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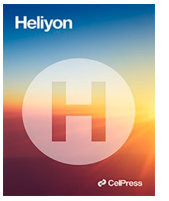

Research article

Economic viability of releasing Bt cotton in Bangladesh: An early insight

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ABSTRACT

Insect resistant genetically modified Bt cotton (containing a gene of *Bacillus thuringiensis*) has substantial potentiality of mounting cotton productivity. This study unveils an early insight on the economic viability of Bt cotton in Bangladesh. A total of 248 traditional cotton farmers and 8 Bt cotton experimental fields were surveyed in April 2022 for achieving the objectives. The data were analysed using descriptive statistics. Findings showed that the cost of Bt cotton production was slightly higher than that of conventional cotton. However, Bt cotton yielded a productivity increase of 0.81 t/ha. The cultivation of Bt cotton resulted in a higher net return (USD 2436/ha) compared to conventional cotton (USD 1624/ha). The results further indicated that the use of insecticides and pesticides in Bt cotton was significantly lower compared to traditional cotton, thereby contributing to the preservation of the natural environment. Overall, cultivation of Bt cotton is economically viable and may generate environmental benefits. Steps are warranted to disseminate and expand its cultivation.

1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the major textiles fibers in the world and plays a key role in the economic and social welfare of the growers [1]. Cotton is the second most important cash crop in Bangladesh after Jute. The weather and soil conditions of Bangladesh are also favorable for cotton production [2]. In 2021-22, around 0.20 million bales of cotton were produced in Bangladesh with a productivity of 6.35 bales per hectare [3]. Cotton cultivation exhibits a lower water requirement compared to paddy cultivation, thereby presenting an opportunity for the expansion of cotton cultivation in regions such as drought-prone and hilly areas of Bangladesh. However, the country's current cotton production meets hardly 5 % of the national demand. Therefore, emphasis has been given to enhance the acreages of cotton cultivation to 100 thousand hectares by 2030 without hampering the production of food crops.

Cotton is classified as a deciduous plant, rendering it vulnerable to infestation by insects and pests [4,5]. Approximately 11–14 % of the overall expenditure on cotton cultivation is allocated towards the acquisition of insecticides and pesticides [6]. The utilization of pesticides also entails concealed health and environmental consequences [7–10]. Nevertheless, the expenses associated with this can be reduced through the implementation of transgenic cotton [11–13]. Transgenic cotton was developed by inserting a gene from *Bacillus thuringiensis* (Bt) into the cotton [14]. The genetically modified (GM) Bt cotton was initially introduced in the USA, Mexico,

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China, Australia, Argentina and South Africa [11,15]. Subsequently, in 2002, Bt cotton was introduced in India as a means of combating bollworm infestation [16]. Its technological advantage was also realized in Pakistan [17–20]. Cotton farmers of these countries readily accepted Bt varieties for its several benefits. Although, there is a rancorous debate on the benefits and beneficiaries of GM technologies [21]. Earlier researches indicated that adopting Bt cotton helps small and marginal farmers to increase their revenues [22–24]. Even, this impact on smallholder farmers is continued in the long run too [25]. Several studies suggested that GM crops require lower insecticide costs and produce higher yields [26,27]. Other researches also visualized the environmental [15,28] and health benefits [29] of Bt cotton adoption.

Considering the benefits of Bt cotton, Cotton Development Board (CDB) of Bangladesh had initiated measures to analyse the possibility of releasing Bt cotton. However, adoption possibility of any newer technology is profoundly related to its economic viability [30]. Hence, prior to the introduction of this Bt cotton in Bangladesh, it was imperative to evaluate its economic viability. Previous research has also been carried out in various countries that have adopted GM crops [31–33]. With this background, present piece of research was taken to estimate the economic viability of adopting Bt cotton over conventional cotton cultivation in Bangladesh. Research questions (RQ) for this study were as follows: RQ_1) Is the adoption of Bt cotton economically viable or profitable than the existing traditional cotton? RQ_2) If the adoption is profitable, is there any change in input use patterns? and, RQ_3) Is there any alteration in the use of insecticides and pesticides in the event of a change? Hence, the study examines the comparative profitability of Bt cotton adoption in Bangladesh with an especial attention to explore the change in input use patterns. The finding of this study will help to initiate the required policy decisions on safe, environment friendly and cleaner agricultural production in Bangladesh.

