was to evaluate the potential impact of BMPs among cotton farmers by rationalizing the use of input resources (viz., seed, fertilizers, pesticides and water). The data were collected from randomly selected adopters of BMPs (n = 400) and non-adopters of BMPs (n = 100) through a well-structured pretested questionnaire using a multistage sampling procedure from four different regions of Punjab province. Descriptive analysis was employing an independent two-sample t-test to evaluate the significant effect of BMPs on the utilization of input resources and profitability of cotton production between adopters and non-adopters of BMPs. The results indicated that adopters of BMPs were efficiently used input resources (at $p \leq 0.001$ & $p \leq 0.01$) and significantly enhanced the average cotton yield (855.09 kg acre^{-1}) in Punjab, while non-adopters of BMPs had a significantly high cost of production by 11% (35,655 PKR acre^{-1}) and output was lower by 15% (751.70 kg acre^{-1}) under conventional farming for cotton cultivation. The economic analysis revealed that the average gross income gained by adopters of BMPs was significantly high by 11% (72,648 PKR acre^{-1} at $p \leq 0.001$) with the maximum net return of 36% (40,785 PKR acre^{-1} at $p \leq 0.001$) as well as a good B:C (1.28) as compared to non-adopters of BMPs. This study provides useful information about the potential impact of BMPs among cotton farmers even without the extra use of inputs. It is concluded that precision in inputs and management practices with lower input costs can significantly improve cotton productivity leading to uplift the farmers' profit.

Keywords: better management practices, cotton production, economic analysis, rational input resources, Punjab

1. Introduction

In agriculture, environmental sustainability implies good stewardship of the input resources and natural systems (Tittonell, 2014; Sabiha et al., 2016). Achieving economic sustainability in agriculture production remains an overwhelming challenge to researchers, policymakers, development partners, and national governments around the globe (Babu et al., 2020). In the current era, the conventional agriculture system has a major concern associated with the extensive use of external inputs including seeds, land management practices, agrochemicals (fertilizers, pesticides & herbicides) and water, which is negatively influencing farmers' profit and yield (Cristache et al., 2018,). Additionally, conventional agriculture poses adverse side effects on the natural environment by deteriorating water and land resources (Lampridi et al., 2019). Environment sustainability and sustainable agriculture both are hooked into each other so improving the input use efficiency can significantly contribute to maintaining sustainability.

Cotton (*Gossypium hirsutum* L.) is one of the economically important crops, leading as a natural fiber, and is grown commercially in more than 100 countries (Ullah et al., 2017). Pakistan is the fifth largest producer of this white gold, where cotton cultivation contributes to the total value of agricultural production by 4.5% and share 0.8% in GDP during the production year 2018-2019 (Ministry of Finance, 2019). Therefore, cotton is making significant support to the development of the national and rural economies in terms of promising sources of livelihood. In Pakistan, cotton production is concentrated mainly in two provinces; Punjab is the leading province accounting for 75% followed by Sindh with 25% of the total national cotton production (FAS, 2018). Moreover, cotton is considered one of the most input-intensive crops contributing to the plentiful consumption of resources all around the globe (Imran et al., 2019). Hence, unjudicial and unsystematic use of agrochemicals (especially fertilizers and pesticides) marks cotton as a 'highly polluted crop (Awan et al., 2015). The excessive utilization of input resources (cultural practices, agrochemicals and water) is not only reducing the scarce assets but also contributing to the degradation of the natural environment (Ullah et al., 2016). For sure, the productivity of cotton depends upon the consumption of fertilizers and irrigation that would otherwise cause the reduction of cotton yield (Watto & Mugera, 2015). Though, the requirement of water will remain a major factor in cotton production (growth and yield) that can be increased by providing the desired level of water during cotton cultivation. But the over-irrigation achieved via flood irrigation resulting in saturated soil with a low percolation rate causes deterioration of land and water resources (Zhang et al., 2016). Yet, proper management requires to provide the knowledge among farmers for the sensible use of available water at the required time in the required quantity (Abid et al., 2011). Likewise, as we concerned with soil nutrient management, if a rational amount of inorganic fertilizers is applied as per-requisite, then there has been a significant improvement (about 30-50%) in the yield of different crops in different zones of the country (Sui et al., 2015; Ripoche et al., 2015; Ullah et al., 2017). Moreover, Rehman et al. (2019a) reported that the precision application of fertilizers and efficient irrigation significantly increased cotton yield per acre as compared to the previous years. Besides, cotton is also a vulnerable host to many diseases especially pests (*i.e.*, sucking pests and some bollworms); an enormous amount of pesticides is applied more than the recommended dose to cope with the common cotton pests (Basit, 2018). Previous studies reported that almost 8-10% of pesticide production is used on the cotton crop which ultimately raised the external social costs (Khan & Damalas, 2015a; Hina & Asad, 2019). Instead, these chemical inputs in the conventional cotton farming system create serious non-negotiable threats for the environment in the long run (Dhananjayan & Ravichandran, 2018).

Conventional agriculture for cotton production has relied on the undue use of synthetic fertilizers, pesticides, herbicides, and water which led to over-exploitation of natural resources in Pakistan (Zulfiqar & Thapa, 2016; Zinyemba et al., 2018). Though cotton cultivation provides a promising source of livelihood to the rural farming community, the traditional cotton farming with the intensive consumption of resources to gain the maximum cotton yield causes the high production costs that put huge economic pressure on the farmer's financial resources (Zulfiqar et al., 2017; Imran et al., 2018). Hence, both agriculture sustainability and farmer's income are challenged by high production costs and environmental vulnerabilities, therefore environmental impacts and economic performances of cotton production are necessary to analyze (Rehman et al., 2019b). Knowing the limitations of the conventional agriculture system, researchers, scientists and policymakers are arguing for the advancement of alternative approaches/practices that can enhance the social, environmental, and financial sustainability of the agriculture production system (Therond et al., 2017; Lencucha et al., 2020; Stringer et al., 2020). Henceforth, there is a dire need for sustainability in cotton production with careful attention to the environment by employing judicious inputs. Better management practices (BMPs) are the chief approach to preserve our scarce resources that not only meet today's farming goals by minimizing the negative impact on the environment but also enhancing crop returns (Hina & Asad, 2019). Some practices are considered as BMPs which include soil management (proper land cultivation practices), nutrient management (rational amount of fertilizers application), pest management (judicial application of pesticides), water management (efficient irrigation) to improve cotton yield sustainably with the least exposure to the environment. The adoption of these BMPs is a viable way to switching from traditional to sustainable farming which synergistically increases the financial requirements and improves yield along with environmental and social concerns (*i.e.*, use of water and pesticide). The implementation of BMPs for sustainable cotton production would lead to several long-term benefits like the sustainability of mankind, conservation of the natural resource and biodiversity followed by a reduction in rural poverty (Ullah et al., 2017).

