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Resource Utilization and Economic Analysis of Cotton Farming in Northern India

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ABSTRACT

The present study was conducted in the northern cotton-growing zone of India, comprising the states of Punjab, Haryana, and Rajasthan, to evaluate resource utilization and the economics of cotton cultivation. It also examined the challenges faced by cotton growers in production and marketing. Primary data for the year 2021-22 were collected from a sample of 120 farmers. The recommended doses of nitrogen and phosphorus was followed by only 40.83 and 22.50 per cent of farmers, respectively. Overuse of potash in Rajasthan highlights inefficiencies in fertilizer application. The average profitability of cotton cultivation has been worked out at Rs. 45087 per ha. Among the states, the profitability of cotton cultivation was Rs. 40153/ha, Rs. 47771/ha and Rs. 47329/ha, in Rajasthan, Haryana and Punjab, respectively. Major issues confronted by cotton growers include poor-quality inputs, price fluctuations, unstable productivity, contamination of cotton, shortage of skilled labour, and limited technical knowledge. Addressing these issues through the supply of high-quality cotton seeds, development of pest-resistant varieties, integrated pest management strategies, and strict regulation of oil mills and ginneries to control the hibernating pink bollworm in seed cotton could significantly enhance cotton cultivation and increase the area under production.

Key Words: Cotton**,** Cultivation, Input use, Northern Zone, Returns, Operational costs, Profitability

INTRODUCTION

The cotton-growing regions of India are primarily divided into three zones: Northern (Punjab, Haryana, and Rajasthan), Central (Gujarat, Maharashtra, and Madhya Pradesh), and Southern (Andhra Pradesh, Tamil Nadu, and Karnataka). In the Northern zone, cotton is typically planted from mid-April to the last week of May, whereas in the Central and Southern zones, planting begins in June and July, extending into August. In Tamil Nadu, part of the Southern zone, cotton planting occurs twice annually: in January/February for the summer crop and in June/July for the winter crop. Harvesting generally takes place from October to February across the country. The Northern zone contributes about 18% of India's total cotton production, from approximately 13% of the total cotton-growing area (GoI 2021). During 2019-20, Punjab had 248 thousand hectares under cotton cultivation, yielding 1206 thousand bales with an average productivity of 827 kg/ha. The major cotton-growing districts in Punjab—Bathinda, Fazilka, Mansa, and Sri Muktsar Sahib—account for 97.4% of the cotton area and 98% of its production in the state (GoP, 2021). In Rajasthan, 760 thousand hectares were under cotton cultivation, producing 2787 thousand bales with an average yield of 623 kg/ha. The primary cotton-growing districts—Sri Ganganagar, Hanumangarh, Alwar, and Nagaur—contributed about 71% of the total cotton area and 70% of production in the state (GoR, 2021). Similarly, in Haryana, cotton was cultivated on 723 thousand hectares, yielding 2484 thousand bales with an average productivity of 584 kg/ha. The major cotton-producing

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Table 1. Land holding of sample farmers in the selected cotton growing states. (Area in ha.)

Particulars	Rajasthan	Haryana	Punjab	Overall
Owned land (a)	4.90	4.19	4.23	4.78
Leased in (b)	0.14	0.04	0.07	0.08
Leased out (c)	0.26	0.36	0.16	0.26
Total operational holding (a+b-c)	4.77	4.88	4.14	4.59

districts—Hisar, Sirsa, Bhiwani, Fatehabad, and Jind—accounted for around 80% of the state's cotton-growing area and 82% of production (GoH, 2021). Cotton production is influenced by a variety of factors, including climatic conditions, rainfall patterns, insect-pest infestations, weed growth, and diseases. In Northern India, pests such as the American bollworm, pink bollworm, whitefly, and aphids have significantly impacted cotton yields. Despite its relatively small share of 5% in India's total cultivable land, cotton accounts for over 50% of the country's insecticide use (Singh *et al*, 2013). Farmers face numerous challenges in cotton production, such as losses from insect and pest attacks, excessive rainfall, unavailability of quality seeds, inadequate quality inputs, and limited technical knowledge. Productivity in the Northern zone is significantly influenced by factors such as climatic conditions, rainfall variability, insect-pest infestations, weed growth, and disease prevalence. Pests like the American bollworm, pink bollworm, whitefly, and aphids have caused substantial yield losses. Additionally, resource use efficiency remains a concern. This study aims to analyze the input use pattern and economics of cotton cultivation in the Northern India along with identification of the key challenges faced by cotton growers to suggest actionable solutions.

