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Research Article

BETTER MANAGEMENT PRACTICES (BMPs) ENSURE SUSTAINABLE COTTON PRODUCTION IN COMPARISON TO CONVENTIONAL FARMING IN SINDH, PAKISTAN

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ABSTRACT. Conventional agriculture system characterized by large inputs reduces soil biodiversity and imposed negative impacts on the ecosystem. The purpose of the current study was designed to assess the positive impact of Better Management Practices (BMPs) on cotton cultivation to reduce the burden on natural scarce resources in three different regions of Sindh (i.e., Ghotki, Sukkur & Khairpur) during the cotton-growing years 2017-2019. The data relevant to cotton production (viz. land, seed, fertilizers, pesticides, water and labour) were collected from the randomly selected better cotton (BC=400) and conventional cotton farmers (100) in three different regions of Sindh through a well-structured questionnaire by using multi-stage cluster sampling survey method. Descriptive analysis was employed on data related to capital inputs, revenue productivity, net return, input-output ratio and cost-benefit ratio to evaluate the significant effect of BMPs on the utilization of input resources and profitability of cotton production. It was calculated that conventional farmers have used significantly higher inputs viz., rate of seed (17%), inorganic fertilizers (21%) and pesticides (26%) and water (20%) as compared to BC farmers, hence the average total output cost by conventional cotton farmers were significantly high by 28%. The results indicated that BC farmers' resource utilization is efficient and yield is also improved by 25% (983.16 kg acre^{-1}) as compared to conventional cotton farmers (784.73 kg acre^{-1}) in Sindh. The economic analysis showed that the average income of BC farmers was significantly high by 11% (92259.22 PKR acre^{-1}) with the maximum profitable return of 62354.91 PKR acre^{-1} and B:C (1:1.07) as compared to conventional farmers. The current analysis revealed that "better cotton" is better than conventional cotton in terms of both inputs using efficiency and financial return. In the light of investigated results, it can be suggested that farming communities should be encouraged for the adoption of BMPs for the promotion of "better cotton" in Sindh and elsewhere.

Keywords: *Cotton productivity, cost-benefit, economic analysis, net returns, Sindh*

INTRODUCTION

The intensive agriculture crop production system is crucial to maintaining the economy of the developing countries which providing sustenance to the global society as well as income and employment to the rural farming community [1] However, overall sustainable development, poverty alleviation and food security fundamentally depend on the improvements in the agricultural production system [2, 3]. There is always a need to implement sound management practices for the production of crops where the livelihood of the population pivots firmly on agricultural production [4]. For this, better management practices (BMPs) are conservational implements that include soil, water and other management practices, and social actions that are developed for environmental protection as effective practical tools for meeting today's farming goals [5, 6, 7]. Moreover, BMPs are technically and environmentally sound approaches that minimize the adverse impact on the environment and prevents or reduces the common problems related to general agricultural production and amplified crop returns [8]. These practices describe ways to manage farmland and activities to mitigate environmental pollution (i.e., judicial use of synthetic fertilizers, pesticides and herbicides to conserve soil, surface and groundwater [9]. Additionally, BMPs include the use of crop rotation, intercropping, cover crops, agroforestry, soil testing, record keeping, tillage practices, nutrient & pest management and efficient irrigation [10].

One single practice or approach can rarely solve the environmental concerns, often a combination of measures must be decided because there is no one system for all crops or farms. Therefore, the combination of BMPs will depend on individual problems and opportunities regarding a specific crop, soils, climate, and management factors [11]. However, poor management practices implemented by some farmers have reduced agricultural crop yield as well as disturbed the stability of several agroecosystems. By knowing the facts of the complex nature of agroecosystems, there is a need to weigh carefully any agricultural crop management practice so as not to compromise the interactions between the crops and their other factors in the physical environment. Keen attention to the adoption of management practices would enhance soil quality, maximize crop yield, and ensure biodiversity conservation while minimizing general environmental costs. As the conventional agriculture production system depends highly on external inputs such as seeds, improper use of chemicals (i.e., synthetic fertilizers, pesticides and herbicides) and water for irrigation, is considered as one of the major causes of depletion of wild resources contribute to environmental pollution.

Similarly, the cotton crop, which cultivates in more than 100 countries and is found as one of the 'highly polluted crops' due to the indiscriminate use of inputs. Previous studies showed that China India, United States, and Pakistan are the world's leading cotton-producing countries in the crop year 2017/2018 [12]. Pakistan is leading as a natural fiber with its major share (0.8%) in GDP and contributes to the total value of agricultural production by 4.1% [13]. Cotton-related amenities play the foremost role in Pakistan's economy and being a non-food cash crop contributes significantly to foreign exchange earnings. However, cotton production is considered a significant contributor to national and rural economies but the excessive use of irrigation water and extensive application of synthetic agrochemicals (fertilizers, pesticides, or herbicides) [14, 15] had severe negative impacts on public health and the environment as well as on financial returns [16]. Besides, inefficient management practices in cotton production also resulted from inefficient use of limited land and water resources including higher production costs [17]. Using conventional cotton cultivation practices, farmers have overused pesticide, which is often applied more than the recommended dose in Pakistan [18, 19].

Whereas, precision application of fertilizers under the nutrient management strategy, contributes to minimize the costs of fertilizers and reduce nutrient runoff into local waterways. Likewise, judicial use of pesticides to manage common cotton pests helps to avoid the undue residual effects of chemicals on farmers' and consumers' health. Many studies have analyzed the relationship between better management practices and economies of scale for different crops, which also revealed that crop yields and profits can be maintained by even reducing the amounts of inputs used [6, 7, 8, 11, 20]. Despite the reduced application of inorganic inputs and irrigation water, the yield of "better cotton" was found to be 11, 18 and 15% higher than the yield of traditional cotton in

China, India, and Pakistan, respectively. This was attributed to the reduction of the use of fertilizer, pesticides and irrigation water.

