

International Journal of Agriculture Extension and Social Development

Volume 9; Issue 6; June 2026; Page No. 666-671

Received: 11-03-2026
Accepted: 15-04-2026

Indexed Journal
Peer Reviewed Journal

Adoption of sustainable inputs in cotton farming: Bridging the knowledge and resource gap

¹Sunil Kumar, ²Mini Goyal and ³Akshdeep Kaur

¹M.Sc. Student, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab, India

²Retd Principal Economist, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab, India

³Research Scholar, Department of Extension Education, Punjab Agricultural University, Ludhiana, Punjab, India

DOI: <https://www.doi.org/10.33545/26180723.2026.v9.i6i.3752>

Corresponding Author: Sunil Kumar

Abstract

This study examines the adoption of sustainable inputs in cotton farming in Punjab, India, using data collected from 90 farmers across major cotton-growing districts. The findings revealed that low adoption of recommended practices, with only 4.25 per cent of the cotton area under recommended Bt varieties, while 95.75 per cent relied on non-recommended seeds. Recommended herbicide use was also minimal. Economic analysis showed that overuse of fertilisers and pesticides increased variable costs by 3.34 per cent and reduced returns over variable costs by 5.27 per cent. The study suggests strengthening farmer training, subsidising quality seeds, and improving access to certified inputs.

Keywords: Cotton, fertilisers, Bt hybrid, varieties, insecticides, weedicides

Introduction

Cotton is an important cash crop of India and contributes a mammoth part in the Indian economy due to the employment of more than 60 million people via support in agriculture (Barwale *et al* 2004) ^[1]. As one of the most widely cultivated crops, it plays a crucial role in both local economies and the global supply chain. However, the environmental footprint of traditional cotton farming practices is a growing concern. The extensive use of synthetic chemicals, excessive water consumption, and poor soil management practices have contributed to soil degradation, water scarcity, and biodiversity loss (Bocci and Blasi, 2020) ^[2]. These environmental challenges, combined with social issues such as labour exploitation and health risks, highlight the urgent need for a transformation in how cotton is grown. The widespread use of pesticides and the significant water requirements of cotton farming have been shown to harm ecosystems, contaminate soil, and lead to adverse health effects for workers (Sivapalan and Jayakody, 2018) ^[10].

In response to these challenges, there has been a global shift towards more sustainable farming practices that aim to minimise the negative impact of cotton production on the environment and improve the overall well-being of farming communities. Sustainable inputs, including organic fertilisers, integrated pest management, and water-efficient irrigation systems, are increasingly seen as key solutions to mitigating the harmful effects of conventional cotton farming. These practices not only reduce the environmental burden but also contribute to enhancing soil health and

water conservation (Liu and Wang, 2019) ^[7]. Furthermore, sustainable practices have the potential to improve the long-term viability of cotton farming systems by increasing their resilience to climate change, shifting weather patterns, and fluctuating market conditions. Despite the significant benefits of sustainable farming practices, the widespread adoption of these inputs remains limited.

A major obstacle is the gap in knowledge and resources available to farmers. Many cotton farmers, particularly those in developing countries, lack access to the necessary information, training, and financial resources to make the transition to sustainable methods. This lack of access to critical resources—whether it be knowledge about sustainable farming practices or financial support to adopt new technologies—poses a significant barrier to widespread adoption (Hassan and Rahman, 2021) ^[6]. Moreover, the economic pressures of maintaining high yields and meeting market demands often discourage farmers from experimenting with unfamiliar practices, leading to a preference for conventional farming methods that may be more profitable in the short term. This knowledge and resource gap represents a critical barrier to the adoption of sustainable cotton farming methods. Bridging this gap is essential for advancing the sustainability of the cotton industry. This research paper aims to explore the key factors that influence the adoption of sustainable inputs in cotton farming, with a particular focus on the barriers and opportunities for knowledge dissemination and resource accessibility.

In Punjab, the area under cotton was 509 thousand hectares

while its production was about 2091 thousand bales and yield was 698kg/ha during 2004-05, which became 291 thousand hectares, 1283 thousand bales and 750kg/ha respectively in 2017-2018 (Punjab Agricultural University, 2019) [9]. The study aims to assess the adoption of recommended sustainable inputs and practices in cotton farming in Punjab and evaluate their economic implications in addressing farmers' knowledge and resource gaps.

