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AB Botare
M.Sc. Scholar, RCSM, COA, Kolhapur, Maharashtra, India

US Bondar
Assistant Professor of Department of Agricultural Economics, COA, Karad, Maharashtra, India

NS Patil
M.Sc. Scholar, RCSM, COA, Kolhapur, Maharashtra, India

SS Ghadage
M.Sc. Scholar, RCSM, COA, Kolhapur, Maharashtra, India

BJ Deshmukh
Senior Research Assistant, Department of Agricultural Economics, COA, Kolhapur, Maharashtra, India

Corresponding Author:
AB Botare
M.Sc. Scholar, RCSM, COA, Kolhapur, Maharashtra, India

Comparative resource use structure and resource use efficiency of conventional Vs high density planting system of bt cotton in Yavatmal District of Maharashtra

AB Botare, US Bondar, NS Patil, SS Ghadage and BJ Deshmukh

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Abstract
The present study was undertaken in Yavatmal district of Maharashtra state in which cotton crop is grown as important commercial crop. The investigation was carried out with view to examine the trends in area, production and productivity and comparative resource use structure, to estimate per hectare cost and returns The study also assessed major constraints faced by farmers practicing high density planting system (HDPS). In cotton cultivation from Yavatmal district of Maharashtra state.The investigation was based on primary data on 45 conventional and 45 HDPS of cotton farmers collected from three tehsil namely Ralegaon, Kalamb and Babhulgaon of Yavatamal district. Pertained to the year 2023-24.

Maharashtra's cotton sector experienced substantial increases in area, production, and productivity area remains steady in last decade's 2004-05 to 2023-24 whereas Yavatmal district experienced moderate growth in acreage and notable increases in both production and yield in 2004-05 to 2013-14 due to use Bt cotton varieties but in this district experienced a gradual and statistically significant rise in the area under cotton cultivation. However, despite some improvements, production and productivity showed inconsistent trends with considerable variability, likely influenced by factors such as climatic changes, pest attacks like bollworm, and uneven use of agricultural inputs in 2014-15 to 2023-24.

HDPS farmers demonstrated comparatively higher utilization of resources across nearly all inputs than the conventional except nitrogen, phosphorus and potash because conventional farmers had not followed fertiliser use recommendations. Additionally, cotton yield was also greater on HDPS farmers compared to the conventional.

The per hectare cost of cultivation of cotton was worked out to be ₹ 160411.80 in HDPS while in Conventional 143067.10 The cost 'A' was ₹ 126043.45 in HDPS and 105793.75 in conventional or contributing 78.57 and 73.95 per cent share in the cost 'C' in HDPS and conventional. In cost 'A', the major item of cost was hired human labour i.e., ₹ 38325.33 and ₹ 49338.78 in conventional and HDPS, contributing 26.79 and 30.76 per cent share in the cost 'C' in conventional and HDPS. The per hectare expenditure on plant protection charges was worked out to ₹ 7100.20 and 12635.51 contributing 4.96 and 7.88 per cent share in the cost 'C' in conventional and HDPS.B:C ratio was 2.09 and 1.48 in HDPS and conventional system.

The constraints such as in-appropriate rainfall, unavailability of timely labour in peak period, bollworm complex management, variable market price of cotton and others were the major constraints faced by HDPS cotton farmers, in the cotton production. The study suggested that, the farmer should enhanced their existing productivity of 28.30 and 44.70 quintals/ha which is fair below than that of potential productivity 30 and 48 quintal/ha of conventional and HDPS by adopting recommend package of practices in cotton for minimizing the yield gap.

Keywords: Cotton, conventional, high density planting system, net return, income, cost of cultivation

Introduction

Drawing from previous Agricultural experiences, Indian farmers are increasingly adopting alternative cultivation techniques, with HDPS emerging as a promising method to enhance cotton yields. HDPS is being viewed as a viable alternative to traditional practices, offering advantages such as suitability for mechanical harvesting, lower labour costs, better resource efficiency, and higher productivity and profitability. This method has already gained widespread acceptance in major cotton-producing countries worldwide.

Efficient water management plays a critical role in the success of HDPS, especially in the face of limited freshwater availability. Proper irrigation practices are necessary to regulate excessive vegetative growth and to ensure that nutrients and assimilates are directed toward the plant's reproductive parts. In this regard, deficit irrigation an approach that conserves water while maintaining yield levels has proven to be effective. It involves using less water than conventional evapotranspiration demands, contributing to more sustainable cotton farming.