Therefore, this study is aimed to evaluate the impact of better management practices (BMPs) for cotton production in terms of input use efficiency and profitability at the three different sites viz., Ghotki, Sukkur and Khairpur of Sindh, Pakistan. The findings of the study will be suggested important policy implications for the promotion of "better management practices" in Pakistan and elsewhere as alternative agriculture that will make sustainable, socially and economically better cotton production than traditional practices, which would contribute to mitigating adverse environmental effects of conventional agriculture as well as help to improve farmers' financial benefit.

MATERIAL AND METHODS

Study sites

Sindh province was selected to conduct the cotton cultivation experiments, which is the second largest contributor in cotton production after Punjab province and accounted for 20% share in Pakistan's total cotton production [21]. Fieldwork for this study was carried out at three different districts of Sindh viz., Ghotki (28° 00′ 21″ N and 69° 18′ 57″ E), Sukkur (27° 42' 50" N and 68° 50' 13" E) and Khairpur (29° 34′ 51″ N and 72° 14′ 11″ E) for cotton production in the cotton cropping years 2017-2019 (Fig. 1). These districts are considered for a remarkable proportion of cotton production in Sindh (Rana et al., 2013). It was piloted by WWF-Pakistan's Better Cotton (BC) projects under the Sustainable Agriculture and Food Programme (SAFP).

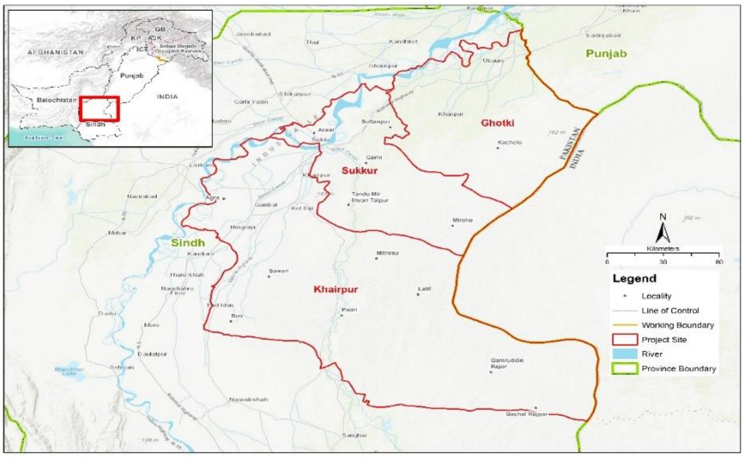

Fig. 1. *Map of experimental sites (Ghotki, Sukkur and Khairpur) in Sindh, Pakistan.*

Selection and training of farmers

In the current study, cotton farmers were registered under the better cotton project, they were randomly selected and grouped in three districts of Sindh (Ghotki, Sukkur and Khairpur). The better cotton project team has generated a training material, whereas field trainers (FTs) and field facilitators (FFs) were conducted training sessions to teach the cotton farmers for the production of better cotton by adapting BMPs in each of the selected regions [7]. The training material was comprised of the following recommendations of better management practices (BMPs) such as:

a) Soil and land management practices such as 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.
b) Nutrients management based on soil test results, utilization of precise amount of inorganic fertilizers [urea; calcium ammonium nitrate (CAN); diammonium phosphate (DAP); nitrophos (NP); ammonium sulfate (AMS)] by following 4R model (right amount, right time, right placement and right source of nutrients) to avoid excessive loss of nutrients runoff.
c) Pest management via judicial use of pesticides against common pests based on regular pest scouting and spray once against each pest to reach the economic threshold for pest management.
d) Water management involves the adaptation of on-farm water conservation practices such as laser land leveling, weeding, cleaning of water channels, efficient sowing techniques to avoid water losses and to improve water productivity for Water management.

Data collection

Better cotton farmers (BC farmers) and conventional farmers were randomly selected from each of three districts (Ghotki, Sukkur and Khairpur) for cotton production. The data were collected using a multistage clustered sampling technique from both groups of cotton farmers [BC farmers (n=400) and conventional farmers (n=100)]. The study was restricted generally to gather primary data from these districts of Sindh because it represents a good case study for cotton production activities. A well-designed questionnaire was developed in the English language while the interview was taken in the local language i.e. Siraiki and Sindhi. Comprehensive information was obtained face to face from both groups of farmers (BC farmers and conventional farmers) involved in cotton farming during three consecutive years (2017-2019) at their farm sites.

Data were collected on a range of themes, such as the history of operations, management structures (i.e., land management, nutrient management, pest management and water management), seed price, yield price, etc., which were used for record-keeping at the beginning. The field facilitator (FF) recorded all the practices in the farmers' field book (FFB). For the current study, the data used for the analysis have comprised of the use of input resources viz., cotton cropping area (acres); seed rate (kg); rate of fertilizers (kg); numbers of pesticides used (n); rate of pesticides (kg); and irrigation water (m^3) as well as the cost of inputs in rupees (PKR) including labor cost. The output data was included cotton yield (kg) and cost of output in rupees (PKR) from three different cotton-growing districts (Ghotki, Sukkur and Khairpur) of Sindh.

Cost of production

The on-farm cost of cotton production was estimated for all inputs utilized viz., seed procurement (i.e., certified/approved/local variety of cottonseed); land management practices; use of inorganic fertilizers (urea, CAN, DAP, NP and AMS); application of pesticides (active ingredients against cotton pests) and irrigation as well as labor.