2. Methodology

Survey method was adopted for collecting data from the conventional cotton farmers. The Bt cotton cultivation related information was gathered from the experimental research stations of CDB at different regions of Bangladesh.

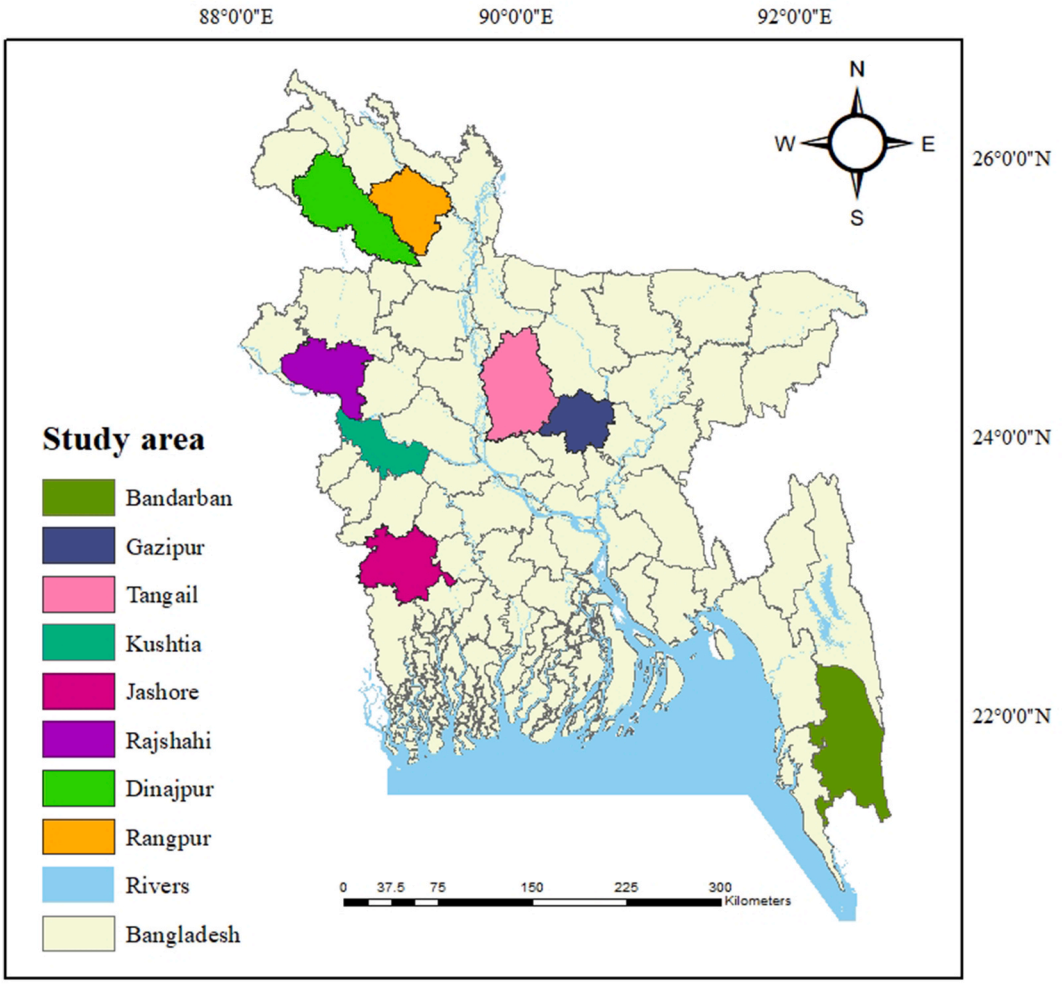

Fig. 1. Map of the study areas.

2.1. Selection of the study areas

In Bangladesh, Bt cotton cultivation trials were set at the regional experiment stations located in Gazipur, Bandarban, Jashore and Dinajpur districts. Before starting regional multi-location trial, CDB has taken all the necessary approvals from the "National Committee on Biosafety (NCB)" under the Ministry of Environment, Forest and Climate Change of the Government of Bangladesh. NCB approved conducting regional multi-location experimental field trial by CDB at their 12th meeting on 7th September 2021 under the addenda 4.0 and decision number 4.1. The data on Bt cotton cultivation were collected from those experimental sites. Besides, conventional cotton farmers from Rangpur and Dinajpur were selected against the experiment station at Dinajpur for the similar agro ecological characteristics. Similarly, farmers from Bandarban and Rajshahi districts against the Bandarban, Jashore and Kushtia districts against the Jashore and Tangail district against the Gazipur cotton research station were considered in this study (see details in Fig. 1 and Table 1). The Fig. 1 was developed with the help of ArcGis software version 10.8 using the shape file of Bangladesh Agricultural Research Council (BARC). Thus, the data on the conventional cotton cultivation were collected from 7 different districts of Bangladesh. It is worth mentioning that CDB monitored both the conventional cotton cultivation and the Bt cotton experiment stations impartially.