MATERIALS AND METHODS

The present study was conducted during the 2021-22 cropping season in the northern cotton growing states of India, encompassing Punjab, Haryana, and Rajasthan. To ensure robust and representative data collection, a multi-stage sampling technique was employed. In the first stage, the two highest cotton-producing districts from each selected state were identified. At the second stage, two villages were randomly chosen from each of these districts. Finally, from each selected village, a sample of 10 cotton growers was drawn, resulting in a total of 40 farmers surveyed per state. In this way, the overall sample comprises 120 cotton growers. Comprehensive primary data were collected from the sampled farmers, covering various aspects of cotton cultivation. These included details on operational land holding, cropping pattern, agronomic practices adopted in cotton cultivation, input usage (such as fertilizers and pesticides), labor and machinery utilization, and the associated costs. Additionally, the study explored various challenges faced by cotton growers, particularly issues related to production and marketing. These insights provide a valuable basis for understanding the economics of cotton farming and addressing the key constraints affecting productivity and profitability in the region.

RESULTS AND DISCUSSION

Operational land holding

The average operational holding of the sampled farmers in north cotton zone of India was 4.59 ha (Table 1). The operational land holding of the sample cotton growers in Haryana was 4.88 ha while in Rajasthan and Punjab, it was estimated at 4.77 ha and 4.14 ha, respectively. The prevailing average land rent was highest in Punjab ranging from Rs. 128079/ha to Rs. 134669/ha and lowest in Rajasthan (ranging from Rs. 66717/ha to Rs. 76601/ha). The reason behind this is higher productivity (hence, higher returns) of crops in Punjab as compared to other two states.

Depth of water table

The depth of water table varies across states and it also varies in different seasons. At overall, the depth of water table was in the range of 31-40 feet at about 40 per cent farms, while at 38.3 per cent farms, the water table was in the range of

Table 2. Depth of water table, source of irrigation and draft power in the selected cotton growing states.

Water table depth (ft.)	Rajasthan (n=40)	Haryana (n=40)	Punjab (n=40)	Overall (N=120)
21-30	-	13 (32.50)	33 (82.50)	46 (38.33)
31-40	17 (42.50)	24 (60.00)	7 (17.50)	48 (40.00)
41-50	3 (7.50)	3 (7.50)	-	6 (5.00)
> 50	20 (50.00)	-	-	20 (16.67)
Source of irrigation				
Canal only	1 (2.5)	3 (7.50)	-	4 (3.33)
Both canal and electric motor	31 (77.50)	26 (65.00)	30 (75.00)	87 (72.50)
Canal, electric motor and diesel engine	8 (20.00)	11 (27.50)	10 (25.00)	29 (24.17)
Source of draft power				
Owned tractor	35 (87.50)	36 (85.00)	33 (82.50)	104 (86.67)
Hired tractor	5 (5.00)	6 (15.00)	7 (17.50)	18 (15.00)
Bullock	-	2 (5.00)	4 (10.00)	6 (5.00)
Camel	3 (7.50)	-	-	3 (2.50)

Figures in parentheses indicate percentages to their respective totals.

21-30 feet (Table 2). Among the states, the deepest water table was observed in Rajasthan where the water level depth was more than 50 feet at about half of the sample farms. At the majority of farms (82.50%) in cotton growing belt of Punjab, the water table depth was in the range of 21-30 feet. In Haryana, the water table depth was 31-40 feet at about 60 per cent of sample farms.

Source of irrigation

Irrigation plays an important and crucial role in production of crops at farm level. At overall level, majority of the farmers (72.50%) were using both canal and electric motor as the source of irrigation (Table 2) followed by the farmers that were using electric motor and diesel engine in addition to canal water (24.17%). Similar trend was being followed by the farmers of Punjab, Haryana and Rajasthan states. The farmers who were using both canal and electric motor were found to be highest in Rajasthan (77.50%) followed by Punjab (75%) and Haryana (65%).