Data analysis

Economic analysis

Economic analysis was estimated to assess the progressive effect of BMPs as compared to the conventional cotton cultivation in three consecutive years (2017-2019) at three different sites of the Sindh province. The input and output cost was used and net return (profit) was compared between BC farmers and conventional farmers to analyze the financial performance of cotton growers using the formulas used by Dagistan et al. [22]; Habib [23].

1) Gross income (GI) = Q×P [Q = yield (kg acre^{-1}), P = price of yield (PKRs acre^{-1})]
2) Total expenses (TE) = V×X (PKRs acre^{-1}) [V = input prices, X = input purchase quantity]
3) Net income (NI) = GI-TE (PKRs acre^{-1})]
4) Input-output ratio = NI/TE
5) benefit-cost ratio (B:C) = NR/TE

Statistical analysis

Initially, the data sets were arranged and organized by using the coding sheet. All the data were tabulated, summarized, and analyzed via descriptive analysis using computer software SPSS. The input and output differences and the cost of production in cotton cultivation between both groups of cotton farmers (BC farmers and conventional farmers) were estimated by an independent two-sample t-test assuming unequal variances for comparing the mean values.

Econometric analysis

The econometric analysis was done using the Stata software to find out the significance of the management interventions (BMPs) and their impacts on input use efficiency, yield and profit. The data about input use and production management practices of BC and conventional farmers were utilized in Stata to find out the overtime impacts on cotton yield. The socioeconomic rationale is important and needs of the hour especially in cotton production where the cost of production is relatively higher. The Pakistan cotton production is at stake due to many critical factors that must be addressed timely to save the farm incomes and import burden [24]. The cotton cultivation data set were utilized for the data analysis (2017-2019) and regression analysis was performed to evaluate the impact of better cotton practices on yield over time. The panel data was utilized using fixed effect and random effect models and the Hausman test was utilized to find the suitable model [24].

$$Yit = \alpha + \gamma X_{1t} + \beta X_{it} + \mu$$

The overtime data related to input, crop management practices, prices, yield, and returns were utilized. The cotton cropping area (acres), seed rate (kg), land preparation cost (PKR), application of urea and DAP fertilizers (kg), pesticide use (kg), irrigation water (m^3), labor cost (PKR), cotton farmer groups (BC farmers and conventional) and location (Ghotki, Sukkur and Khairpur) were the important variables.

RESULTS

Input resources

Our results revealed that a significant difference in cotton production has been found between BC farmers and conventional farmers in the cropping years of 2017-2019. The average cotton cultivation area in all three regions of Sindh (Ghotki, Sukkur and Khairpur) owned by BC farmers was 8.57 acres that were significantly high by 77% as compared to conventional farmers (4.83 acres) in the cropping years 2017-2019 (Fig. 2). It was estimated that the difference of average cultivated area for cotton production between BC farmers (9.29 acres) and conventional farmers (3.89 acres) was considerably pronounced (>100%) in Ghotki followed by Sukkur (71%) and Khairpur (45%) in 2017-2019. It affirmed that cotton growers of the Ghotki region showed a willingness to adopt BMPs to achieve effective cotton production. Besides, it was observed that cotton cultivated area was almost persistent from 2017-2019 by BC farmers in all three regions of Sindh. While in the Khairpur region, although there was a significant difference between BC farmers and conventional farmers for cotton cultivation but the average area of conventional farmers was also gradually increased by 21% from 2017 to 2019.

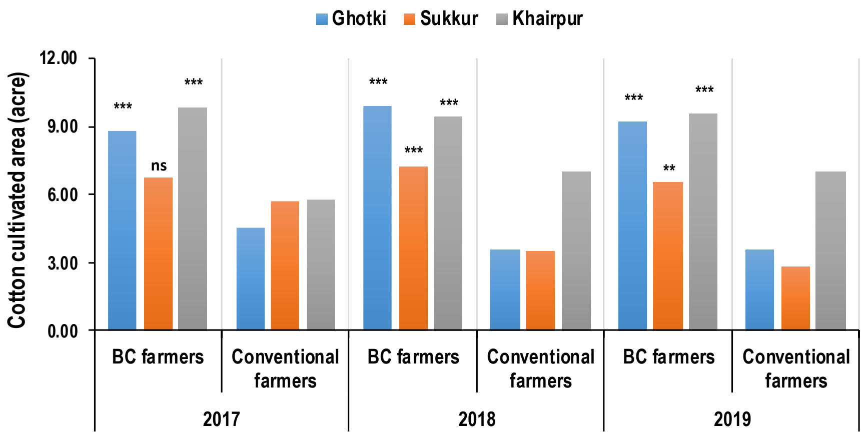

Fig. 2. *Average cotton cultivated area (acre) by BC farmers and conventional farmers adopting BMPs (better management practices) in cotton-growing years (2017, 2018 & 2019) at three regions (Ghotki, Sukkur and Khairpur) of Sindh, Pakistan.*
Note: The significance values ** at p≤0.01; *** at p≤0.001; ns at a non-significant level for two-groups (BC farmers and conventional farmers) mean comparison t-test assuming unequal variances

As BC farmers were trained for adopting aforesaid BMPs rather than conventional approaches, henceforth they have efficiently used input resources such as land management practices, seed rate, fertilizers, pesticides, irrigation and labor power than conventional farmers.