This review emphasizes the significance of integrating HDPS with deficit irrigation to develop a sustainable cotton production model. By merging the latest research with field-level practices, it provides a theoretical framework to guide the future evolution of cotton cultivation systems. HDPS also involves the targeted use of herbicides such as Quizalofop-ethyl 5 percentage EC and Pyrithiobac-sodium 10 percentage EC for weed control, as well as growth regulators like Mepiquat Chloride and Chlormequat Chloride to manage plant development. In combination with optimized fertilization and comprehensive pest and insect control measures, HDPS is ushering in a new era in cotton farming.

It is one of the new systems of cultivation of cotton, popularly known as "Ultra Narrow Row" cotton developed in India by the Central Institute of Cotton Research, Nagpur in 2010 This system conceived as an alternate production system having potential for improving yield, profitability, increasing efficiency, reducing input costs and risk minimization associated with the cotton production system.

Methodology

Study Area: Ralegaon, Kalamb and Babhulgaon tahsils, Yavatmal district.

Sample Size: 90 farmers (45 Conventional and 45 High Density Planting System).

Data Collection: Primary data was collected using personal interviews with structured questionnaires during the year 2023-24.

Cost Concepts

Variable Costs: Human labour, Bullock power, Machine labour, Seed, Manure, Fertiliser, Plant protection, Irrigation, etc.

Analytical Tools

- Functional Analysis
- $Y = a\, x_1^{b1} x_2^{b2} x_3^{b3} x_4^{b4} x_5^{b5} x_6^{b6} x_7^{b7} x_8^{b8} x_9^{b9} x_n^{bn}\, e$

Where,

- Y= Output (qtls)
- a = Intercept (constant)
- b = Regression parameters
- X_1 = Human labour (Days)
- X_2 = Bullock hours (hrs)
- X_3 = Machine hours (hrs)
- X_4 = Manure (q)
- X_5 = Seed (Kg)
- X_6 = N (Kg)
- X_7 = P (Kg)
- X_8 = K (Kg)
- X_9 = Plant protection (Rs)

Cobb-Douglas type of production function to determine the resource use structure.

Estimation of Resource Use Efficiency

$$\mathbf{MVP} = \left[\mathbf{bi} \frac{\bar{\bar{\mathbf{Y}}}}{\bar{\bar{\mathbf{X}}}_{\mathbf{1}}} \right] \mathbf{P_y}$$

Results and Discussion

Resource Use Structure for Cotton in Conventional vs High Density Planting System

Balanced use of input is crucial in farming business, it leads to success of farming business, and it leads to success of farming. The per hectare utilisation of physical quantity of different inputs for cotton in Yavatmal district of Maharashtra presented in Table No.1.

1. Human labour

Labour use is significantly higher in HDPS, with 245.99 days compared to 205.70 days in the conventional system. This suggests that HDPS is more labour-intensive, possibly due to the higher plant population and more frequent operations like pruning, spraying, or harvesting.

2. Bullock Power

The use of bullock power is slightly lower in HDPS (10.76 hours) than in the conventional system (11.27 hours), indicating a marginal shift away from traditional animal-drawn implements, possibly due to changes in field layout or increased mechanization.

3. Machine Power

Machine use is also lower in HDPS (8.99 hours) compared to conventional farming (11.96 hours). This could imply reduced mechanized operations in HDPS or better optimization of machinery usage due to higher plant density.

4. Seed

Seed requirement in HDPS is almost double, at 4.96 kg versus 2.49 kg in the conventional system. This reflects the nature of HDPS, which involves closer spacing and a higher number of plants per unit area, requiring more seed.

5. Manure

The application of manure is higher under HDPS (23.47 quintals) compared to conventional farming (16.96 quintals). This increase likely supports the higher nutrient demand of densely planted crops.

Table 1: Resource Use Structure for Cotton in Conventional vs High Density Planting system (Per ha)

Sr. No.	Resource use structure	Conventional	High Density Planting System
1	Human labour (Days)	205.70	245.99
2	Bullock power (Hr)	11.27	10.76
3	Machine power (Hr)	11.96	8.99
4	Seed (Kg)	2.49	4.96
5	Manure (Qtl)	16.96	23.47
6	N (Kg)	230.32	125.03
7	P (Kg)	159.50	68.78
8	K (Kg)	75.00	43.47
9	Plant Protection (₹)	7100.20	12635.51

6. Nitrogen

Surprisingly, the nitrogen application is lower in HDPS (125.03 kg) compared to the conventional system (230.32 kg). This might be due to more efficient nutrient management or the use of organic inputs in HDPS.

7. Phosphorus

The use of phosphorus is also reduced in HDPS, with 68.78 kg compared to 159.50 kg in conventional farming. This further indicates a shift in nutrient management practices under HDPS.