The present study is aimed at examining the impact of BMPs for resilient and sustainable cotton production at the four different sites viz., Bahawalpur, Multan, Muzaffargarh and Jhang of Punjab province, Pakistan. Our experiment focused on resource use efficiency and economic analysis of cotton production with an alternative agriculture approach (BMPs) that will reduce undue inputs of inorganic agrochemicals and irrigation water, further, that will make sustainability, socially and economically better cotton production than conventional practices.

2. Method

2.1 Study Sites

Punjab province was selected for the experiments, which is the largest cotton-producing province and contributed its major share in Pakistan's total cotton production by 80% (Rehman et al., 2015; Zulfiqar and Thapa, 2017). The experiments for the cotton production were carried out at four different regions of Punjab viz., Bahawalpur (29° 25' 5.04" N and 71° 40' 14.47" E), Multan (30° 10' 53.25" N and 71° 29' 31.77" E), Muzaffargarh (30° 04' 24.99" N and 71°10' 49.80" E), and Jhang (31° 15' 36.22" N and 72° 19' 9.38" E) in the cotton cropping years 2017-2019 (Figure 1). These areas are preferred because they are considered for cotton cultivation and a remarkable proportion of cotton yield in Punjab comes from these areas (Wei et al. 2020). It was piloted by WWF-Pakistan's Better Cotton (BC) projects under the Sustainable Agriculture and Food Programme (SAFP). Method section describes in detail how the study was conducted, including conceptual and operational definitions of the variables used in the study, Different types of studies will rely on different methodologies; however, a complete description of the methods used enables the reader to evaluate the appropriateness of your methods and the reliability and the validity of your results, It also permits experienced investigators to replicate the study, If your manuscript is an update of an ongoing or earlier study and the method has been published in detail elsewhere, you may refer the reader to that source and simply give a brief synopsis of the method in this section.

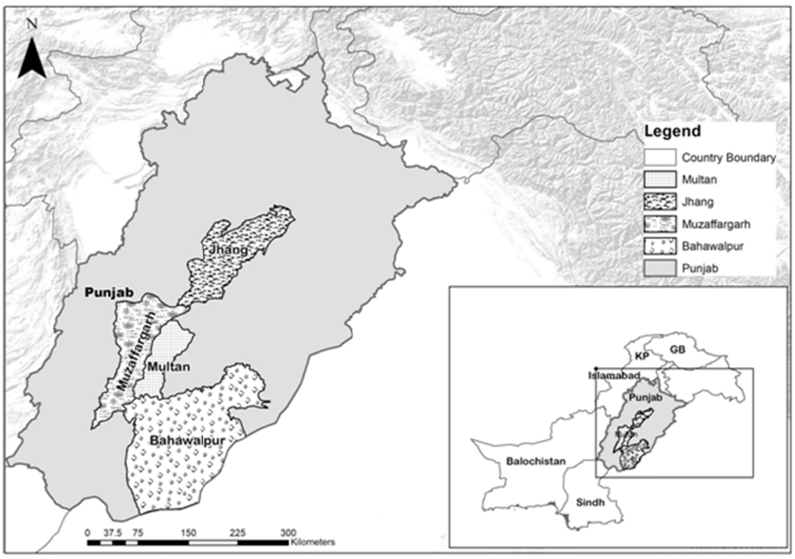

Figure 1. Map of experimental sites (Bahawalpur, Multan, Muzaffargarh and Jhang) in Punjab, Pakistan

2.2 Data Source and Training of Farmers

In the current study, more than 150,000 cotton farmers were purposefully involved and registered under the better cotton project from the selected regions of Punjab (viz., Bahawalpur, Multan, Muzaffargarh, and Jhang). Depending upon the number of farmers and cotton cultivated areas, producer units (PU) were established. Wherein, each producer unit was comprised of about a hundred learning groups (LGs) and each LG consisted of 30-40 cotton farmers. After the selection and grouping of cotton growing farmers, project team generate a training material that contains the recommendations for better management practices (BMPs) and cover the following aspects of cotton production: i) Land/Soil management via minimum tillage practices, laser land leveling, efficient use of land cultivation & intercultural practices (cultivator, disc plough, rotavator), multibed-planter and drill for cottonseed sowing, ridger for weeding purpose after sowing; ii) Nutrient management via utilization of rational amount of inorganic fertilizers [urea; calcium ammonium nitrate (CAN); diammonium phosphate (DAP); nitrophos (NP)] for the right amount and right source of nutrients to avoid their excessive loss by nutrient runoff based on soil test results; iii) Pest management via judicial use of pesticides against common pests based on regular pest scouting and spray once to reach the economic threshold for each pest; iv) Water management via on-farm water conservation practices e.g., laser land leveling, weeding, cleaning of water channels, efficient sowing techniques to avoid water losses and improve water productivity. The project team includes field trainers (FTs) and field facilitators (FFs) who were conducted the training to teach the farmers for the adaptation of the aforesaid BMPs in each of the selected regions.