BC farmers have opted for the low frequency of land preparation and cultural practices as compared to conventional farmers in all regions (Ghotki, Sukkur and Khairpur). As they were adopted laser land leveling (n=1-time) for the land preparation to conserve water and soil. Likewise, BC farmers have practiced cultivator (n=2-3 times); disc plough (n=1-time) and rotavator (n=1-time) before sowing as well as used a multi-bed planter or drill for seed sowing and a ridger for weeding (n=1-2 times). While conventional farmers have not practiced laser land leveling and used simple land leveling blades for land preparation due to a lack of knowledge and training. As conventional farmers were followed conventional agricultural management practices hence they were practiced more numbers cultural practices such as cultivator (n=4 times); disc plough (1 time), and rotavator (1-2 time) as well as used drill and dibbling methods for seed sowing and practiced ridger (n=1-2 times) for weeding after sowing. As far as we are concerned with the average seed rate (kg acre^{-1}), it was found that BC farmers were used precise rates of cottonseed as 6.97 kg, 7.23 kg, 6.95 kg when compared to conventional farmers 8.34 kg, 8.16 kg, 8.89 kg in Ghotki, Sukkur and Khairpur, respectively (Table 1). Our results indicated that conventional farmers were used significantly high (at $p \leq 0.01$ and $p \leq 0.001$) amounts of seed (kg acre^{-1}) by 16%, 11% and 22% as compared to BC farmers in Ghotki, Sukkur and Khairpur, respectively.

Inorganic fertilizers were considered as a very important input resource, in this study a rational amount of inorganic fertilizers were applied by BC farmers with overall a significant reduction of 21% as compared to conventional cotton farmers. Our results revealed that in the Khairpur region input of fertilizers by BC farmers was considerably reduced (27% at $p \leq 0.05$ & $p \leq 0.001$) as compared to conventional farmers (Table1). Whereas, in the Ghotki region ammonium sulfate (AMS) fertilizer was applied by BC farmers only and therefore a non-significant difference was observed in the cropping years 2017 and 2018, but a significant reduction of 20% was calculated in the total amount of fertilizers applied in 2019. Moreover, it was observed that urea is the maximum using fertilizer (25-30%) in all three regions of Sindh by conventional farmers as compared to BC farmers (Table 1).

As far as pest management is concerned, BC farmers were guided/trained to use a judicial amount of pesticides against common cotton pests and overall a significant reduction of 26% was estimated in pesticides application by BC farmers as compared to conventional farmers. Henceforth, the frequency (n) and amount (kg acre^{-1}) of pesticides applied were significantly reduced ($p \leq 0.01$and $p \leq 0.001$) by 10% and 33% in Ghotki; 7% and 25% in Sukkur; 40% and 31% in Khairpur, respectively as compared to conventional farmers. Our results indicated that in the Khairpur region, fewer pesticides (applied three different pesticides) were applied by BC farmers than conventional farmers (applied five different pesticides) and therefore a significant reduction (at $p \leq 0.001$) of 31% in pesticides amount (kg acre^{-1}) was found in Khairpur (Table1).

Our results showed that BC farmers were applied efficient irrigation, hence the input of water resources was significantly reduced (at $p \leq 0.001$) by 25% in Ghotki and Khairpur as compared to conventional farmers. While in the Sukkur region, there was a non-significant difference in irrigated water from 2018 to 2019 but a significant reduction (at $p \leq 0.001$) by 18% was found in the cropping year 2017.

***Table 1**. Inputs used (acre^{-1}) by Better cotton (BC farmers) and non-Better cotton farmers (conventional farmers) for cotton production in three different regions (Ghotki, Sukkur and Khairpur) of Sindh province in three consecutive cotton cropping years 2017-2019.*

Variables (acre^{-1})	Sindh Regions	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)
		2017		2018		2019	
Seed rate (kg)	Ghotki	6.18	6.72***	6.38***	7.76	8.37	10.65***
	Sukkur	5.74	6.08**	7.45^{ns}	7.24	8.50	11.01***
	Khairpur	6.04	7.96***	7.39	9.39***	7.42	9.34***
CAN (kg)	Ghotki	3.50	7.50**	16.32	12.00^{ns}	7.63	13.76**
	Sukkur	5.63^{ns}	2.25	-	-	-	-
	Khairpur	-	-	-	-	-	-
DAP (kg)	Ghotki	49.65	63.28***	49.18	57.69***	48.70	55.40***
	Sukkur	45.46	48.27*	46.92	50.09**	20.15	27.14**
	Khairpur	43.14	51.02***	49.54	50.09^{ns}	46.11	47.12^{ns}
NP (kg)	Ghotki	9.22^{ns}	5.00	1.25	2.30^{ns}	1.55	1.85^{ns}
	Sukkur	1.06	0.00	-	-	29.91**	22.89
	Khairpur	4.75***	0.00	0.38^{ns}	0.00	3.88^{ns}	2.51
AMS (kg)	Ghotki	2.25***	0.00	0.25***	0.00	-	-
	Sukkur	-	-	-	-	-	-
	Khairpur	-	-	-	-	-	-
Urea (kg)	Ghotki	147.17	186.58***	131.53	196.58***	144.69	180.91***
	Sukkur	146.51	197.59***	116.05^{ns}	111.2	111.64	153.83***
	Khairpur	111.55	171.57***	130.07	201.38***	139.70	186.50***
Total fertilizers (kg)	Ghotki	211.79	262.36^{ns}	198.53	268.58^{ns}	202.57	251.92***
	Sukkur	198.66	248.11^{ns}	162.97^{ns}	151.29	161.70	203.86*
	Khairpur	159.44	222.59***	179.98	251.47*	189.68	236.13*
No. of pesticides (n)	Ghotki	5.17	5.38^{ns}	5.04	5.70***	5.40	5.85***
	Sukkur	4.91	5.07^{ns}	4.50	4.95***	3.97	4.39***
	Khairpur	2.93	5.26***	2.85	4.80***	3.15	4.34***
Total pesticides (kg)	Ghotki	2.00	2.33***	1.77	2.43***	1.65	2.38***
	Sukkur	1.87	2.39***	1.92	2.08**	1.91	3.14***
	Khairpur	1.52	2.35***	1.52	2.28***	1.60	2.03***
Water (m^3)	Ghotki	1345.86	1752.16***	1332.38	1739.46***	1322.15	1843.95***
	Sukkur	1395.00	1704.20***	1366.94	1410.36^{ns}	1364.70^{ns}	1362.94
	Khairpur	1279.80	1767.56***	1367.02	1845.45***	1390.99	1686.88***