2.2. Crop husbandry

Traditional cotton farmers and Bt cotton experiment trial related people were encouraged to follow the guideline provided on the "Technical guidebook on cotton cultivation" published by CDB, Bangladesh (https://cdb.gov.bd/). The recommendation followed to produce Bt and traditional cotton are attached in Table 2.

2.3. Selection of the samples and sampling technique

A list was prepared comprising the conventional cotton cultivators of the selected districts with the help of field officers and field level assistant of the CDB and the local farmers. That list was served as the population of the study. In this study, a total number of 248 conventional cotton cultivators (at least 30 from each district) were randomly selected from the population (Table 1). Experiment on Bt cotton was done on two separate plots in 4 regional research stations. A set of data was collected from all the 8 plots to make a meaningful inference.

2.4. Preparation of the questionnaire and collection of data

Based on preliminary knowledge and expertise, an interview schedule was prepared. The schedule was finalized by addressing the problems faced during the pre-test survey at Nagorpur area in Tangail district. Afterword, the primary data was collected by interviewing the selected respondents from 10th April to 21st April 2022. Secondary data was collected from Bangladesh Bureau of Statistics (BBS), Department of Agricultural Extension (DAE), CDB, books, journals, newspapers, articles, etc.

2.5. Analytical techniques

Descriptive statistical analysis was done for analyzing the collected data. The tabular technique of analysis was done to determine and compare the input use patterns, costs, returns, and profitability of conventional and Bt cotton cultivation in the study area.

2.5.1. Profitability analysis

In this study, costs, returns and profitability of cotton cultivation were estimated and compared by using the following algebraic equations as used by Sujan et al. [34]:

Gross Return: Total return was calculated by adding the values received from the main product (cotton fiber) and by-products (Equ. 1).

Table 1
Area wise distribution of the respondents/experiment station.

Traditional Cotton		Bt cotton	
Districts	Number of respondents	Experiment station	Number of fields/trials
Rangpur	31	Dinajpur	2
Dinajpur	31		
Bandarban	31	Bandarban	2
Rajshahi	31		
Jashore	30	Jashore	2
Kushtia	30		
Tangail	64	Gazipur	2
Total	248	Total	8

Table 2
Agronomic practices recommended for cultivating Bt and traditional cotton in Bangladesh.

Genotype name	Planting time	Seed rate (kg/ha)	NPK fertilizer (kg/ha)	R × R (cm)	P × P (cm)	Harvesting time
For Bt, JKCH 1947 and JKCH 1050; For traditional cotton, CB 12, CB 13, CB 14, CB 15, CB 16 and CB 17	01 July to 15 August	0.6–1	120-80-225	90–100	45–60	15 November to 30 January

Note: One unit Nitrogen (N), Phosphorus (P), and Potassium (K) require 2.17 kg, 5.00 kg and 2.00 kg Urea, TSP and MoP fertilizer, respectively.

$$GR_i = \sum_{i=1}^{n} Q_{mi}P_{mi} + \sum_{i=1}^{n} Q_{bi}P_{bi} \quad (1)$$

where, GR_i = Gross return of ith farmer (USD/ha); Q_{mi} = Quantity of the ith cotton cultivator (kg/ha); P_{mi} = Average price received by ith cotton cultivator (USD/kg); Q_{bi} = Quantity of the ith cotton cultivator's by-product (kg/ha); P_{bi} = Average price received by ith cotton cultivator on by-product (USD/kg); i = 1,2,3, … … … n.

Gross Margin: Gross margin was estimated by deducting all the variable costs from the total return. To calculate the gross margin from cotton cultivation the following equation (Equ. 2) was used in this study:

$$GM = TR - VC \quad (2)$$

where, GM = Gross margin, TR = Total Revenue, VC = Variable Cost.