2.3 Data Collection

A multi-stage sampling technique was used to collect data from the adopters of BMPs (better cotton framers) and non-adopters of BMPs (conventional farmers) were randomly selected with simple size as n = 400 and n = 100, respectively from each region of the project area (Bahawalpur, Multan, Muzaffargarh and Jhang) under cotton cultivation. The quantitative data were collected from the cotton farmers of both groups (adopters and non-adopters of BMPs) during three consecutive years of cotton-cropping season 2017-2019 at their farm sites.

The maximum data were collected through a pretested well-developed and comprehensive questionnaire to obtain relevant and appropriate information on cotton cultivation (Naveed & Anwar, 2015). For the current study, the data used for the analysis have comprised the use of input resources viz., cotton cropping area (acres); seed rate (kg); rate of fertilizer (kg); numbers of pesticides used (f); rate of pesticides (kg); and irrigation water (m3) as well as the cost of inputs in rupees (PKR) including labor cost. The output data was included harvested cotton yield (kg) and cost of output in rupees (PKR) in four different cotton-growing regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab.

2.4 Cost of Production

As various inputs (fixed and variable) were involved in cotton production. The on-farm cost of cotton production was estimated for all inputs viz., i) seed procurement (*i.e.*, certified/approved/local variety of seed); ii) land management practices; iii) application of inorganic fertilizers (Urea, CAN, DAP, NP); iv) pesticides (active ingredients against cotton pests) and v) irrigation as well as labor.

2.5 Economic Analysis

Economic analysis was estimated to assess the progressive effect of BMPs on cotton production as compared to conventional cotton cultivation in three consecutive years (2017-2019) at four different sites of the Punjab province. The input and output cost was used and net return (profit) was compared between better cotton farmers and conventional farmers to analyze the financial performance of cotton growers. The gross income [GI = Q×P [Q = yield (kg acre^{-1}), P = price of yield (PKRs acre^{-1})]; total expenses [TE = V × X (PKRs acre-1) [V = input prices, X = input purchase quantity]; net return [NR = GI – TE (PKRs acre^{-1})]; input-output ratio (GI/TE) and benefit-cost ratio (B:C = NR/TE) were computed using the mentioned formula (Dagistan et al., 2009; Imran et al., 2018; Imran et al., 2019).

2.6 Statistical Analysis

The quantitative data were analyzed via descriptive analysis using Statistical Package of Social Science (SPSS) version 25. The input and output differences in cotton cultivation between both groups of cotton farmers were estimated by an independent two-sample t-test assuming unequal variances for comparing the mean values.

3. Results and Discussion

Our results revealed that input resources such as crop area, land management practices, seed, fertilizers, pesticides, irrigation and labor power significantly and positively affect the cotton production in three cropping years (2017-2019) at the project sites. Hence, crop productivity depends on the potential use of available resources (aforesaid inputs) with the implementation of better management practices (BMPs) can save the variable cost and have a significant role in cotton production. Likewise, Ahmad et al. (2016) determined that cropped area, land preparation, seed, fertilizer, pesticides, irrigation and labor statistically significant and positively affect cotton production. Similarly, the positive impact of BMPs on crop productivity was reported by (Makarewicz et al., 2009; Awan et al., 2015; Ullah et al., 2017; Schimmelpfennig, 2018; Hina & Asad, 2019).

3.1 Cotton Cultivation Area

The average cotton cultivated area owned by adopters of BMPs was about 7.00 acres which were significantly high by 40% (at $p \leq 0.001$) as compared to non-adopters of BMPs/conventional farmers (5.00 acres) in cotton cropping years 2017-2019 at four different regions of Punjab (Figure 2). Besides, data showed that amongst four regions of Punjab, Muzaffargarh showed the maximum average cotton cultivated area in cropping year (2017-2019) by adopters of BMPs (8.72 acres) that was significantly high by > 100% than that of non-adopters of BMPs (4.15 acres). It displayed that cotton growers of Muzaffargarh showed a willingness to adopt BMPs in cotton cultivation. Imran and Ozcatalbas (2017) also reported that in Muzaffargarh, the majority of the cotton farmers were required holistic participatory approaches to improve farmers' understanding of technology, recommended strategies and demand-driven.

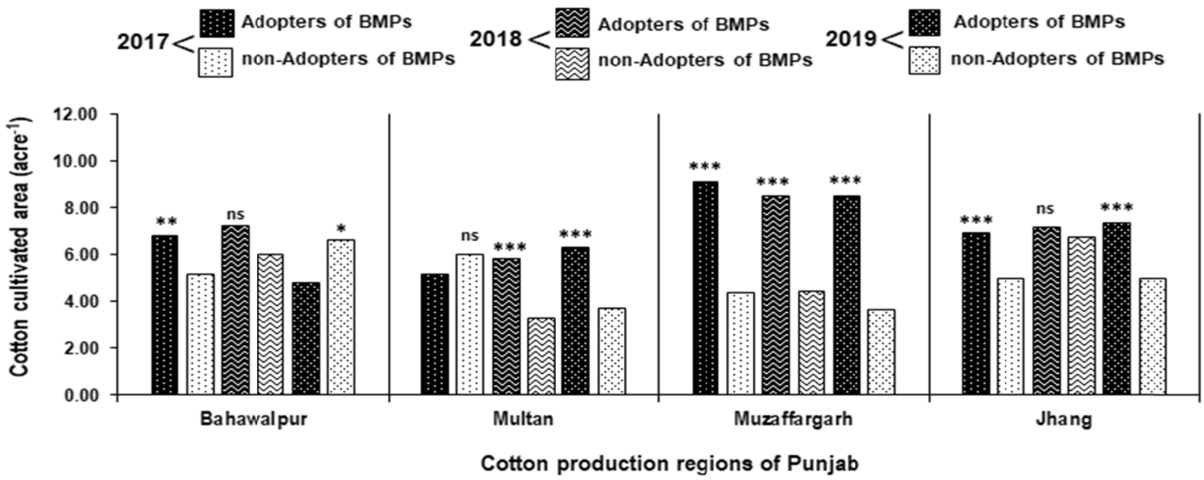

Figure 2. Average cotton cultivated area (acre) of Adopters and non-adopters of BMPs (better management practices) in cotton-growing years (2017, 2018 & 2019) at four regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab, Pakistan

Note. The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$; *** at $p \leq 0.001$; ns at a non-significant level for two-groups (adopters of BPMs and non-adopters of BMPs) mean comparison t-test assuming unequal variances.