Note: The significance values * at $p \leq 0.05$; ** at $p \leq 0.01$; *** at $p \leq 0.001$; ^{ns} at non-significant level mean comparison t-test between two groups (BC farmers & conventional farmers) assuming unequal variances. **CAN**: Calcium ammonium nitrate; **NP**: Nitrophos; **DAP**: Diammonium phosphate; **AMS**: Ammonium Sulfate; **n**: frequency; **kg**: kilogram; **m^3**: cubic meter

Cotton Yield

Our results revealed that the cumulative average cotton yield (983.16 kg acre^{-1}) harvested by BC farmers was significantly high by 25% as compared to conventional farmers (784.73 kg acre^{-1}) from three regions of Sindh (viz., Ghotki, Sukkur and Khairpur) (Fig. 3). Besides, BC farmers were produced significantly (at $p \leq 0.001$ & $p \leq 0.01$) high cotton yield in consecutive three years of cotton production by 922.97 kg acre^{-1}, 935.00 kg acre^{-1} and 1091.51 kg acre^{-1} when compared with the cotton yield of conventional farmers 742.07 kg acre^{-1}, 754.36 kg acre^{-1} and 857.76 kg acre^{-1} in Ghotki, Sukkur and Khairpur, respectively (Fig. 3). It was noticed that the maximum average cotton yield was produced by BC farmers (1091.51 kg acre^{-1}) is 27% high as compared to conventional farmers in the Khairpur region. Despite using a low/precise amount of input resources (viz., seed, inorganic fertilizers, pesticides and water irrigation) by adopting BMPs, a pronounced effect on cotton production was showed by BC farmers who were gained relatively high yield per acre as compared to conventional farmers in all three districts of Sindh province (2017-2019).

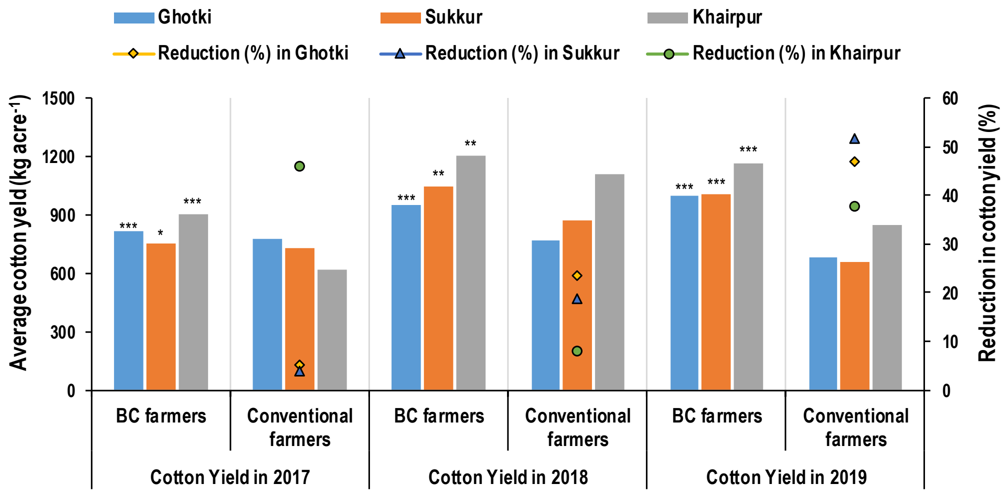

Fig. 3. *Average cotton production [cotton yield (kg acre^{-1}) and reduction percentage (%)] cultivated by BC farmers and conventional farmers in cotton-growing years (2017, 2018 & 2019) at studied regions (Ghotki, Sukkur and Khairpur) in Sindh, Pakistan.*
Note: The significance values * at p≤0.05; ** at p≤0.01; *** at p≤0.001 for two groups (BC farmers and conventional farmers) mean comparison t-test assuming unequal variances.

Cost of production

Aforesaid results of this study revealed that BC farmers were utilized the optimized/rational level of inputs so the total cost of production was significantly reduced than conventional farmers. As conventional farmers have practiced several cultural operations land preparation, seed sowing and intercultural practices so the average cost of land management was significantly high by 23% (at p≤0.001) in Ghotki while almost 6% high in Sukkur and Khairpur as compared to BC farmers (2017-2019) (Table 2). The results of seed cost showed that BC farmers have used the optimized rate of seed (~6 kg acre^{-1}) so the average cost of seed was significantly reduced by 17% as compared to conventional farmers (Table 2). Similarly, BC farmers were utilized a rational amount of fertilizers and judicially applied pesticides against cotton pests in the cropping year 2017-2019, henceforth the costs of fertilizers and pesticides were significantly reduced by 22% and 33% (p≤0.001) as compared to conventional farmers (2017-2019) (Table 2). In contrast, it was observed that BC farmers paid a 30% high average cost on labor power as compared to conventional farmers. Besides, results indicated that the average cost of irrigated water had no significant difference between both groups of farmers (BC and conventional farmers) in cotton production (2017-2019).