Methodology

The entire state of Punjab was classified into three agro-climatic zones for the purpose of the study (Chaudhary and Singh 2021) [3]. The research was conducted during the agricultural year 2019-20 across all agro-economic zones of Punjab. In the South-Western region, cotton emerged as the major crop alongside wheat and paddy. This region comprises the districts of Barnala, Bathinda, Faridkot, Fazilka, Ferozepur, Mansa, Moga, Sangrur, and Sri Muktsar Sahib. Approximately 245 thousand hectares of land in this zone were dedicated to cotton cultivation in 2019-20 (Statista, 2021) [11]. Nearly 99 per cent of Punjab's total cotton area was concentrated in the South-Western region during this period (Government of Punjab, 2020) [5]. Among the cotton-producing districts of Punjab, Sri Muktsar Sahib and Fazilka were purposefully selected for being the largest producers of cotton in this zone. From Sri Muktsar Sahib, the villages of Lambi, Bhagsar, and Sammewali were randomly selected, while the villages of Nukerian, Jandwala Bhimeshah, and Jhotianwali were chosen from Fazilka district.

A complete list of cotton growers in each village was prepared, and 15 farmers from each list were randomly selected, making a total sample of 90 cotton growers across six villages in these two districts. The farmers were categorised based on their operational landholdings as follows: small farmers (operational landholding up to 5 acres), medium farmers (operational landholding between 5 and 25 acres), and large farmers (operational landholding exceeding 25 acres). A sample of 90 cotton growers was selected using the probability proportional to the number of cotton growers in each category. A structured and pre-tested

questionnaire was developed, incorporating questions that were deemed important during pre-testing.

The study primarily relied on primary data collection. However, due to the COVID-19 pandemic in March 2020, data collection through personal interviews posed significant challenges. Farmers were reluctant to interact with strangers and often denied entry to their homes due to health and safety concerns. Despite these difficulties, the initial phase of data collection was conducted through personal interviews. Subsequently, data were collected via telephonic interviews using the structured and pre-tested schedules, ensuring comprehensive coverage and minimal risk during the pandemic.

Statistical analysis of the data

The responses of the sampled farmers were transferred to the master-sheets and tabulated according to the objectives of the study. The various statistical tools were used for the analysis of collected data to achieve the stipulated objectives of the study, including Frequency distribution of the respondents, Percentage, Range, Arithmetic Mean (Average), and Net returns.

Results and Discussion

The present study was designed to estimate the extent of the adoption gap of major inputs in cotton cultivation. The results of the study are discussed as follows:

Adoption gap in recommended varieties of Cotton by Punjab Agricultural University

Bt cotton is resistant to bollworms, and therefore all the sampled farmers were found to be growing Bt cotton in the sample area. Category-wise, an average area under recommended by PAU and un-recommended varieties of cotton by PAU being cultivated by the sample farmers was worked out and presented in Table 1. The results revealed that out of the total cotton area, only 4.25 per cent of the total cotton area grown by sample farmers was under recommended varieties, while the remaining 95.75 per cent was under un-recommended varieties

Table 1: Average area under recommended and non-recommended varieties of Bt cotton by Punjab Agricultural University in Punjab, 2019-20 (Per acre)

Varieties	Small		Medium		Large		Overall	
	Area	Percentage	Area	Percentage	Area	Percentage	Area	Percentage
Un-recommended of Bt cotton (American cotton)								
Rasi 773	1.05	45.26	3.48	34.97	14.5	42.03	3.38	36.82
Rasi 776	0.72	31.03	3.23	32.46	6.75	19.57	2.78	30.28
Rasi 778	0.14	6.03	1.83	18.39	5.25	15.22	1.57	17.10
Rasi 650	0.32	13.79	1	10.05	6.25	18.12	1.06	11.55
Sub-total (a)	2.23	96.12	9.54	95.88	32.75	94.93	8.79	95.75
Recommended of Bt cotton (American cotton)								
NCS 855 BG II	-	-	-	-	-	-	-	-
Ankur 3028 BG II	0.09	3.88	0.41	4.12	1.75	5.07	0.39	4.25
MRC 7017 BG II	-	-	-	-	-	-	-	-
MRC 7031 BG II	-	-	-	-	-	-	-	-
PAU Bt 1	-	-	-	-	-	-	-	-
Sub-total (b)	0.09	3.88	0.41	4.12	1.75	5.07	0.39	4.25
Grand Total (a+b)	2.32	100	9.95	100	34.5	100	9.18	100