3.2 Inputs Use Efficiency

The efficiency of input resources in cotton production can be attained by optimizing inputs of available resources (Zulfiqar et al., 2017; Mehta, 2019). Our results revealed that the input use efficiency of the vital resources (*i.e.*, seed rate, fertilizers, pesticides and water) used by adopters of BMPs was considerably high than non-adopters of BMPs (conventional cotton growers) in consecutive three years (2017-2019) (Table 1). Additionally, the current results displayed that opting for a set of sustainable agricultural practices such as BMPs in cotton production with the use of precision inputs, makes it eco-friendly, more secure and sustainable (Ullah et al., 2017).

3.2.1 Seed Rate

As a seed is a basic input in the crop production system, plant growth and crop yield noticeably depend on the seed germination and growth rate (Tian et al., 2014). As cotton growers were trained for opting for the BMPs, adopters of BMPs were procured approved/certified variety of seed; and an optimized rate of seed was applied in the field for the cotton cultivation in three consecutive years. Tokel et al. (2021) reported that by using certified and approved varieties of cottonseed farmers gained the maximum yield and made a profit of million dollars from reduced pesticide use. Our results indicated that the average seed rate (kg acre^{-1}) used by adopters and non-adopters of BMPs was 8 kg and 9 kg in Bahawalpur; 9 kg and 10 kg in Multan; 9 kg and 11 kg in Muzaffargarh while 12 kg and 13 kg in Jhang, respectively (Table 1). The results indicated that adopters of BMPs in Muzaffargarh were used a significantly low seed rate of 17% as compared to non-adopters of BMPs. While overall average seed rate used by non-adopters of BMPs was 10% high as compared to adopters of BMPs in Punjab province. The same results were also found by previous studies, where cotton farmers opted for conventional agriculture using a high seed rate as compared to better cotton farmers (Zulfiqar & Thapa, 2016; Zulfiqar et al., 2017).

3.2.2 Land Preparation & Intercultural Practices

As far as we are concerned with land preparation, seed sowing and intercultural practices; the adopters of BMPs from all regions (Bahawalpur, Multan, Muzaffargarh & Jhang) have opted for the low frequency of cultural practices as compared to non-adopters BMPs (Table 1). Adopters of BMPs were practiced laser land leveling (n = 1-time) for the land preparation. Abdullaev et al. (2007) reported that laser land leveling is an innovative practice that reduced the demand for water irrigation and this technology conserved a considerable amount of energy and operating time (about 15%) during on-farm agricultural operations. Besides, before sowing adopters of BMPs were practiced cultivator (n = 2-3 times); disc plough (n = 1-time) and rotavator (n = 1-time). Also, they were used a multi-bed planter or drill for seed sowing and used a ridger for weeding (n = 1-2 times) usually depending upon weeds. In contrast, non-adopters of BMPs have not opted for laser land leveling and used simple land leveling blades for land preparation. As the non-adopters of BMPs were followed conventional agricultural management practices hence they were adept more numbers of cultural practices (Gomiero et al., 2011; Harkes et al., 2019), such as cultivator (n = 4 times); disc plough (1 time), and rotavator (1-2 time) as well as used drill and dibbling method for seed sowing. Alike adopters of BMPs, they were also practiced ridger (n = 1-2 times) for weeding after sowing.

3.2.3 Fertilizers

Most of the soils in Punjab are nitrogen deficient; hence, there is always a need to improve soil fertility through fertilizers amendment to mitigate nutrients deficiency (Maqsood et al., 2016). Our results showed that adopters of BMPs applied a rational amount of inorganic fertilizers; and an average amount of fertilizers input (urea, CAN, DAP and NP) was significantly reduced by 19% for cotton production (2017-2019) in Punjab. Besides, the maximum reduction in fertilizer consumption was found in Multan (35%) followed by Jhang (22%), where the adopters of BMPs were applied urea, CAN and NP significantly low (at $p \leq 0.001$) as compared to non-adopters of BMPs (Table1). Moreover, Bakhsh et al. (2005) reported a positive impact of fertilizers (especially N and P) on the productivity of cotton in Punjab (Sargodha district). Our findings are coherent with the previous studies, as a rational or precise amount of fertilizers are necessarily applying in the soil to gain the maximum cotton production (quality and quantity of yield) (Reetz, 2014; Oseko & Dienya, 2015; Baio et al., 2017; Honfoga, 2018).

3.2.4 Pesticides

The incidence of weeds, pests and disease on a cotton crop is an emerging problem in all cotton growing areas of Pakistan, and the adoption of chemical control methods is becoming prevalent among the cotton growers in Pakistan (Bakhsh et al., 2005). But, adopters of BMPs have significantly reduced the rate of pesticides (kg acre^{-1}) and some pesticides used against cotton pests by 23% and 20%, respectively as compared to non-adopters of BMPs. Our results displayed that the maximum consumption (3.15 kg acre^{-1}) of pesticides were found in Muzaffargarh by non-adopters of BMPs with an average of eight various pesticides spray, Likewise, a conventional cotton grower in the Jhang region used the maximum number of pesticides spray that was significantly high by 40% as compared to adopters of BMPs (Table 1). Alike, Khan et al. (2010) reported that BMP farmers applied around 72% less synthetic pesticides as compared with non-BMP.