Net return: Net return was calculated by deducting all costs (variable and fixed) from gross return. To determine the net return from cotton cultivation the following equation (Equ. 3) was used in this study:

$$\pi = GR - TC \quad (3)$$

where, π = Net return (USD/ha), GR = Gross return (USD/kg), TC = Total cost (USD/ha).

2.5.2. Undiscounted benefit cost ratio (BCR) analysis

Average return to each dollar spent on production is an important criterion for measuring profitability. Undiscounted BCR was estimated using Equ. 4 and Equ. 5.

Table 3
Comparison of input use patterns between traditional and Bt cotton cultivation.

Sl. No.	Items	Rangpur & Dinajpur (n = 62)	Bandarban (n = 31)	Rajshahi (n = 31)	Jashore & Kushtia (n = 60)	Tangail (n = 64)	Traditional cotton (n = 248)	Bt cotton
		Amount	Amount	Amount	Amount	Amount	Amount	Amount
01.	Human labour (man-days/ha)	128.10 (29.13)	141.47 (27.48)	156.94 (30.22)	123.91 (30.66)	139.95 (33.45)	134.56 (30.67)	136.28 (31.71)
	Hired labour	93.44	97.99	113.45	101.94	88.67	97.74	136.28
	Family labour	34.65	43.49	43.49	21.97	51.28	36.82	–
02.	Land preparation cost (USD/ha)	161.72 (10.30)	175.52 (12.07)	161.34 (10.62)	180.24 (9.44)	146.19 (8.29)	163.87 (9.75)	156.64 (9.20)
03.	Seed (kg/ha)	10.16 (13.73)	8.55 (19.03)	10.41 (18.22)	7.53 (10.38)	11.29 (16.92)	9.65 (14.75)	7.09 (15.19)
04.	Manures (t/ha)	1.28 (6.13)	3.04 (3.29)	3.62 (4.26)	5.83 (9.24)	3.73 (8.51)	3.52 (7.11)	7.29 (7.35)
05.	Fertilizers (kg/ha)	1219.80 (19.89)	965.75 (16.85)	1012.70 (17.05)	1296.18 (22.21)	993.20 (16.00)	1120.39 (18.83)	1194.37 (21.55)
	Urea	266.96	212.68	217.51	298.97	230.19	252.25	311.71
	TSP	312.43	248.35	260.43	289.24	295.65	287.98	286.46
	MoP	303.99	348.80	368.49	488.54	389.50	384.37	402.64
	Gypsum	148.06	134.67	144.33	190.81	38.09	126.11	143.54
	Borax	8.15	12.76	16.14	12.57	23.50	14.75	23.15
	Others	180.22	8.48	5.81	16.05	16.27	54.92	26.87
06.	Insecticides & pesticides (liter/ha)	5.34 (14.84)	3.47 (15.56)	5.94 (14.90)	6.84 (11.32)	7.03 (14.08)	5.98 (13.75)	2.61 (9.31)
07.	Irrigation (USD/ha)	93.83 (5.98)	83.07 (5.71)	71.87 (4.73)	128.64 (6.74)	48.50 (2.75)	86.46 (5.14)	96.86 (5.69)

Note:
1. Numbers in the parenthesis indicate the percentage of total input use.
2. Findings from Rangpur and Dinajpur districts are presented together for their similar agro-ecological characteristics.
3. Findings from Jashore and Kushtia districts are presented together for their similar agro-ecological characteristics.
4. One USD was considered to be equivalent with Bangladeshi Taka (BDT) 86.2 as per the exchange rate shown in Bangladesh Bank website.

$$\text{BCR on total cost basis} = \frac{GR}{TC} \quad (4)$$

$$\text{BCR on variable cost basis} = \frac{GR}{TVC} \quad (5)$$

where, GR = Gross return, TC = Total cost, TVC = Total variable cost.

2.6. Ethical consideration

This research was a survey based study. Ethical approval on conducting field survey was taken from Cotton Development Board (CDB) of Bangladesh. Prior starting the survey, purpose of the interview was explained to the responded traditional cotton farmers and their oral consent about the use of their responses in research, and publication were taken. Respondents were assured that "the survey data will be used only for research purpose and their identity will be kept confidential".