Out of five recommended varieties, only one variety, named Ankur 3028 BGII, was grown by the sample farmers on an average area of 0.39 acres. The adoption of this variety

varied with farm size. It was cultivated on only 0.09 acres on small farms, 0.41 acres on medium farms and 1.75 acres on large farms, which constituted about 3.88, 4.12 and 5.07

per cent of the total cotton area, respectively.

Among the un-recommended varieties of cotton, Rasi was the most dominant variety and was grown on 95.75 per cent of the total area. An average area under un-recommended varieties came out to be 2.23, 9.54 and 32.75 in case of

small, medium and small farmers, which constituted 96.12, 95.88 and 94.93 per cent of the total cotton area. Hence, the share of un-recommended varieties decreases with an increase in farm size.

Table 2: Distribution of sampled farmers according to the seed used in Punjab, 2019-20 (Per acre)

Seed rate (900 gm/Packets)	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
Up to 2	2	9.09	5	7.81	1	25.00	8	8.89
>2.0 - 2.5	15	68.18	24	37.50	1	25.00	40	44.44
> 2.5	5	22.73	35	54.69	2	50.00	42	46.67
Total	22	100.00	64	100.00	4	100.00	90	100.00

Adoption gap of seed rate and seed treatment

As per PAU recommendation, the seed requirement of Bt hybrid cotton is 900 gms, nearly two packets of Bt cotton (one packet contains 450 gm of Bt cotton) per acre. Table 2 indicates that the highest number of farmers, i.e. 42 (46.67 per cent), were using more than 2.5 packets of cotton seeds for sowing one acre of cotton fields. Likewise, about 44 per cent of the farmers in the total sample were using a seed rate between 2 and 2.5 packets for sowing one acre of cotton. Only 8 farmers have reported using the recommended seed rate, i.e. 2 packets for sowing one acre of cotton. Category-wise, the number of farmers using the recommended seed rate (2 packets) turned out to be 2, 5 and 1 on small, medium and large farms, which were 9.09, 7.81 and 25.00

per cent of the total sample farmers. Similarly, the proportion of farmers who have used seed between 2.0-2.5 packets is estimated to be 68.18, 37.5 and 25.00 per cent on small, medium and large farms, while the respective figures are 22.73, 54.69 and 50.00 per cent in the case of farmers using a seed rate of more than 2.5 packets. It is worth mentioning here that only 8.89 per cent of the total sample farmers were following the recommended seed rate, while the majority, i.e. 91.11 per cent of the total sample farmers, were reported to use a higher seed rate in the study area. Therefore, farmers should be advised to follow the recommended seed rate to economise the cost of cotton cultivation.

Table 3: Distribution of farmers according to seed treatment of cotton seed in Punjab, 2019-20

Seed Treatment	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
Yes	1	4.55	7	10.94	1	25	9	10
No	21	95.45	57	89.06	3	75	81	90
Total	22	100	64	100	4	100	90	100

Seed treatment

Seed treatment prevents the crop from many fungal and viral infections. Chemical seed treatment with recommended chemicals helps the crop for proper germination and prevents it from many seed-borne diseases. The seed is soaked in a 0.5 g solution with 5 litres of water for 2-4 hours for better growth of the plant. Used 5 g Gaucho 70 WS (imidacloprid) or 7 g Cruiser 30FS

(Thiomethoxam) per kg seed for preventing damage by cotton jassid as per PAU recommendations (Punjab Agricultural University, 2019a) [8]. The results reveal that only 9 farmers in the total sample were reported to follow seed treatment before sowing, while the remaining 81, i.e. 90 per cent, were reported to sow the crop without chemical treatment of cotton seed.