Table 1. Level of inputs/resources used ($acre^{-1}$) by adopters and non-adopters of BMPs (better management practices) for cotton production in four different regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab in three consecutive cotton cropping years 2017-2019

Variables ($acre^{-1}$)	Region of Punjab	2017		2018		2019	
		Adopters of BMPs (N = 400)	non-Adopters of BMPs (N = 100)	Adopters of BMPs (N = 400)	non-Adopters of BMPs (N = 100)	Adopters of BMPs (N = 400)	non-Adopters of BMPs (N = 100)
Seed rate (kg)	Bahawalpur	8.82***	8.03	7.80	8.57***	8.57	9.36***
	Multan	8.06	9.70ns	10.76ns	10.53	7.71	9.73***
	Muzaffargarh	7.68	10.86***	10.66	12.02***	9.44	10.51***
	Jhang	11.31	12.51***	15.30ns	15.01	10.11	11.5***
No. of pesticide spray (f)	Bahawalpur	14.73	16.73***	13.14	13.25ns	17.86	20.05***
	Multan	11.33***	10.19	12.30	16.17***	12.343	16.42***
	Muzaffargarh	10.53	12.32***	16.17	16.92*	12.51	14.84***
	Jhang	6.10	13.30***	12.39	20.00***	8.98	12.27***
Total pesticides applied (kg)	Bahawalpur	2.61	2.77**	0.18	0.193***	3.52	3.74***
	Multan	1.86	2.20***	2.06	3.10***	1.78	2.79***
	Muzaffargarh	2.20	2.55***	3.26	3.64***	2.87	3.27***
	Jhang	0.99	1.926***	1.89	3.80***	1.82	2.421***
Calcium ammonium nitrate (kg)	Bahawalpur	26.98	34.51ns	20.63ns	20.51	27.51	41.52***
	Multan	43.86	85.52**	53.04	85.35***	36.82	74.07***
	Muzaffargarh	22.21	47.02***	32.01	54.52***	42.39	47.02ns
	Jhang	8.09	0.00	0.00	0.00	35.03	48.92***
Diammonium phosphate (kg)	Bahawalpur	42.77	51.02***	40.45	48.52***	40.02	45.02**
	Multan	51.76	57.21*	39.90	45.80**	40.19	48.05***
	Muzaffargarh	52.05	60.52***	46.21***	39.02	33.68	44.77***
	Jhang	15.99	50.02***	40.27	50.02***	13.89	24.63***
Nitrophos (kg)	Bahawalpur	15.66	27.01***	12.63***	4.00	13.38ns	13.01
	Multan	20.93	27.83*	18.22	32.81***	15.89	29.53***
	Muzaffargarh	15.03	20.26ns	27.26*	21.51	25.39***	8.00
	Jhang	56.50	0.00	29.89	50.02***	37.40	43.35***
Urea (kg)	Bahawalpur	96.99***	74.28	116.92	135.05***	120.10ns	116.30
	Multan	70.33	79.02ns	77.83	138.17***	63.22	109.36***
	Muzaffargarh	124.23	113.30**	96.42	100.79***	115.36	132.55***
	Jhang	55.54	100.04***	35.76	50.02***	62.79	84.85***
Irrigation (m^3)	Bahawalpur	1791.18	2405.00***	1982.98	2170.83***	2078.83	2133.77**
	Multan	1909.56	2279.18***	1978.55	2549.93***	1735.05	2346.50***
	Muzaffargarh	1659.03	1823.95***	1964.34	2024.67**	1693.48	1976.29***
	Jhang	2146.99	2327.80***	1920.08	2149.21***	2205.01	2524.35***

Note. The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$; *** at $p \leq 0.001$; ns at a non-significant level for two-groups (adopters of BPMs and non-adopters of BMPs) mean comparison t-test assuming unequal variances. f: frequency; kg: kilogram; m^3: cubic meter.

3.2.5 Water

Globally, water is a scarce commodity and agricultural production is directly dependent on the availability and effective use of water for crop production (D'Odorico et al., 2020). Moreover, the sensible use of the available water through flood irrigation is a management issue and, therefore, requires motivation among farmers in using water at the required time in the required quantity (Li et al., 2020). Our results revealed that the adopters of BMPs were trained for efficient irrigation, hence input of water resource was significantly reduced by 13%, 22%, 9%, and 10% in Bahawalpur, Multan, Muzaffargarh and Jhang, respectively as compared to non-adopters of BMPs (Table 1). Likewise, the frequency of irrigation was also found to be higher for non-adopters of BMPs compared to adopters of BMPs with similar findings (Khan et al., 2010).

3.3 Cotton Yield

Notably, adopters of BMPs produced cumulative average cotton yield despite a relatively low amount of inorganic fertilizers, pesticides and water irrigation that was significantly higher by 15% than that of non-adopters of BMPs in Punjab. The average cotton yield in Punjab was estimated as 855.09 kg acre-1 by adopters of BMPs as compared to non-adopters of BMPs (751.70 kg acre^{-1}). Likewise, the percentage reduction in the average yield of adopters of BMPs was found to be 7%, 24%, 11% and 13% in Bahawalpur, Multan, Muzaffargarh and Jhang, respectively in three consecutive years (2017-2019) of cotton production (Figure 3). Amongst the four regions of Punjab, the maximum average cotton yield was produced in Multan 961.90 kg acre^{-1} that was significantly high by 41% and 25% in the cropping year of 2017 and 2018, respectively by the implementation of BMPs as compared to conventional cotton farming (Anwar et al., 2009). Our results depicted that the cotton yield produced by both groups of cotton farmers in all four regions (Bahawalpur, Multan, Muzaffargarh and Jhang) was gradually decreased in 2019 as compared to the rest of the years (2017 & 2018). This issue is ascribed to most of the farmers in Pakistan who have virtually no land and face financial difficulties in cultivating cotton over the years (Aslam, 2016; Abro & Awan, 2020). Conferring by adopters of BMPs, they were consuming fewer amounts of inputs without compromising on cotton yield, which had contributed to making efficient use of scarce water resources and conserve soil and land to maintain the essential conditions for sustainable crop production (Hasanov & Nomman, 2011; Khan et al., 2011; Zulfiqar et al., 2017).