Source of draft power

Farmers use a variety of draught power sources for their various farming operations. It was found that at overall, 86.67 per cent of respondents owned tractors, whereas 15.00 per cent of farmers were using tractors on custom hiring basis for performing farm activities (Table 2). In Rajasthan, 87.50 per cent of farmers were having own tractors, while just 5 per cent were using custom hired tractors. Similarly, the 85.00 and 82.50 per cent of farmers in Haryana and Punjab, respectively were possessing tractors. In Rajasthan, 7.50 per cent of farmers also kept camels for performing farm operations.

Cropping pattern

The cropping patterns followed in the states under consideration (Table 3) revealed that the area under wheat was having highest share (38.42%) in the total cropped area followed by cotton crop (29.70%). The allocation of area under wheat in Punjab, Haryana and Rajasthan was 43.79, 36.55 and 34.92 per cent, respectively to their respective total cropped areas. As far as cotton crop is concerned, Haryana was the leading state amongst the selected states comprising 31.73 per cent of total cropped area followed by Rajasthan (29.10%) and Punjab (27.51%). The share of area under paddy and mustard in the total

Table 3. Cropping pattern at sample farms in the selected cotton growing states (ha/farm)

Crop	Rajasthan	Haryana	Punjab	Overall
***Kharif* season**				
Cotton	1.10 (29.10)	1.25 (31.73)	0.93 (27.51)	1.09 (29.70)
Paddy	-	0.12 (3.05)	0.65 (19.23)	0.26 (7.08)
Cluster bean	0.56 (14.81)	0.46 (11.68)	-	0.34 (9.26)
Maize	0.02 (0.53)	0.03 (0.76)	0.01 (0.30)	0.02 (0.54)
Moong	0.14 (3.70)	-	-	0.04 (1.09)
Sorghum fodder	0.05 (1.32)	0.10 (2.54)	0.07 (2.07)	0.07 (1.91)
Bajra fodder	0.05 (1.32)	-	-	0.02 (0.54)
***Rabi* season**				
Wheat	1.32 (34.92)	1.44 (36.55)	1.48 (43.79)	1.41 (38.42)
Mustard	0.37 (9.79)	0.32 (8.12)	0.10 (2.96)	0.26 (7.08)
Barley	-	0.08 (2.03)	-	0.02 (0.54)
Berseem fodder	-	0.06 (1.52)	0.04 (1.18)	0.03 (0.82)
Oats	0.08 (2.12)	0.06 (1.52)	0.04 (1.18)	0.06 (1.63)
Gram	0.12 (3.17)	-	-	0.04 (1.05)
Maize	0.02 (0.47)	-	-	0.01 (1.09)
***Zaid* season**				
Summer moong	-	0.02 (0.51)	0.06 (1.78)	0.02 (0.54)
Total cropped area	3.78 (100.00)	3.94 (100.00)	3.38 (100.00)	3.67 (100.00)

Figures in parentheses indicate percentages to their respective total cropped area.

cropped area was about seven per cent each. The cluster bean was being cultivated in Haryana (11.68%) and Rajasthan (14.81%) which comprised about 9.3 per cent area in total cropped area at the overall level. However, some other crops were also being cultivated in the study area like sorghum fodder having 1.91 per cent area followed by oats (1.63%), moong (1.09%), gram (1.09%), berseem fodder (0.82%), maize (0.54%), bajra fodder (0.54%), barley (0.54%) and summer moong (0.54%).

Seed rate

The study revealed significant variations in the quantity of cotton seed used per hectare across the sampled respondents. At the overall level, 49.17 per cent of farmers were using seed @2.25Kg/ha, while 45 per cent were using 2.812 Kg/ha(Table 4). The state-wise analysis showed distinct differences in seed usage patterns. In Punjab, 90 per cent of farmers adhered to the recommended seed rate of 2250 grams/ha, compared to 52.5 per cent in Haryana and only 5 per cent in Rajasthan. Conversely, the higher seed rate of 2.812 Kg/ha was predominantly used by 95 per cent of farmers in Rajasthan and 40 per cent in Haryana. Additionally, a small proportion of farmers (10%) used significantly higher quantities of seed in Punjab and 7.5 per cent farmers in Haryana were applying 3375 grams/ha. This overuse of seed may indicate a lack of awareness about optimal seeding rates or a response to perceived issues such as poor seed germination or pest susceptibility. Promoting education on recommended seed rates, alongside ensuring the availability of high-quality seeds, is essential for optimizing resource use, reducing cultivation costs, and improving productivity.