Table 4: Number of farmers who practised non-Bt cotton as a refuge in cotton fields in Punjab, 2019-20

Used refuge	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
Yes	1	4.55	3	4.69	-	0.00	4	4.44
No	21	95.45	61	95.31	4	100.00	86	95.56
Total	22	100.00	64	100.00	4	100.00	90	100.00

Table 3 reveals that Category-wise, only 4.55 per cent of the total farmers in the case of small farms, 10.94 per cent of the farmers in the case of medium farms and 25 per cent of the total farmers in the case of large farms were reported to follow seed treatment before sowing the cotton crop. The finding were contradicted with Deepthi *et al* (2014) [4] which studied that the farmers in Andhra Pradesh's Ranga Reddy district had adopted the suggested package of Bt cotton techniques. In terms of seed treatment, the survey found that 100 per cent of the respondents were fully

adopted.

Growing of non-Bt cotton as refuge around the Bt cotton field

Growing 250 gms of non-Bt cotton as refuge around the Bt cotton field is also recommended by PAU to avoid the development of resistance in bollworms against the Bt toxin. It is evident from Table 4 that only 4 cotton growers, i.e. 4.44 per cent of farmers in the total sample, were reported to grow non-Bt cotton around the cotton field. The study

revealed that out of the total sample of farmers, only one farmer (4.55 per cent) in the case of small farmers and 3 farmers (4.69 per cent) in the case of medium farms used Bt-cotton as refuge. However, no farmer was reported to grow non-Bt cotton as refuge in case of large farmers.

Adoption gap in the time of sowing

As per the recommendation, sowing of the cotton crop must be completed before mid-May. Delay in sowing of cotton may lead to a loss in crop yield. Table 5 shows that out of

the total 90 farmers, 81 (90 per cent) farmers reported completing the sowing of the crop up to mid-May sowing, while the remaining 9, i.e. 10 per cent, were reported to have delayed sowing of cotton, i.e. after mid-May. Category-wise, all the 4 farmers in the case of large farms reported to complete sowing before mid-May, while about 91 and 89 per cent of the total farmers in the case of small and medium farmers were reported to complete sowing up to mid-May.

Table 5: Distribution of farmers according to adopting/non-adopting recommended date of sowing (DOS) of cotton 2019-20

DOS as per Punjab Agricultural University recommendation	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
Yes	20	90.91	57	89.06	4	100.00	81	90.00
No	2	9.09	7	10.94	-	-	9	10.00
Total	22	100.00	64	100.00	4	100.00	90	100.00

In connection with the above, the analysis further proceeds to assess the distribution of farmers according to date of sowing and the results are given in Table 6. But cotton must be sown in lines with plant spacing of 45 cm in rows. Plant-to-plant distance should be kept at 75 cm. Most farmers used a seed drill for sowing cotton. As reported by the sample farmers, the sowing of cotton starts from mid-April. About 23 per cent of total farmers completed sowing of cotton in the month of April. The majority of the farmers, i.e. 66.67 per cent, completed sowing of cotton between May 1 and 15. About 10 per cent of the farmers delay sowing time up to the end of May. All the large farmers in the sample were found to complete the sowing of cotton up to mid-May. Nearly 9 per cent of the small farmers and 10.94 per cent of the medium farmers were found to delay sowing up to May end. So the cotton growers are advised to

complete the sowing of cotton till mid-May for its proper establishment. The finding were contradicted with Deepthi *et al* (2014) ^[4] which studied that the farmers in Andhra Pradesh's Ranga Reddy district had adopted the suggested package of Bt cotton techniques. In terms of seed treatment, the survey the 4 per cent of respondents partially adopted the suggested time of sowing, pest management methods, and harvest time, whereas 96 per cent fully accepted the recommended time of sowing, pest management practices, and harvest time, 90 per cent of respondents fully adopted suggested sowing methods, fertilizer application times, and weeding routines, with the other 10 per cent falling into the partially adopted category. Gap filling was entirely embraced by 88 per cent of respondents, while the remaining 12 per cent were just partially adopted.