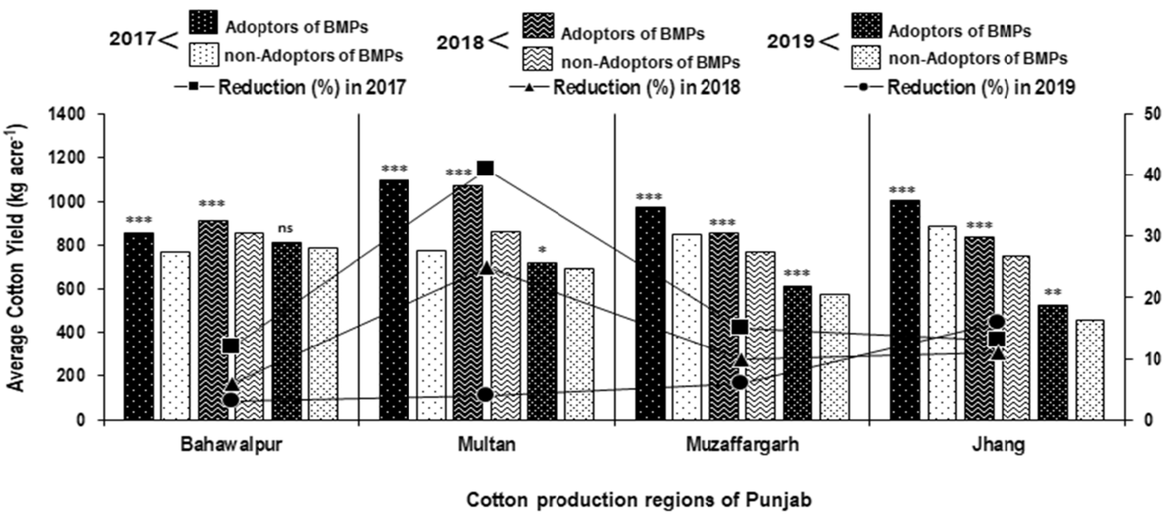

Figure 3. Average cotton [cotton yield (kg acre^{-1}) and reduction percentage (%)] produced by adopters and non-adopters of BMPs (better management practices) in cotton-growing years (2017, 2018 & 2019) at studied regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab, Pakistan

Note. The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$; *** at $p \leq 0.001$; ^{ns} at a non-significant level for two-groups (adopters of BPMs and non-adopters of BMPs) mean comparison t-test assuming unequal variances.

3.4 Input-Output Costs & Economic Analysis

3.4.1 Cost of Production Summary

As described above non-adopters of BMPs were utilized the maximum inputs so the total cost of conventional cotton production was significantly higher than that of cotton yield produced by adopters of BMPs, which was attributed to the application of higher amounts of inorganic inputs (agrochemicals) and irrigation water (Zulfiqar & Thapa, 2016; Altieri & Nicholls, 2017; Imran et al., 2019). Similarly, non-adopters of BMPs were practiced maximum cultural operations (frequency) for land preparation, seed sowing and intercultural practices. Hence, the cost of land management practices paid by non-adopters of BMPs was significantly high (at $p \leq 0.001$) by 15-30% in Jhang followed by the Multan region (10-20%), while Bahawalpur and Muzaffargarh were showed a non-significant difference in land management cost between adopters and non-adopters of BMPs. The results of seed cost showed that as non-adopters of BMPs were used the maximum average seed rate (10.75 kg acre^{-1}) ultimately the average cost of seed was significantly high by 20% as compared to the adopters of BMPs in Punjab. Alike, non-adopters of BMPs had a significantly high (at $p \leq 0.001$) cost of fertilizers by 8-22% when compared to adopters of BMPs as they were applied the rational amount in Punjab (2017-2019) (Tables 2A-2D).

Table 2A. Input-Output costs of cotton production (PKR acre^{-1}) in Bahawalpur region of Punjab (2017-2019)

Variables	2017		2018		2019	
	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)
Input Cost (PKR acre^{-1})						
Cost of Land Preparation	5528.81ns	5065.05	9473.48	9845.88ns	8862.84	9019.65ns
Cost of seed	1664.83	1605.51ns	1560.26	1713.69***	1713.03	1871.02***
Cost of Pesticides	3395.89	3791.03***	4139.95	4841.96***	6497.50	7430.51***
Cost of Fertilizers	5849.04	6427.60***	7639.51	8318.37***	9099.81	9679.92***
Cost of Irrigation	4386.76	9297.16***	5636.28	7385.49***	4034.38	4256.72ns
Cost of Labor	5492.90ns	5473.59	6925.09***	6480.62	8151.43ns	7928.21
Total Expenses	26418.23	31659.95***	35374.57	38586.02***	38358.99	40186.03***
Output Cost (PKR acre^{-1})						
Total Yield (kg)	857.23***	765.30	908.02***	856.55	808.80ns	788.32
Gross Income	64413.11***	57552.50	89747.00***	84939.87	79612.98ns	78040.58
Profit	37994.87***	25892.56	54372.43***	46353.86	41253.98**	37854.55
Output/input ratio	2.49***	1.84	2.55***	2.21	2.07***	1.94
Benefit-cost ratio	1.49***	0.84	1.55***	1.21	1.07***	0.94

Table 2B. Input-Output costs of cotton production (PKR acre^{-1}) in Multan region of Punjab (2017-2019)

Variables	2017		2018		2019	
	BCI farmers	non-BCI farmers	BCI farmers	non-BCI farmers	BCI farmers	non-BCI farmers
Input Cost (PKR acre^{-1})						
Cost of Land Preparation	5258.55	5953.43***	7904.83	8697.16***	7155.996	8944.593***
Cost of seed	1611.29	1940.39***	2152.11ns	2106.13	1542.29	1945.18***
Cost of Pesticides	2683.55	3684.51***	3871.99	5376.75***	4952.91	7034.97***
Cost of Fertilizers	5999.20	6798.39***	7993.26	11774.19***	8075.26	11665.71***
Cost of Irrigation	5440.74	6804.60***	7105.06	8527.14***	5604.26	9042.65***
Cost of Labor	7282.24***	4862.81	8561.93***	7290.65	7066.62*	6742.58
Total Expenses	28275.57	30044.13***	37589.17	43772.03***	34397.33	45375.69***
Output Cost (PKR acre^{-1})						
Total Yield (kg)	1094.34***	776.49	1072.02***	860.03	719.201*	691.574
Gross Income	75790.71***	53387.46	90396.09***	72008.11	66464.38***	63077.21
Profit	47515.14***	23343.33	52806.92***	28236.09	32067.06***	17701.52
Output/input ratio	2.67***	1.79	2.41***	1.65	1.93***	1.39
Benefit-cost ratio	1.67***	0.79	1.41***	0.64	0.93***	0.39

Note. The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$ *** at $p \leq 0.001$; ns at a non-significant level for two-group mean comparison t-test assuming unequal variances.