Irrigation applied to cotton crop

Cotton is a long duration crop which matures in 160-170 days which requires 5 to 6 irrigations. At the overall, five to six irrigations were applied to cotton crop by 53.33 per cent of sampled famers while 23.83 and 25 per cent of the farmers have applied seven to eight and three to four irrigations, respectively (Table 4). In Punjab, Haryana and Rajasthan, mostly five to six

Table 4. Cotton seed rate and number of irrigation applied by the sample farmers. (No. of farmers)

Seed rate (Kg/ha)	Rajasthan (n=40)	Haryana (n=40)	Punjab (n=40)	Overall (N=120)
2.250	2 (5.00)	21 (52.50)	36 (90.00)	59 (49.17)
2.812	38 (95.00)	16 (40.00)	-	54 (45.00)
3.375	-	3 (7.50)	4 (10.00)	7 (5.83)
Number of irrigation applied				
3-4	12 (30.00)	12 (30.00)	6 (15.00)	30 (25.00)
5-6	17 (42.50)	26 (65.00)	21 (52.50)	64 (53.33)
7-8	14 (35.00)	2 (5.00)	15 (37.50)	31 (25.83)

Figures in parentheses indicate percentages to their respective totals.

Table 5. Recommended application of nitrogen, phosphorus and potash to cotton.

Fertilizers (in nutrient form)	Rajasthan (n=40)	Haryana (n=40)	Punjab (n=40)	Overall (N=120)
Nitrogen	52.50	40.00	30.00	40.83
Phosphorous	15.00	20.00	32.50	22.50
Dose of potash (kg/ha)				
Nil	22.50	50.00	47.50	40.00
<25	2.50	-	-	0.83
25-50	35.00	27.50	25.00	29.17
50-75	32.50	-	5.00	12.50
75-100	7.50	22.50	22.50	17.50

irrigations were being applied by 42.5. 65 and 52.5 per cent of the farmers, respectively. Due to the issue of brackish water in some parts of Haryana, the farmers have to use canal water alone or by mixing the canal and tube well water. In Rajasthan, due to lesser irrigation facilities, about 40 per cent farmers applied four to five irrigations.

Fertilizer application

Nitrogen and phosphorous

Nitrogen is an important component for the plant growth. As per recommendations of agricultural scientists, the recommended dose of nitrogen for cotton crops is 103.8 kg per ha (PAU 2021), whereas for Rajasthan it is 148.3 kg/ha as there is problem of nitrogen leach down in sandy soils. It was observed that at overall level only 36.67 per cent cotton growers were applying recommended dose of nitrogen (Table 5). In Rajasthan, 50.00 per cent of the sampled farmers have applied recommended dose of nitrogen, followed by Haryana (35.00%) and Punjab (25.00%). Phosphorous plays crucial role in plant's reproductive growth. According to the agricultural scientists, if phosphorous is applied in *rabi* season, then its application may be skipped in the following *kharif* season. The recommended quantities of phosphorus in cotton in Punjab and Haryana are same (30 kg/ha) while in Rajasthan its recommended dose is higher (40 kg/ha). There is no need to apply phosphorous to cotton crop in *kharif* season. It was observed that only 22.50 per cent of sampled farmers have applied the recommended dose of phosphorus to cotton crop.