Table 6: Distribution of sampled farmers according to date of sowing of cotton in Punjab, 2019-20

Date of sowing	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
April 1-15	-	-	-	-	-	-	-	-
April 16-30	5	22.73	15	23.44	1	25.00	21	23.33
May 1-15	15	68.18	42	65.63	3	75.00	60	66.67
May 16-31	2	9.09	7	10.94	-	0.00	9	10.00
Total	22	100.00	64	100.00	4	100.00	90	100.00

Adoption gap in weed management

As per the recommendation of packages and practices 2019, use of 1 litre stomp 30 EC (Pendimethalin) per acre for the control of weeds, particularly itsit, madhana/makra, as

preemergence within 24 hours of sowing (Punjab Agricultural University, 2019a) ^[8] is advised. It was seen that most sample farmers avoid chemical weed control.

Table 7: Distribution of farmers using recommended dose of weedicides for weed control in cotton field in Punjab, 2019-20

Weedicides	Small		Medium		Large		Overall	
	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age	No. of farmers	%age
Yes	-	-	4	6.25	-	-	4	4.44
No	22	100.00	60	93.75	4	100.00	86	95.56
Total	22	100.00	64	100.00	4	100.00	90	100.00

Only 4 farmers on medium farms were reported to follow chemical weed control in the cotton (Table 7). All other remaining farmers in the sample preferred two or three hoeing's with tractor-mounted cultivators/triphali for weed control in Bt cotton.

Extent of the adoption gap of inputs as compared to the recommended inputs

Actual farm input practices followed by sample cotton growers were compared with recommended input use practices in this section. The difference between the level of

actual input used with recommended input used was worked out. The extent of this difference may be referred as adoption gap. The negative sign of the adoption gap represents under use of inputs, while the positive sign represents the over use of inputs than that of recommended input use. The level of recommended input use assumed to be constant on all farms. The prices of inputs and the sale value of output was also kept constant, while estimating enterprise budget in both the conditions (actual and recommended input farm practices).

Extent of adoption gaps on the overall farm

An average productivity of the main and by-product of Bt hybrid cotton worked out to be 9.83 q/acre and 13.71 q/acre in case of actual farm conditions on average farms (Table 8). Compared to Rs 55600/acre, the gross returns turned out

to be Rs 54530/acre on actual farm conditions, which is about 1.92 per cent (Rs 1070/acre) lower than that of recommended practices. The total variable cost came out to be higher on (Rs 223102/acre) on an average farm under actual conditions, which was about 3.34 per cent (Rs 721/acre) higher than recommended practices. Labour used, machinery used, fertilizers, and insecticides were the major cost items. Based on the sign of the adoption gap, many inputs like seed, Urea, DAP, Potash, Polo, Actara, Confidor, Amistar and Blitox were over-utilised by 32.27, 2.27, 69.14, 68.00, 1.11, 137.78, 119.44 and 100 per cent over the recommended input use. The over-use of these inputs increased the variable cost by 3.34 per cent and declined the returns over variable cost (ROVC) by 5.27 per cent (Rs 1791/acre) on actual farm condition as compared to recommended practices.

Table 8: Adoption gap in input use pattern on overall farms in Punjab, 2019-20 Per acre