3. Results

3.1. Input use pattern

All the inputs used for producing cotton were considered to explore the input use patterns of Bt and traditional cotton cultivation in the study locations. Findings of the study revealed that on an average 135 man-days/ha of human labour was used for producing traditional cotton, while 136 man-days/ha were required for Bt cotton cultivation at the experimental fields (Table 3). It seems that human labour use in both traditional and Bt cotton is same. It is found that human labour use was 157 man-days/ha in Rajshahi while 124 man-days/ha in Jashore/Kushtia, 128 man-days/ha in Rangpur/Dinajpur and about 140 in Bandarban and Tanagail which indicates human labour use slightly differ across locations of the country. Farmers of Kushtia using lower amount of human labour compared to other districts. Conventional cotton farmers in the study areas used 9.65 kg of seed per hectare, whereas Bt cotton trials required 7.09 kg of seed per hectare. Highest 11.29 kg seed per hectare was applied by the farmers of Tangail district. The findings also

Table 4
Comparison of cost of production between traditional and Bt cotton.

Sl. No.	Items	Rangpur & Dinajpur	Bandarban	Rajshahi	Jashore & Kushtia	Tangail	Traditional cotton	Bt cotton
		Amount (USD/ha)	Amount (USD/ha)	Amount (USD/ha)	Amount (USD/ha)	Amount (USD/ha)	Amount (USD/ha)	Amount (USD/ha)
A.	Variable Cost	1593.74 (78.45)	1501.61 (80.88)	1565.34 (77.97)	1951.14 (81.82)	1831.36 (81.38)	1726.46 (80.36)	1756.18 (80.53)
	Land preparation cost	161.72 (7.96)	175.52 (9.45)	161.33 (8.04)	180.24 (7.56)	146.18 (6.50)	163.87 (7.63)	156.65 (7.18)
	Human labour	457.24 (22.51)	399.49 (21.52)	459.01 (22.86)	585.34 (24.55)	590.10 (26.22)	515.52 (23.99)	540.07 (24.76)
	Seed	215.61 (10.61)	276.69 (14.90)	276.69 (13.78)	198.16 (8.31)	298.42 (13.26)	248.03 (11.54)	258.67 (11.86)
	Organic manure	96.18 (4.73)	47.87 (2.58)	64.66 (3.22)	176.38 (7.40)	150.13 (6.67)	119.52 (5.56)	125.16 (5.74)
	Chemical fertilizers	312.31 (15.37)	244.92 (13.19)	258.87 (12.89)	423.97 (17.78)	282.33 (12.55)	316.48 (14.73)	367.08 (16.83)
	Urea	60.77 (2.99)	42.76 (2.30)	42.76 (2.13)	63.17 (2.65)	42.30 (1.88)	52.08 (2.42)	65.16 (2.99)
	TSP	86.36 (4.25)	69.85 (3.76)	72.92 (3.63)	110.12 (4.62)	75.45 (3.35)	85.55 (3.98)	73.11 (3.35)
	MoP	56.58 (2.79)	61.88 (3.33)	65.53 (3.26)	123.36 (5.17)	67.77 (3.01)	77.41 (3.60)	74.69 (3.42)
	Gypsum	26.81 (1.32)	28.27 (1.52)	29.95 (1.49)	57.75 (2.42)	13.26 (0.59)	31.38 (1.46)	54.10 (2.48)
	Borax	20.46 (1.01)	32.55 (1.75)	38.10 (1.90)	32.62 (1.37)	54.52 (2.42)	35.90 (1.67)	75.08 (3.44)
	Others	61.33 (3.02)	9.59 (0.52)	9.59 (0.48)	36.95 (1.55)	29.03 (1.29)	34.15 (1.59)	24.94 (1.14)
	Insecticides and pesticides	233.00 (11.47)	226.28 (12.19)	226.28 (11.27)	216.10 (9.06)	248.42 (11.04)	231.21 (10.76)	158.50 (7.27)
	Irrigation	93.84 (4.62)	83.07 (4.47)	71.87 (3.58)	128.63 (5.39)	48.50 (2.16)	86.46 (4.02)	96.86 (4.44)
	Carrying cost	23.84 (1.17)	47.77 (2.57)	46.60 (2.32)	42.31 (1.77)	67.27 (2.99)	45.36 (2.11)	53.18 (2.44)
B.	Fixed cost	437.81 (21.55)	354.92 (19.12)	442.24 (22.03)	433.46 (18.18)	418.92 (18.62)	422.08 (19.64)	424.72 (19.47)
	Interest on operating capital	159.37 (7.84)	150.16 (8.09)	156.53 (7.80)	195.12 (8.18)	183.13 (8.14)	172.65 (8.04)	175.61 (8.05)
	Land use cost	278.43 (13.71)	204.76 (11.03)	285.71 (14.23)	238.34 (10.00)	235.79 (10.48)	249.43 (11.61)	249.10 (11.42)
	Total Cost (A + B)	2031.54 (100.00)	1856.53 (100.00)	2007.58 (100.00)	2384.59 (100.00)	2250.29 (100.00)	2148.54 (100.00)	2180.89 (100.00)