8. Potassium

Potassium application follows the same trend, with HDPS using 43.47 kg, significantly less than the 75.00 kg in the conventional system. This suggests that overall chemical fertilizer usage is lower in HDPS.

9. Plant Protection Chemicals

Expenditure on plant protection is much higher in HDPS, with a cost of ₹12,635.51 compared to ₹7,100.20 in conventional farming. The denser plant population in HDPS may create a more humid microclimate, increasing pest and disease risk and thereby necessitating more frequent pesticide applications. These results indicate general trend of comparative resource use structure similar findings were obtained by Rao and Meena (2020) [8].

Resource Use Productivities in Cotton Production

The analysis of Cotton cultivation using the Cobb-Douglas production function provides a comprehensive view of how various inputs affect yield. The results detailed in Table No.2 include estimated parameters related to the elasticities of yield, standard errors of regression coefficients, their significance levels and the coefficient of multiple determination (R^2**)**. The (R^2**)** expressed impact of the independent variable on cotton yield. The regression coefficient for input reflect the production elasticity, indicating percentage change in yield associated with a one unit change in the respective input, assuming other factors remain constant. These results are crucial for estimating the impact of resource use on yield. For production function analysis, nine inputs were evaluated: human labour, bullock power, machine power, seed, manure, nitrogen, phosphorus, potash and plant protection. By using Cobb-Douglas production function gives detailed insights into the relationship between various inputs and yield.

Coeffient of Determination (R^2**)** indicates proportion of total variation in cotton yield explained by input variables. Higher value of it signifies a better fit of the model to the data. Production elasticities which means regression coefficients for each variable measures percentage change in yield resulting from a one unit change in respective input, assuming other factors remains constant.

Results of Cobb-Douglas Production Function for Cotton Farmers For conventional the coefficient of multiple determination (R^2) was calculated to be 0.7522, indicating that 75% of the variation in output could be explained collectively by the nine independent resource variables included in the model. This value reflects the proportion of yield variation attributable to changes in input levels, assuming all other factors remain constant. These findings are particularly valuable, as they offer clear insights into how adjustments in resource use may influence crop yield. Among the inputs analysed, the regression coefficients for Manure (X_5), Fertiliser K (X_8), and Plant protection (X_9) were found to be positive and statistically significant at the 1% level and Machine power (X_3) statistically significant at the 10% level, suggesting that increasing the application of these resources could lead to higher production. Conversely, the coefficient for X_1, X_2, X4, X6 and X_7 was statistically insignificant, indicating limited or no potential for yield improvement through increased use of this input.

For the conventional group specifically, the significant encouraging coefficients suggest that a one-unit increase in machine power, manure, potassium and plant protection usage could enhance yield by approximately 0.13%, 0.47%, 0.62%, and 0.06%, respectively.

Table 2: Results of Cobb-Douglas Production Function for Cotton Farmers

Particular		Conventional	High Density Planting System
Intercept	A	-1.5000	-1.2450
Human labour (Days)	Log X_1	0.2264 (0.2360)	0.2669 (0.2772)
Bullock power (Hrs)	LogX_2	0.1027 (-0.0883)	-0.0389 (0.0944)
Machine power(Hrs)	LogX_3	0.1332* (0.0780)	0.0416 (0.0873)
Seed(Kg)	LogX_4	-0.3376 (0.2864)	-0.6917*** (0.3190)
Manure(Qtl)	LogX_5	0.4715*** (0.1048)	0.6625*** (0.1085)
Fertiliser N(Kg)	LogX_6	0.0900 (0.1492)	0.1475 (0.1746)
Fertiliser P(Kg)	LogX_7	-0.0280 (0.2116)	-0.2839 (0.2362)
Fertiliser K(Kg)	LogX_8	0.6255*** (0.2896)	0.8437*** (0.3340)
Plant protection (Rs)	LogX_9	0.0691*** (0.0180)	0.0237 (0.0810)
R square		0.7522	0.6400

Note:*, **and *** indicates significance at 10, 5 and 1%level of significance.

(Figures in parentheses are standard errors of respective regression coefficient)

For HDPS the coefficient of multiple determination (R^2) was calculated to be 0.6400, indicating that 64% of the variation in output could be explained collectively by the nine independent resource variables included in the model. This value reflects the proportion of yield variation attributable to changes in input levels, assuming all other factors remain constant. These findings are particularly valuable, as they offer clear insights into how adjustments in resource use may influence crop yield.

Among the inputs analysed, the regression coefficients for Seed (X_4), Manure (X_5) and Fertiliser K (X_8) were found to be negative(X_4), others positive and statistically significant at the 1% level, suggesting that increasing the application of these resources could lead to higher production. Conversely, the coefficient for X_1, X_2, X3, X_6, X_7 and X9 was statistically insignificant, indicating limited or no potential for yield improvement through increased use of this input.