Table 6. Application of zinc and pesticide spray to cotton crop at the sample farms
(Per cent farmers)

Dose (kg/ha)	Rajasthan (n=40)	Haryana (n=40)	Punjab (n=40)	Overall (N=120)
Not applied	77.50	97.50	90.00	88.33
Applied by	22.50	2.50	10.00	11.67
Number of pesticide sprays				
1-2	7.50	15.00	5.00	9.17
3-4	92.50	67.50	87.50	82.50
5-6	-	17.50	7.50	8.33

Potash

The agriculture experts advocate that potash application in cotton crop should be based on soil test results. Potash is necessary only if the soil is deficient in this nutrient. However, the adoption of this practice varies across regions. At the overall level, 40 per cent of the sampled farmers did not apply potash to their cotton crop (Table 5). The highest proportion of non-application was observed in Haryana, where 50 per cent of farmers did not use potash, followed by Punjab (47.5%) and Rajasthan (22.5%). In Rajasthan, approximately 35 per cent of farmers were observed applying 25 to 50 kg of potash per hectare, likely reflecting the region's specific soil characteristics and fertility needs. This relatively higher adoption rate may be attributed to awareness of soil potash deficiency and its impact on crop productivity in the region. Encouraging farmers to adopt soil test-based nutrient management practices can enhance resource efficiency, reduce input costs, and improve cotton yields. Providing access to affordable soil testing services and creating awareness about the critical role of potash in plant nutrition are essential steps to bridge the gap between recommendations and field practices.

Zinc

It was observed that in the selected cotton growing states, 88.33 per cent of the sampled farmers did not apply zinc fertilizer to their cotton crop (Table 6). State-level analysis revealed significant variation in zinc application practices. In Rajasthan, Punjab and Haryana, around 77.50, 90.00 and 97.5 per cent of farmers, respectively, avoided the use of zinc. The relatively higher adoption of zinc fertilization in Rajasthan, where 22.5 per cent of farmers applied zinc, can be attributed to the region's sandy soil texture, which is often deficient in zinc. Zinc deficiency in soil negatively affects plant growth and yields, as zinc is a critical micronutrient for enzymatic and physiological processes in plants. Recognizing this, a subset of farmers in Rajasthan incorporated zinc into their fertilization practices to address the nutrient deficit and improve crop productivity. The widespread avoidance of zinc fertilization in Punjab, Haryana, and by most farmers in Rajasthan is due to the fact that these farmers think that their lands are not zinc deficient. To address this issue, agricultural extension services should focus on educating farmers about soil testing and the role of micronutrients in optimizing cotton yields.

Pesticides use in cotton crop

Cotton cultivation is highly vulnerable to various insect pests, which can cause significant damage to the crop if not managed effectively. To combat these pests, farmers in the cotton-growing regions of northern India rely heavily on chemical insecticides and pesticides. However, this intensive use of chemicals poses challenges related to cost, environmental impact, and pest resistance. In Punjab and Haryana, approximately 87.5 and 67.5 per cent of farmers, respectively, reported applying pesticides to their cotton crops three to four times (Table 6). In contrast, 92.50 per cent of farmers in Rajasthan applied pesticides three to four times. These application patterns

Table 7. Profitability of cotton cultivation in the selected states **(Rs./ha)**

Particulars	Rajasthan	Haryana	Punjab	Overall
A. Total operational costs	62711	58392	53687	58263
Average cotton yield (q/ha)	17.75	18.36	17.34	17.82
i) Value of main product	98335	101476	96150	98657
ii) Value of by product	4529	4687	4865	4694
B. Gross returns (i+ii)	102864	106163	101015	103350
Profitability (B-A)	40153	47771	47329	45087

Table 8. Cotton production and marketing related issues confronted by the sample farmers

(Mean values)

Issue	Rajasthan	Haryana	Punjab
Poor quality seed	3.93***	4.15***	4.30***
Poor quality pesticides/fertilizer	4.28***	4.20***	4.25***
Insect/pest incidence	4.05***	4.08***	4.18***
Productivity instability	3.83***	3.90***	4.08***
Rainfall at harvesting	2.83NS	3.78***	3.50***
Costly labour	3.30**	2.85NS	3.05NS
Lack of skilled labour availability	2.85NS	2.65***	2.60***
Inadequate technical know-how	3.07NS	2.53***	2.40***
Price fluctuations	3.85***	3.98***	3.90***
Contamination in cotton produce	2.80*	2.70**	3.83***
Long distance market access	2.47***	2.50***	3.49NS
High transportation cost	2.42***	3.20NS	3.48***
Delay in payment	3.03NS	2.65***	2.73**
Lack of storage facility	2.90NS	2.43***	2.65***
Market fees	2.95NS	2.48***	2.09NS