Table 2. *Cost of production summary (PKR acre^{-1}) of better cotton (BC farmers) and conventional farmers in three different regions (Ghotki, Sukkur and Khairpur) of Sindh province in three consecutive cotton cropping years 2017-2019.*

Variables	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)
	2017		2018		2019	
Cost of cotton production in Ghotki (PKR acre^{-1})						
Cost of land management	6263.16	7640.09***	7586.05	10369.70***	7707.44	10241.37***
Cost of seed	1235.71	1344.20***	1276.54	1551.85***	1673.71	2130.92***
Cost of fertilizers	7361.68	9960.58***	8297.13	11274.56***	9132.84	12374.11***
Cost of Pesticides	4031.14	5538.54***	4095.10	6126.15***	3338.20	4400.39***
Cost of Irrigation	299.45	300.12^{ns}	311.25	312.73^{ns}	290.13	300.13^{ns}
Cost of Labor	6115.72***	5807.35	8336.15***	6737.83	10135.17***	6929.41
Cost of cotton production in Sukkur (PKR acre^{-1})						
Cost of land management	5903.05	6126.15^{ns}	7268.45^{ns}	7120.90	8197.73	8980.90***
Cost of seed	1148.86	1216.76**	1487.29 ^{ns}	1464.84	1699.08	2201.05***
Cost of fertilizers	6847.30	8298.72***	7795.70	8003.13**	9340.35	11600.71***
Cost of Pesticides	3591.67	4527.31***	2573.20	2604.61^{ns}	2355.51	3776.78***
Cost of Irrigation	299.76	300.14^{ns}	294.94	303.71*	399.87	529.85**
Cost of Labor	4937.45***	4616.45	10452.81	11502.27***	8162.91	8980.90***
Cost of cotton production in Khairpur (PKR acre^{-1})						
Cost of land management	5553.82	5891.72***	6344.12	6413.73^{ns}	7185.15	7653.58***
Cost of seed	1208.96	1592.67***	1477.42	1877.55***	1484.16	1868.04***
Cost of fertilizers	6567.66	9464.83***	8311.42	11554.07***	9262.09	11720.33***
Cost of Pesticides	2242.63	4649.40***	2313.91	4895.66***	3008.13	4596.84***
Cost of Irrigation	300.93	308.59*	306.16^{ns}	305.08	300.84^{ns}	300.79
Cost of Labor	7903.62***	5416.69	12015.98	12460.72***	14022.93***	10582.72

Note: The significance values * at p≤0.05; ** at p≤0.01; *** at p≤0.001; ^{ns} at non-significant level mean comparison t-test between two groups (BC farmers & conventional farmers) assuming unequal variances. **PKR**: Pakistani rupee; **kg**: kilogram; 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.

Input-Output costs analysis

The results of input and output analysis have shown a significant difference between BC farmers and conventional farmers in three different regions (Ghotki, Sukkur and Khairpur) of Sindh (Table 3; Fig 4). The average total expenses (input costs) of conventional farmers on cotton production were estimated as 33,562.86 PKR acre^{-1} which were significantly high by 11% as compared to BC farmers (29,900.44 PKR acre^{-1}) during years 2017-19. The maximum average total expenses were observed in the Ghotki region

(36,382.46 PKR acre^{-1}) for cotton production by conventional farmers that were 14% high as compared to BC farmers (31,204.10 PKR acre^{-1}) (Table 3).

While a reduction difference in total expense between both groups of farmers (BC and conventional) in Sukkur was least as 6% when compared to the rest of two regions [Ghotki (14%) and Khairpur (12%)]. Moreover, our results computed that the average gross income was profoundly generated (92,259.22 PKR acre^{-1}) by BC farmers that were significantly high by 28% as compared to conventional farmers (71,801.50 PKR acre^{-1}) in cotton-growing years 2017-2019 (Fig. 4).

Table 3. *Input-Output cost summary (PKR acre^{-1}) of better cotton (BC farmers) and conventional farmers in three different regions (Ghotki, Sukkur and Khairpur) of Sindh province in cropping years 2017-2019.*

Variables	**BC farmers (N=400)**	**Conventional farmers (N=100)**	**BC farmers (N=400)**	**Conventional farmers (N=100)**	**BC farmers (N=400)**	**Conventional farmers (N=100)**
	2017		**2018**		**2019**	
Input-Output costs analysis in Ghotki (PKR acre^{-1})						
Gross Income	63691.62***	59709.24	96964.59***	78382.56	107166.19***	69477.45
Total Expense	31422.59	36398.23***	29902.21	36372.81***	32287.49	36376.33***
Net return	32269.03***	23311.01	67062.38***	42009.75	74878.71***	33101.12
Input-Output costs analysis in Sukkur (PKR acre^{-1})						
Gross Income	58975.50***	56166.52	101469.93***	83200.08	102080.31***	66284.32
Total Expense	22728.09	25085.51***	29705.70	30991.82***	33247.92	35288.15***
Net return	36247.41***	31081.01	71764.23***	52208.26	68797.57***	30996.17
Input-Output costs analysis in Khairpur (PKR acre^{-1})						
Gross Income	68618.29***	47065.05	115737.05***	103839.35	115629.46***	82088.92
Total Expense	23777.62	27323.89***	30769.03	37506.81***	35263.30	36722.30***
Net return	44840.67***	19741.15	84968.02***	66332.54	80366.16***	45366.62

Note: The significance values * at p≤0.05; ** at p≤0.01; *** at p≤0.001; ^{ns} at non-significant level mean comparison t-test between two groups (BC farmers & conventional farmers) 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 described above (Fig 3), BC farmers have produced the maximum cotton yield (983.16 kg acre^{-1}) hence eventually gained a profitable net return (PKR acre^{-1}) than conventional farmers. The average net return (profit: 62,354.91 PKR acre^{-1}) of BC farmers was found to be significantly higher by 64% (at p≤0.001) than that of conventional farmers (38,238.63 PKR acre^{-1}) in all three regions of Sindh (Fig 4). Moreover, the maximum profit (70058.28 PKR acre^{-1}) was gained by BC farmers in the Khairpur region followed by Sukkur (58,936.40 PKR acre^{-1}) and Ghotki (58,070.04 PKR acre^{-1}) as compared to conventional farmers in 2017-2019. Additionally, the maximum reduction in profit by conventional farmers as compared to BC farmers was observed in Ghotki (77%) followed by Khairpur (60%) and Sukkur (55%).