This study used the average exchange rate for the years 2017, 2018 and 2019 (1 PKR = 0.0095, 0.0081 and 0.0072 USD, respectively) when the study was carried out.

Table 2C. Input-Output costs of cotton production (PKR acre^{-1}) in Muzaffargarh region of Punjab (2017-2019)

Variables	2017		2018		2019	
	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)
Input Cost (PKR acre^{-1})						
Cost of Land Preparation	7560.60	7675.61ns	5234.30	5681.30*	7497.23**	6749.73
Cost of seed	1536.12	2171.08***	2131.27	2403.97***	1888.81	2101.15***
Cost of Pesticides	3311.78	3856.56**	7859.62ns	7646.09	5349.79	6245.03***
Cost of Fertilizers	6942.43	7790.15***	8710.78ns	8691.32	9300.95	9621.94*
Cost of Irrigation	2079.60	2975.20***	4136.46	4263.98ns	3432.01	4887.48***
Cost of Labor	8081.09ns	8043.49	7862.17	8136.04ns	6387.90***	6028.19
Total Expenses	29511.62	32512.09***	35934.59	36822.70***	33856.69	35633.52***
Output Cost (PKR acre^{-1})						
Total Yield (kg)	971.03***	847.83	852.17***	770.11	615.10***	577.43
Gross Income	68801.61***	66053.59	76665.67*	72920.21	62479.51***	58923.85
Profit	39289.99***	33541.50	40731.08***	36097.51	28622.82***	23290.33
Output/input ratio	2.35***	2.03	2.14***	1.98	1.85***	1.65
Benefit-cost ratio	1.34***	1.02	1.1.3***	0.98	0.85***	0.65

Table 2D. Input-Output costs of cotton production (PKR acre^{-1}) in Jhang region of Punjab (2017-2019)

Variables	2017		2018		2019	
	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)	BCI farmers (N = 400)	non-BCI farmers (N = 100)
Input Cost (PKR acre^{-1})						
Cost of Land Preparation	3633.06	5193.10***	3556.69	3699.50***	3236.74	3689.95***
Cost of seed	2262.70	2502.46***	3059.99ns	3001.21	2938.30**	2206.48
Cost of Pesticides	1364.00	2625.56***	4262.73	5814.35***	3292.15	4643.72***
Cost of Fertilizers	4499.71	5977.42***	5643.66	7192.91***	7020.86	9493.76***
Cost of Irrigation	4366.70	5241.12***	3935.09	4377.77***	5057.46	5830.97***
Cost of Labor	9841.19***	8834.08	8347.38***	7487.03	6322.59***	5455.87
Total Expenses	25967.37	30373.73***	28805.53	31572.78***	27868.10	31320.75***
Output Cost (PKR acre^{-1})						
Total Yield (kg)	1001.54***	883.41	834.74***	748.70	526.88***	454.66
Gross Income	67600.96***	66255.56	76392.79***	68528.23	53409.51***	45919.03
Profit	41633.60***	35881.83	47587.26***	36955.46	25541.42***	14598.28
Output/input ratio	2.62***	2.19	2.65***	2.17	1.92***	1.47
Benefit-cost ratio	1.62***	1.19	1.65***	1.17	0.92***	0.47

Note. The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$ *** at $p \leq 0.001$; ns at a non-significant level for two-group mean comparison t-test assuming unequal variances.

This study used the average exchange rate for the years 2017, 2018 and 2019 (1 PKR = 0.0095, 0.0081 and 0.0072 USD, respectively) when the study was carried out.

As stated above non-adopters of BMPs were applied more numbers pesticides than adopters of BMPs with the maximum rate, henceforth the cost of pesticides in all four regions was significantly high (at $p \leq 0.001$) by 23%. Also, the highest cost of pesticides was estimated as 41% by non-adopters of BMPs as compared to adopters of BMPs in the Jhang region (Table 2D). Likewise, our data showed that adopters of BMPs were paid a significantly less (25%) cost of irrigation as compared to non-adopters of BMPs. Besides, in the Bahawalpur region, non-adopters of BMPs were consumed excessive water for cotton irrigation that was significantly high by 52% in the year 2017 as compared to adopters of BMPs (Table 2A). While, the maximum water consumption for irrigation was noticed in the Multan region by non-adopters of BMPs as 20%, 17% and 38% in three consecutive years (2017-2019) of cotton production as compared to adopters of BMPs (Table 2B). Also, Muzammil et al. (2020) reported that the cost of irrigation is directly depending upon the input use efficiency of irrigation for cotton production. As labor is considered a very important resource in cotton production, the results of input and output analysis showed that the cost of labor was found to be non-significant between adopters and non-adopters of BMPs in Bahawalpur, Muzaffargarh and Jhang (Tables 2A, 2C and 2D). Whereas, in Multan, adopters of BMPs were utilized the maximum labor power in different farm activities with a significant increase of 50%, 17% and 5% in 2017, 2018 and 2019, respectively as compared to the non-adopters of BMPs (Table 2B). Moreover, former studies showed that cotton farmers, who are already deficient in resource use, cannot bear the burden of increasing the cost of inputs (Abid et al., 2011). Our results on the cost of production are in line with the findings of other studies (Abid et al., 2016; Khan & Damalas, 2015b; Zulfiqar & Thapa, 2016). Additionally, to obtain the maximum cotton yield, the intensive application of fertilizers poses an additional burden on the quality and fertility of the soil (especially topsoil) (Anwar et al., 2009; Timane, 2014). Better management practices enhance the crop yield with the reduction in input cost and also maintain the fertility of the soil (Reetz, 2014; Shah & Wu, 2019).