S. No.	Inputs	Actual		Recommended		Gap		% gap
		Quantity	Value (Rs)	Quantity	Value (Rs)	Quantity	Value (Rs)	
A	Gross returns							
	Main Products (quintal)	9.32	49862	10	53500	-0.68	-3638	-6.80
	By product (quintal)	13	1820	15	2100	-2	-280	-13.33
	Total		51682		55600	-	-3918	-7.05
B	Input use							
1	Seed (gm)	1023	1653	900	1454	123	199	13.67
2	Fertilizers							
	Urea(kgs)	82	475.6	90	522	-8	-46	-8.89
	DAP (kgs)	41	492	27	324	14	168	51.85
	Potash (kgs)	10	180	20	360	-10	-180	-50.00
	Zinc sulphate (kgs)	-	-	10	150	-10	-150	-100.00
3	Weedicides							
	Stomp(ml)	-	-	1000	500	-1000	-500	-100.00
4	Insecticides							
	Ujala (gm)	68	510	80	600	-12	-90	-15.00
	Lano (ml)	400	520	500	650	-100	-130	-20.00
	Polo (gm)	200	300	200	300	0	0	0.00
	Actara (gm)	80	96	40	48	40	48	100.00
	Confidor (ml)	50	50	40	40	10	10	25.00
5	Fungicides							
	Amistar (ml)	-	-	200	40	-200	-40	-100.00
	Blitox (gm)	1000	500	500	250	500	250	100.00
6	Irrigation (number)	3	240	6	480	-3	-240	-50.00
7	Labour used (hours)	279.6	11184	300	12000	-20.4	-816	-6.80
8	Machine used (hours)	7	3500	7	3500	-	-	0.00
9	Interest @ 7% for half period		345		371	-	-27	-7.15
10	Total variable cost		20045		21589	-	-1544	-7.15
11	Returns over variable cost		31637		34011	-	-2374	-6.98

Conclusion

The study conducted in Punjab highlights significant challenges in adopting recommended practices for cotton cultivation. It was observed that only 4.25% of the cotton area was cultivated with approved Bt cotton varieties, while most farmers relied on non-recommended seeds. Excessive seed rates, lack of seed treatment, and preference for manual weed control over chemical methods further exacerbated the inefficiencies. The overuse of inputs like fertilizers and pesticides increased costs by 3.34%, leading to a 5.27% reduction in returns over variable costs. To bridge this adoption gap, several measures were proposed. Farmers require training on selecting appropriate Bt cotton varieties, integrated pest management, and judicious use of inputs.

The availability of subsidized seeds and access to quality agricultural inputs must be prioritized. Timely irrigation, development of crop-specific weedicides, and village-level dissemination of literature on cotton cultivation are crucial for improving productivity. Additionally, government supervision is needed to ensure the quality of inputs and promote crop insurance schemes to mitigate financial risks. Adopting sustainable and scientifically recommended practices can significantly enhance economic returns, environmental sustainability, and the long-term viability of cotton farming in the region.

References

1. Barwale RB, Gadwal VR, Usha Z, Brent Z. Prospects

- of Bt cotton technology in India. *Journal of Agrobiotechnology Management and Economics*. 2004;2(1):23-26.
2. Bocci F, Blasi E. Sustainable cotton farming: A review of current practices and future directions. *Environmental Sustainability Journal*. 2020;14(3):445-460.
 3. Chaudhary A, Singh S. Socio-economic conditions of agricultural labourers in Punjab. *Indian Journal of Agricultural Economics*. 2021;76(3):443-452.
 4. Deepthi V, Hema B, Jyothi V. A study on the adoption of the recommended package of practices in Bt cotton by the farmers of Ranga Reddy district of Andhra Pradesh. *International Journal of Development Research*. 2014;4(1):262-265.
 5. Government of Punjab. Statistical Abstract of Punjab. Chandigarh: Economic and Statistical Organization, Government of Punjab; 2020. www.esopb.gov.in
 6. Hassan H, Rahman M. Transforming cotton farming: The role of knowledge dissemination and resource accessibility. *Sustainable Agriculture Review*. 2021;18(2):153-174.
 7. Liu Y, Wang X. Adoption of sustainable agricultural practices: Barriers and facilitators in cotton production. *Agricultural Economics*. 2019;51(4):455-467.
 8. Punjab Agricultural University. Statistics of Punjab Agriculture. Ludhiana: Punjab Agricultural University; 2019. www.pau.edu
 9. Punjab Agricultural University. Package and practices for kharif crops. Ludhiana: Punjab Agricultural University; 2019. p. 35-50. www.pau.edu
 10. Sivapalan M, Jayakody P. Challenges and opportunities in the global cotton industry: A review of sustainability challenges. *Agriculture and Environmental Management*. 2018;32(1):67-81.
 11. Statista. Leading cotton-producing countries worldwide in 2020/2021. 2021. <https://www.statista.com/statistics/263055/cotton-production-worldwide-by-topcountries/>