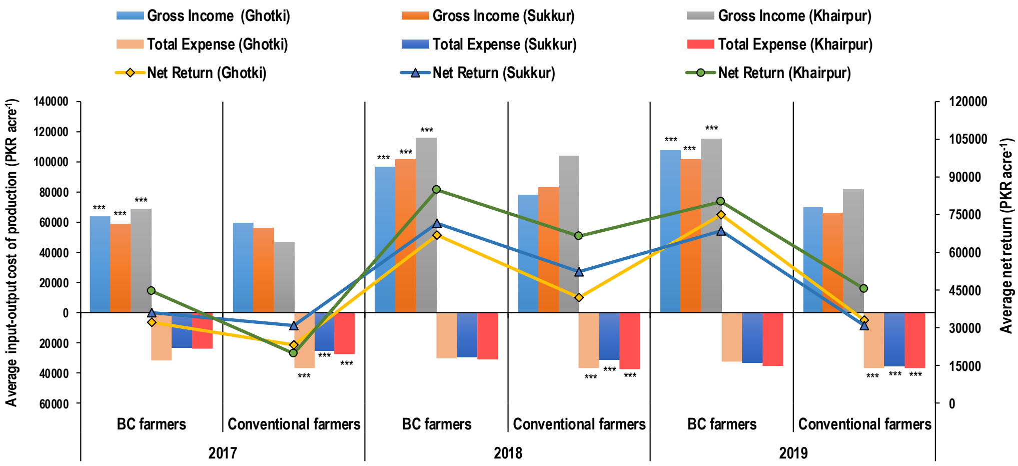

Fig. 4. *Average input-output cost of cotton production and net return (PKR acre*$^{-1}$*) of BC farmers and conventional farmers in cotton-growing years (2017, 2018 & 2019) at studied regions (Ghotki, Sukkur and Khairpur) of Sindh, Pakistan*

Note: The significance values *** at p≤0.001 for two groups (BC farmers and conventional farmers) mean comparison t-test assuming unequal variances.

Input-Output and Benefit-Cost Ratio

The average estimated value of input-output ratio was 1:2.07 by BC farmers that were 43% high over conventional farmers which represented that the cotton cultivation was significantly profitable for "Better Cotton" farmers. In table 4 the results indicated the average benefit-cost ratio in cotton production (2017-2019) by BC farmers in Ghotki was 1:0.51, Sukkur with 1:1.47 and Khairpur with 1:1.22. It showed that cotton producers obtained an average benefit of Rs. 1:1.07 while spending a rupee in Sindh, which showed cotton production was found to be economically efficient.

Table 4. *Input-output and benefit-cost ration estimated by better cotton (BC farmers) and conventional farmers in three different regions (Ghotki, Sukkur and Khairpur) of Sindh province in cropping years 2017-2019*

Sindh regions	Ratio	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)	BC farmers (N=400)	Conventional farmers (N=100)
		2017		2018		2019	
Ghotki	Input-output	2.03	1.66	3.24	2.16	3.32	1.91
	B:C	1.03	0.66	2.24	1.16	2.32	0.91
Sukkur	Input-output	2.60	2.25	3.41	2.70	3.07	1.88
	B:C	1.60	1.25	2.41	1.70	2.07	0.88
Khairpur	Input-output	2.90	1.73	3.77	2.77	3.28	2.23
	B:C	1.90	0.73	2.77	1.77	2.28	1.23

Econometric analysis

The econometric models were utilized to access the significance of yield due to better management practices (BMPs). The econometric analysis was performed to analyze the significance of BC and conventional farmers' yield impacts over time. The yield produced by BC farmers was significantly higher than conventional farmers. Likewise, the farm area also has significant impacts on cotton yields. The amount of pesticide has negative impacts on crop yields that describe the overuse of pesticide by conventional farmers. The yield has a positive relationship with the application of fertilizers such as urea & DAP, irrigation water and labor utilization. The stated results describe the positive contribution of BMPs in cotton production (Table 5).

Table 5. *Impact analysis of better cotton production in three different regions (Ghotki, Sukkur and Khairpur) of Sindh province in cropping years 2017-2019*

Variable	**Description**	**Fixed effect model**	**Random effect model**
Farm area (ha)	hectare	0.311***	4.95***
Pesticide use	kg per hectare	-11.89	-9.61
Urea application	kg per hectare	0.028***	0.31***
DAP application	kg per hectare	0.023***	0.19***
Seed rate	kg per hectare	2.76**	2.56
Irrigation water	cubic meter per hectare	0.159***	0.1648**
Land preparation cost	Rupees per hectare	0.002***	0.001***
Labor cost	Rupees per hectare	0.051***	0.053***
Farmer groups	(Better cotton farmers = 1, Conventional farmers = 0)	557.06	532.35
Location	Khairpur = 0; Ghotki = 1 and Sukkar = 2	-46.15***	-47.01***
Constant		-238.01	113.61
F statistics (10, 4489)		321.53*	226.81
Hausman test			256.08***

***at 1 percent level of significance (p > 0.01); **at 5 percent level of significance (p > 0.05)
Number of observations = 4478
LR chi2(11) = 5047.41
Log likelihood = -31329.937 Prob > chi2 = 0.0000