***, ** and *: Statistically significant at 1, 5 and 10 per cent probability level, respectively.
NS: Non-significant

reflect differences in pest pressure, climatic conditions, and agricultural practices across the states. The frequent use of chemical pesticides highlights the high susceptibility of cotton to pests such as bollworms, whiteflies, etc. While chemical interventions provide immediate control, over-reliance on these methods can lead to several issues, including the resurgence of secondary pests, resistance development among target pests, and contamination of soil and water resources. To mitigate these challenges, it is crucial to promote Integrated Pest Management (IPM) strategies so that the use of chemicals may be minimized. IPM practices, such as monitoring pest populations, using pheromone traps, and introducing natural predators, can help reduce pesticide dependence while maintaining productivity. Moreover, educating farmers about the judicious and targeted application of pesticides can prevent overuse and ensure sustainable cotton production. Awareness campaigns and training sessions by state agriculture departments can play a vital role in this regard. This comprehensive approach is essential to safeguard the environment, improve the economic viability of cotton farming, and ensure long-term pest management effectiveness.

Profitability of cotton cultivation

To work out the profitability of cotton cultivation, a detailed analysis of operational costs

and gross returns was conducted. The overall operational costs incurred in cotton cultivation were estimated at Rs. 58263 per hectare (Table 7). It includes the cost of seed, fertilizers, irrigation, plant protection, use of human labour, use of tractor use, transportation and marketing. The results revealed that Rajasthan had the highest expenditure at Rs. 62711/ha, followed by Haryana (Rs. 58392/ha), and Punjab (Rs. 53687/ha). The average productivity of cotton in the region was 17.82 quintals/ha. The gross returns and returns over variable costs were calculated at Rs. 103350/ha and Rs. 45087/ha, respectively. Profitability of cotton cultivation in Haryana was Rs. 47771/ha, followed by Punjab (Rs. 47329/ha), and Rajasthan (Rs. 40153/ha).

Production and marketing challenges in cotton cultivation

The cotton growers face multiple challenges that affect economic returns, including price volatility, input quality issues, unstable productivity, labour shortages, and contamination during production and processing. The results revealed that the poor quality seed and other inputs (like pesticides, fertilizers), insect/pest incidences and instability in cotton productivity were the major problems faced by cotton growers (Table 14). In Punjab and Haryana, the problems of rainfall at the time of harvesting, lack of skilled labour availability and lack of technical knowledge were found statistically significant. However, the problems of price fluctuations and contamination in produce were reported by the all the sampled cotton growers of all three states. In Rajasthan, the respondents expressed the constraint of higher labour cost. The difficulty in accessing the remunerative markets due to long-distance was reported by Haryana and Rajasthan farmers whereas lack of storage facilities and the issue of payment delays was noticed in Punjab and Haryana states. By addressing these challenges, the Northern zone can optimize resource use and increase cotton production and profitability.

CONCLUSION AND POLICY IMPLICATIONS

To enhance resource efficiency and economic returns, the following measures are recommended:

1. The supply of high-quality seeds, fertilizers, and pesticides should be ensured at affordable prices to make cotton cultivation a more profitable enterprise.

2. To prevent the sale of substandard inputs by private dealers, the government must implement stringent regulations and take strong action against such malpractices to protect cotton growers.

3. A significant portion of cotton seeds is produced and distributed by the Central and Southern states. These seeds should be thoroughly checked for approved hybrids and pest infestations to maintain quality standards.

4. Encouraging farmers to apply fertilizers based on soil testing can enhance resource efficiency, reduce input costs, and improve cotton yields. State agriculture departments should conduct awareness campaigns and training programs to educate cotton growers on the judicious application of fertilizers and pesticides.

5. Research efforts should focus on developing cotton cultivars that can tolerate the insect-pest attack and diseases. This can help increase cotton acreage and sustainability across the country.

6. State Departments of Agriculture and Agricultural Universities should jointly promote the Integrated Pest Management (IPM) approach, particularly in major cotton-growing regions, to reduce dependency on chemical pesticides and mitigate pest infestations.

7. Pink bollworm infestation often originates from seed cotton stored at oil mills and ginneries, where the pest hibernates. These facilities should be kept under strict surveillance throughout the year, as they are major sources of infestation.

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