Note:
Numbers in the parenthesis indicate the percentage of total cost.

indicate that manure and fertilizer application was higher in Bt cotton compared to conventional one. The most intriguing findings was that Bt cotton production required approximately 2.61 L of pesticide and insecticides, whereas 5.98 L of pesticide and insecticides were used for conventional cotton. Overall, input use patterns were similar for the Bt and traditional cotton production except seed and insecticide & pesticides.

3.2. Cost of cotton production

Cost of cotton cultivation included different variable and fixed costs. The cost of human labour, land preparation, seed, fertilizers, insecticides, irrigation, land use and interest on operating capital etc. were calculated on per hectare basis. The cost of human labour was the highest followed by cost of chemical fertilizers and seed for both traditional and Bt cotton cultivation (Table 4). On average, the total cost of conventional cotton cultivation was USD 2148.54 per hectare, whereas total cost of Bt cotton cultivation was USD 2180.89/ha. In both the case, more than 80 % of the input costs constituted by the variable cost items, though they differed across the regions. Thus, the costs of Bt and traditional cotton cultivation were almost similar.

3.3. Profitability of cotton cultivation

The profitability analysis suggested that Bt cotton cultivation (4.33 ton/ha) ensured higher yield compared to conventional cotton (3.52 ton/ha) (Table 5). The difference was more than three-fourths of a ton per hectare. The average gross margin and net return were USD 2046.11/ha and USD 1624.05/ha for the conventional cotton, while it were USD 2860.95/ha and USD 2436.24/ha for the Bt cotton, respectively. The BCR was 1.76 for conventional cotton while 2.12 for Bt cotton based on full cost. However, the BCRs were 2.19 and 2.63 based on variable cost for conventional and Bt cotton, respectively. The higher net return and BCR suggested the better economic viability of Bt cotton cultivation.

3.4. Problems of cotton cultivation

Major constraints in conventional cotton cultivation were also noted to generate some implications for the policy makers. Insects and pest infestation was the mostly quoted problem faced by the conventional cotton farmers (Table 6). Among the other problems, the requirement of intensive care, higher seed price, requirement of higher labour and fertilizer inputs, and insufficient subsidies were the mostly mentioned cases. Additional training on enhancing resource use efficiency could be a probable solution to these problems.

4. Discussion

Cotton cultivation has been spreading in Bangladesh through multiple initiatives for technology transfer and research of the CDB. Agronomic management practices are very important to increase the productivity of cotton [28] and it depends on the input use patterns. Results revealed that similar amount of human labour was required for both the Bt and traditional cotton cultivation (Table 3). This labour requirement was varied across the country. Change in agro climatic condition may responsible for those changes. The adherence to recommended doses of manure and fertilizers was observed in the production of Bt cotton, whereas traditional farmers exhibited a certain degree of reluctance in upholding the recommended practices. The application of insecticides and pesticides in Bt cotton production was approximately 50 % lower compared to the conventional method. This change in insecticide use is the main attribute featured in the Bt cotton. Nevertheless, the reduction of insecticide usage could be further attained if there was no

Table 5
Comparison of profitability between traditional and Bt cotton.

Items	Unit	Rangpur & Dinajpur	Bandarban	Rajshahi	Jashore & Kushtia	Tangail	Traditional cotton	Bt cotton
Yield (Y)	t/ha	3.32	3.12	3.56	3.61	3.81	3.52	4.33
Farm gate Price (P)	USD/kg	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Return from by products	USD/ha	32.54	88.40	88.40	29.86	148.85	96.25	96.25
Gross return (GR)	USD/ha	3497.89	3340.75	3808.20	3799.50	4126.37	3772.58	4617.13
Total variable cost (TVC)	USD/ha	1593.74	1501.61	1565.34	1951.14	1831.36	1726.46	1756.18
Total cost (TC)	USD/ha	2031.54	1856.53	2007.58	2384.59	2250.29	2148.54	2180.89
Gross margin (GR-TVC)	USD/ha	1904.15	1839.13	2242.87	1848.36	2295.01	2046.11	2860.95
Net return (GR-TC)	USD/ha	1466.36	1484.21	1800.63	1414.91	1876.09	1624.05	2436.24
BCR on full cost (GR/TC)		1.72	1.80	1.90	1.59	1.83	1.76	2.12
BCR on variable cost (GR/TVC)		2.19	2.22	2.43	1.95	2.25	2.19	2.63