For HDPS, the significant positive coefficients suggest that a one-unit increase in manure and potassium usage could enhance yield by approximately 0.66%, 0.84% or unitary increase in input seed express negative impact on yield due to overcrowding at 0.69% level respectively.

Resource Use Efficiency in Cotton Production

Production function analysis is commonly applied to assess how efficiently resources are utilized. This involves calculating the marginal value product (MVP) of each input. A resource is deemed to be used efficiently when its MVP is equal to its corresponding cost. Thus, achieving efficiency in resource use requires that the MVP of each input matches its factor cost. In this context, Table No.3 presents the MVPs of various resources, calculated at the geometric mean level using the estimated production function, alongside their respective per-unit costs.

- MVP/MC=1 (Optimum use of resources)
- MVP/MC<1 (Excess use of resources)
- MVP/MC>1 (Underutilization use of resources)

Table No.3: Resource Use Efficiency in Cotton Production

CS	Particulars	Unit	GM OF X	GM OF Y	Unit price output	Bi value	MP	MVP	MC	MVP/MC
1	Labour	Days	2.15	1.42	7500.00	0.23	0.66	788.58	250.00	3.15
2	Bullock	Hrs	1.03	1.42	7500.00	0.10	1.38	746.78	700.00	1.06
3	Machine	Hrs	1.05	1.42	7500.00	0.13	1.35	949.40	700.00	1.35
4	Seed	Kg	0.39	1.42	7500.00	-0.34	3.60	-6413.92	1728.00	-3.71
5	Manure	Qtl	1.21	1.42	7500.00	0.47	1.17	2913.88	400.00	7.28
6	N	Kg	2.36	1.42	7500.00	0.09	0.60	286.12	6.00	47.68
7	P	Kg	2.20	1.42	7500.00	-0.03	0.65	-95.58	29.00	-3.29
8	K	Kg	2.17	1.42	7500.00	0.63	0.65	2159.08	30.00	71.96
9	Plant protection	Rs	3.48	1.42	7500.00	0.07	0.41	148.85	3.48	42.77
					HDPS					
1	Labour	Days	2.33	1.64	7500.00	0.27	0.70	1409.99	250	5.64
2	Bullock	Hrs	1.02	1.64	7500.00	-0.04	1.62	-471.65	700.00	-0.67
3	Machine	Hrs	0.94	1.64	7500.00	0.04	1.75	546.43	700.00	0.78
4	Seed	Kg	0.69	1.64	7500.00	-0.69	2.37	-12281.87	1728.00	-7.11
5	Manure	Qtl	1.37	1.64	7500.00	0.66	1.20	5975.39	400.00	14.94
6	N	Kg	2.10	1.64	7500.00	0.15	0.78	867.79	6.00	144.63
7	P	Kg	1.84	1.64	7500.00	-0.28	0.90	-1906.51	29.00	-65.74
8	K	Kg	1.64	1.64	7500.00	0.84	1.00	6354.48	30.00	211.82
9	Plant protection	Rs	4.10	1.64	7500.00	0.02	0.40	71.29	4.10	17.39

Conventional system indicates that the marginal value product to marginal cost (MVP/MC) ratio was positive and more than unity for inputs such as human labour, bullock hours, machine, manure, nitrogen, potassium and plant protection, Indicating that these resources were underutilized and that enhancing their use could improve resource efficiency and potentially increase output. However, the MVP/MC ratio for seed and phosphorus was less than unity, indicating it was over utilised. These inputs were overuse of seed and phosphorus implies that further increasing its application would not contribute to higher yields and may instead be inefficient.

In case of HDPS indicates that the marginal value product to marginal cost (MVP/MC) ratio exceeded one for inputs such as labour, manure, nitrogen, potassium and plant protection This suggests these resources were underutilized and that enhancing their use could improve resource efficiency and potentially increase output. However, the MVP/MC ratio for bullock hour, machine, seed, and phosphorus was below one, indicating it was over utilised. In this group, the overuse of bullock, machine, seed, and phosphorus implies that further increasing its application would not contribute to higher yields and may instead be inefficient.

Conclusion and policy implications

The study revealed that, HDPS practice is profitable as compare to the conventional most of the farmers are unaware about CICR recommended technologies for cotton crop, therefore there is need to disseminate the technology through extension workers of the state to increase the cotton productivity. The study conclude that there is existence of high wages and labour scarcity problems so it can be overcomes by provision of subsidies machines and implements like cotton picking implements because cotton harvesting is most expensive operation. Promotion of high density planting system among the farmers because it has more potential to increase benefit of farmers as compared to the conventional method.

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