DISCUSSION

In agricultural crop production "Better Management Practices" (BMPs) is an alternative sustainable approach to conventional farming that is ecofriendly and technically sound which prevents or reduces the common problems related to general agricultural production [7, 8, 25, 26]. Similarly, the leading objective of "better cotton" with the adoption of BMPs is to alleviate adverse environmental and financial effects of conventional cotton cultivation arising from intensive use of inputs such as inorganic agrochemicals (fertilizers, pesticides, or herbicides) and irrigation water [14]. Former studies have reported that cropped area, land management practices, seed, fertilizer, pesticides, irrigation and labor significantly affect cotton production [7, 27, 28, 29]. The findings of our analysis revealed that the Ghotki region undoubtedly related with the cultivation of "better cotton" in three consecutive years, which is explained the fact that the BC farmers with relatively large landholdings had also better economic conditions that enabled them to take any possible risk low yield arising from the cultivation of fewer inputs intensive “better cotton”. Eventually, BMPs need to be aimed at raising cotton farmers’ potential and decreasing their risks without drawing on already scarce resources and conserve soil and land to maintain the essential conditions for sustainable crop production [2, 30].

Conservation land management practices (viz., zero tillage, laser land leveling) have the potential for cotton growers using low-inputs (low frequency of cultivation practices) [31, 32]. Previous studies reported that the implementation of BMPs permits farmers to improve the overall resiliency of their land for cotton cultivation while simultaneously generating economic returns [7, 8, 21, 33, 34]. Perhaps, a farmer’s decision to adopt conservation tillage techniques leads to reduced compaction, less soil erosion and improved moisture retention; this reduces equipment, fuel, and labor costs while improving the long-term health of their soil and the resiliency of their land [35]. Besides, Aryal et al. [36] reported that the practice of laser land leveling is reduced the demand for water irrigation and conserved a considerable amount of energy and irrigation operating time by 47-69 h/ha/season and improved yield by ~7% compared with traditionally leveled fields. Additionally, BMPs have minimized the input cost, and the expected profit with conservation tillage is higher than that of using conventional tillage [37]. Moreover, BC farmers also used manual and mechanical ways of weeding, which not only helps in better weed control but also contributes to improving soil fertility by making soil loose.

As our results revealed that BC farmers have used fewer amounts of inorganic inputs (inorganic fertilizers and pesticides), and they have utilized a significantly rational amount of fertilizers [38], judicial use of pesticides [39], which is not only good for the soil quality improvement as well as for alleviating adverse health effects of inorganic pesticides without compromising on crop yield as compared to conventional farmers. As nitrogen (N) being the most important crop nutrient but also associated with high losses, such losses pollute the environment and increase greenhouse gas production and other environmental events. Dimkpa et al. [40] reported that the net outcomes for the plant are reduced N uptake and crop productivity which combine increase the costs associated with fertilization of agricultural lands and diminish farmers' confidence in the efficacy and profitability of fertilizers. Noor et al. [41] critically focused on the challenges faced by the small farmers with persistent farming in managing the precise use of agriculturally important nutrients [i.e.., nitrogenous (N) and phosphorus (P) fertilizers] and the management of nutrients for sustainable productivity (on small farms). Likewise, the selection of pesticides must critically consider the chemical solubility, volatility and degeneration characteristics to find out if it would least or no impact on the environment or leach easily through the soil [39, 42]. Previous studies were found that the cost of pesticides/insecticides and their class of impact were related having a destructive impact on the environment as well as human health [43, 44, 45, 46, 47, 48]. Our results align with the findings of Khan et al. [49], who concluded that adopters of BMPs were used pesticides judicially (frequency and amount), who applied less synthetic pesticides as compared with non-BMP and hence less exposed to any health risks arising from the application of inorganic pesticides and herbicides.

Furthermore, upgrading of the water use efficiency is an important precept for “better cotton” production and the BC farmers were trained to carry out water scouting before any irrigation application. This had contributed to make efficient use of scarce water resources and improve the health of the soil, which are essential conditions for the sustainable yield of any crop [50, 51]. The positive impact of BMPs on crop productivity was previously reported by Makarewicz et al. [5] Awan et al. [7]; Ullah et al. [8]; and

Hina and Asad [52]. The reduced cost of input resources and improved yield together made "better cotton" significantly better than conventional cotton as reflected in its significantly higher net income and return per unit of input cost than that of conventional cotton [16, 18, 53]. Better financial return was the most important factor attributed with the maximum yield production which motivating farmers to grow "better cotton". This study estimated that BC farmers have enjoyed higher crop yield and financial return under the BMPs, which is sustainable, profitable and environment friendly in Sindh unlike the previous study of cotton production in Punjab that emphasize high resource use for high-profit margin rather than reducing the cost of production [7]. Hence, crop productivity depends on the potential use of available resources (aforesaid inputs) with the implementation of better management practices (BMPs) and can save the variable cost. Additionally, Hina et al. [34] reported that the results of the regression analysis showed the impact of different agriculture inputs and BMPs on cotton yield and the results of this study conveyed policy messages for the private and public organizations to promote BMPs for the betterment of the farming community.

CONCLUSION

It is concluded that cotton cultivation by adopting better management practices (BMPs), the cost of production as well as returns (physical and revenue) have increased over time. Better cotton (BC) farmers have produced significantly high yields with minimum use of input resources as compared to conventional cotton farmers. Normally, the increases in revenue returns take place because of the technologically backstopping of technical efficiencies, abundant availability of water in the area and the use of hybrid/certified cottonseed for cotton cultivation. The results of the regression model revealed that seed rate, fertilizer application and efficient irrigation had a positive impact on cotton yield per acre. Therefore, cotton production of BC farmers is in sound stage and earning reasonable profit by following the new and improved farming practices (BMPs) as compared to conventional cotton farmers who spent a substantial portion of their financial resources as they were involved in surplus use of resource inputs by bearing the higher variable cost and ultimately receiving lesser profits.

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