Table 6
Constraints faced by cotton cultivators.

Sl. No.	Problem statements	Positive response	Rank
01.	Insect and pest infestation	20.16	1st
02.	Requirement of intensive care	18.55	2nd
03.	Higher seed price	17.74	3rd
04.	Insufficient subsidy	16.94	4th
05.	Requirement of higher labour and fertilizer inputs	9.68	5th

need for additional insecticides to control sucking type insects [4,23]. Previous studies conducted by Hou et al. [26] and Kranthi and Stone [27] demonstrated that genetically modified crops exhibited a reduced reliance on pesticides. Therefore, the adoption of Bt cotton leads to a decrease in pesticide usage, expenses, and environmental harm [13,15,28], thereby resulting in health advantages as well. The total cost of Bt cotton production was slightly higher than that of traditional cotton (Table 4). This could be attributable to the use of recommended doses of various inputs in Bt cotton production. Similar results were also found by Frisvold et al. [35] in USA, Pray et al. [36] and Huang et al. [37] in China, Gouse et al. [38] in South Africa and Traxler et al. [14] in Mexico. The findings further revealed that the cost of insecticide and pesticide application was lower for Bt cotton compared to the traditional cotton, which is in the line with the findings of Kathage and Qaim [25] and Kranthi and Stone [27]. Arshad et al. [39] and Hou et al. [26] claimed that the pesticide use in cotton cultivation could be further minimized by raising awareness and disseminating knowledge among the farmers.

Adoption of Bt cotton generated 0.81 t/ha higher yield than the traditional cotton (Table 5). Insect resistance of Bt cotton could lead to less loss and more production. Earlier studies also indicated that Bt cotton adoption contributed to mounting the productivity [11,18,20,29,37]. By incorporating Bt cotton into the 44.3 thousand hectares of current cotton cultivating land in Bangladesh, the country's cotton production could be increased by approximately 33.23 thousand tons. Results also depicted that Bt cotton cultivation ensured higher net return and BCR which implied that Bt cotton has the potential to boost farmers' income and hence plays an important role in the country's anti-poverty programmes [22]. Subramanian and Qaim [40] also found the contribution of Bt cotton adoption on poverty reduction and rural development in India. Higher profitability was also achieved by the farmers of China [11,37]), India [25], Pakistan [13], and Africa [41]. Serval other studies have asserted that in addition to the cost of input, achieving a higher economic return from Bt cotton is contingent upon several factors, such as international cotton prices [15,42]. Nevertheless, the reduction of insecticide and pesticide usage can yield substantial environmental advantages [29]. Bt cotton has been found to decrease reliance on insecticides and pesticides, which has been identified as a significant limitation faced by traditional cotton farmers (Table 6). Overall, the cultivation of Bt cotton resulted in higher yields and net return, thereby improving the economic viability.

5. Conclusions

This study was conducted to assess the economic viability of Bt cotton production in Bangladesh. Bt cotton was less susceptible to some pests. It required lower pesticide use and generated higher net return. Bt cotton has the potential to boost up the farmers' income in Bangladesh. The cultivation of Bt cotton in Bangladesh was economically viable over the traditional cotton. In addition, reducing the use of pesticides can potentially yield environmental advantages.

Although this study offers valuable insights, it is important to acknowledge its inherent limitations. The conclusions are derived from the data collected from 240 conventional cotton farmers and 8 experimental fields of Bt cotton. Conducting a comparative analysis between traditional cotton growers and Bt cotton cultivation in research stations could produce less significant results. There is a need for additional research initiatives focusing on the social, economic, and environmental dimensions of Bt cotton in Bangladesh.

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Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Md. Hayder Khan Sujan: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohammad Mizanul Haque Kazal:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Md. Akhteruzzaman:** Validation, Resources,

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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