3.4.2 Financial Performance

The results of input and output costs of cotton production were noticeably different between adopters and non-adopters of BMPs in four different regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab (Figure 4). The average input (total expenses) was significantly high (11%) by non-adopters of BMPs as (35,655 PKR acre^{-1}) as compared to adopters of BMPs (31,863 PKR acre^{-1}). Besides, the maximum average total expenses (39,731 PKR acre^{-1}) of cotton production was consumed by the non-adopters of BMPs was 23% high as compared to the adopters of BMPs from Multan in cropping years (2017-2019). In contrast, the average gross income has generated by adopters of BMPs (72,648 PKR acre^{-1}) was significantly greater by 11% as compared to non-adopters of BMPs as compared to non-adopters of BMPs (65,634 PKR acre^{-1}) (Figure 4).

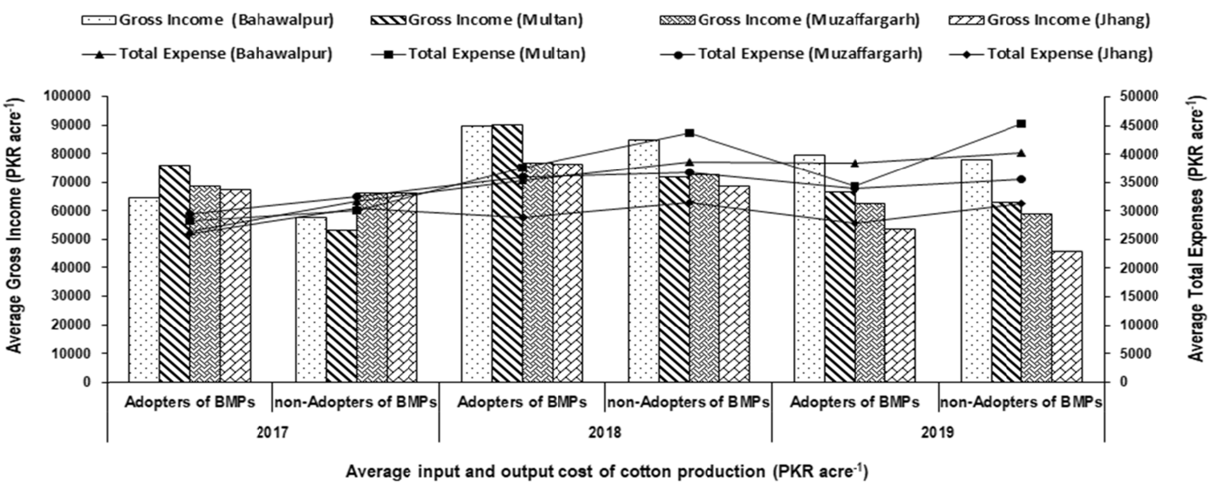

Figure 4. Average input and output cost of cotton production (PKR acre^{-1}) by Adopters and non-adopters of BMPs (better management practices) in cotton-growing years (2017, 2018 & 2019) at different regions (Bahawalpur, Multan, Muzaffargarh and Jhang) of Punjab, Pakistan

Note. This study used the average exchange rate for the years 2017, 2018 and 2019 (1 PKR = 0.0095, 0.0081 and 0.0072 USD, respectively) when the study was carried out.

As our results displayed that cotton farmers who adopted BMPs attained the maximum cotton yield (kg acre^{-1}) (Figure 3) and ultimately enjoyed high net return (PKR acre^{-1}) than non-adopters of BMPs. The average net return (profit) in Punjab by adopters of BMPs was found to be significantly higher by 36% (40,785 PKR acre^{-1} at $p \leq 0.001$) than that of non-adopters of BMPs (29,979 PKR acre^{-1}) (Tables 2A-2D).

The current study indicated that the net income by opting BMPs for cotton production was found to be several times higher than that of conventional cotton (Tables 2A-2D), signifying that "better cotton" was financially far better than conventional cotton (Zulfiqar et al., 2017; Zulfiqar et al., 2017). In Punjab, the average value of output and input ratio calculated for adopters of BMPs was 2.28, which represented that the cotton cultivation by adopters of BMPs was significantly profitable by 23% in these four regions of Punjab as compared to non-adopters of BMPs (1.85). That means if 1 PKR invested in cotton production it gained 2.28 so a net return is 1.28 in the investment of 1 PKR. Likewise, the average benefit-cost ratio (B:C) of cotton production Punjab shown by adopters of BMPs was 1.28 that was 51% higher than non-adopters of BMPs (0.85). Likewise, in previous studies the benefit-cost ratio was estimated as 1.32, 1.35 and 1.48 for cotton production denoted the profitability of cotton cultivation (Khan et al., 2010; Khan et al., 2011; Ahmad et al., 2016).

It is concluded that management practices for land preparation, selection of appropriate cotton variety, application of the rational amount of fertilizers, judicial use of pesticides, and effective irrigation are the most important factors responsible to maintain sustainability. It has been found that adopters of BMPs improved input (resource use efficiency) and output (productivity and farm income) as compared to non-adopters of BMPs. Hence, cotton production of BMPs adopters is economically and environmentally sustainable than that of non-adopters of BMPs. Overall, the study confirms and quantifies that cotton farmers can efficiently use inputs by adopting BMPs in the cotton-growing areas of Punjab and elsewhere in Pakistan.

The findings suggested that intensive and adequate extension and research services should pursue to create awareness and financial support for the cotton farmers to accelerate the adoption of BMPs in the cotton-growing areas of Punjab. This can enhance resource use efficiency, net farm income, and the livelihood of rural masses.

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