Original Research Article

Integrated Pest Management Technology as a Means to Cost Efficiency for Cotton Crop in Rajasthan, India

ABSTRACT

Aim: This research is an attempt to uncover the production opportunities of cotton grown with IPM for sustainable agriculture in Rajasthan, India.
Study Design: The study was based on both descriptive and exploratory type of research design.
Place and Duration of the Study: The study was conducted at Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan. Sri Ganganagar and Hanumangarh districts of Rajasthan were selected as the major districts under cotton cultivation for the study. The time duration of the project was for the crop year 2017–18.
Methodology: The respondents for the study were cotton farmers following different pest control measures in the study area. Multistage stratified random sampling method was followed for the research. Two major districts of Irrigated North Western Plain Zone (Zone Ib) were purposively selected. Based on experts' opinion, villages were selected under three technologies viz. IPM, conventional and mix of both technologies. The list of farmers following IPM and mix of both technologies was collected from CIPMC, Sri Ganganagar and lists of farmers following conventional technology were collected from respective *gram panchayats*. The sample size for the study was 90. The selection of farmers was based on probability proportional to size (PPS) method on the basis of their land holdings from each village. The analysis was done by calculating returns over variable cost, benefit-cost ratio and resource use efficiency of data collected from the field.
Results: The total variable costs for the cultivation of cotton per hectare are ₹ 48001.78, ₹

49105.66 and ₹ 48441.93 for the farmers following IPM, conventional and the mix of both technologies, respectively. The benefit to cost ratio in IPM was found to be the highest i.e. 2.23, whereas in mix of both technology the B: C ratio was 2.04, followed by the B: C ratio of 1.85 in case of conventional technology. The estimation of resource use efficiency in cotton indicated the under-utilization of human labour in case of IPM and mix of both technologies and over-utilization of machine labour in case of conventional and IPM technology.

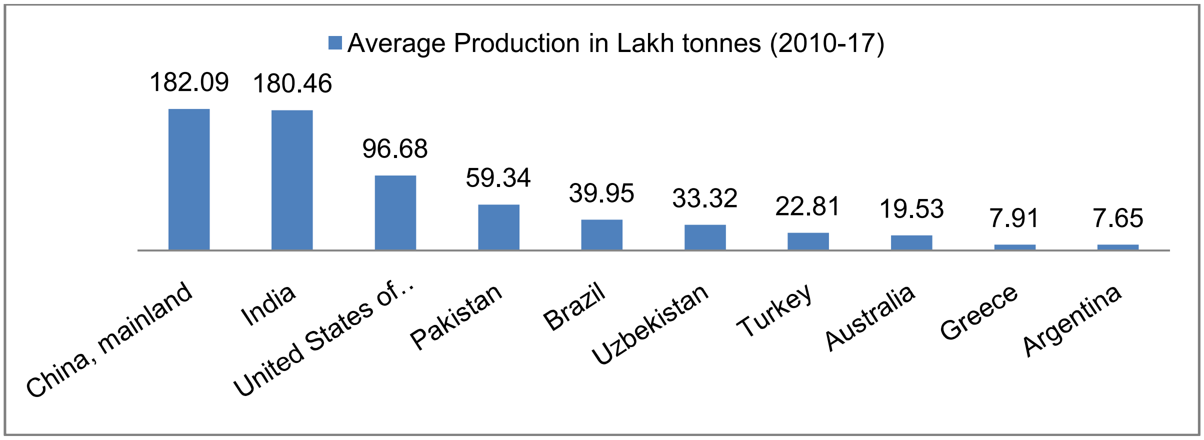
Conclusion: The IPM technology was found to be economical for the farmers growing cotton in the study area. The resources like human labour, machine labour, fertilizers and manure as well as plant protection measures, were suggested to be effectively utilized for better cost effectiveness among the farmers in the study area.

Keywords: Integrated Pest Management, Cotton, Economics, Efficiency, Rajasthan, India

1. INTRODUCTION

The demand for Integrated Pest Management (IPM) technology in the world has been valued at USD 91.8 billion in 2016, which is expected to grow at a compound annual growth rate (CAGR) of 5.8 per cent, valued at USD 151 billion by 2025. With an anticipated CAGR of 6.4 per cent from 2017 to 2025, the Asia pacific region is expected to witness the fastest growth in IPM technology. Few multi-national companies like Badische Anilin und Soda Fabrik (BASF), Advanced IPM, IPM Services, Société Générale de Surveillance (SGS), MB Integrated Pest Control, Bayer Crop Science, Ecolab Incorporated, IPM Technologies Proprietary Limited, and Integrated Pest Management Solutions India Private Limited are the major market players in IPM industry [11]. Agriculture plays a crucial role in ensuring security to India's economy and this situation is unlikely to change in the future also. India could remain the world's most populous country with nearly 1.5 billion inhabitants, followed by China with just under 1.1 billion, Nigeria with 733 million, the United States with 434 million, and Pakistan with 403 million inhabitants by 2050 [14]. As per the Land Use Statistics 2014-15, the total geographical area of the country is 328.7 million hectares, of which 140.1 million hectares is the reported net sown area and 198.4 million hectares is the gross cropped area with a cropping intensity of 142 per cent. The net sown area works out to 43 per cent of the total geographical area. The net irrigated area is 68.4 million hectares. Agriculture accounts for 16.5 per cent of the country's Gross Value Added (GVA) for the year 2019-20 at current prices [2]. The agricultural productivity has to be doubled by minimizing cost of production to meet growing demands of the population by 2050. Farmers' cumulative loss in 2000–2016 for not getting rightful price for produce was ₹45 lakh crore. Between 2004 and 2014, the average earning of an agricultural household per month was ₹214 and expenditure ₹207 [8]. The consumption of pesticide in India was 59,670 Metric Tonnes (MT) during 2018–19 and increasing with a CAGR of 2.3 per cent during 2014–2019. Maharashtra and Uttar Pradesh have the maximum share of pesticide consumption among all states of India, with five years average of 12,228 metric tonnes and 10,536 metric tonnes, respectively during 2014–2019.
Cotton is an international crop grown by about 80 countries across the world. On an average, cotton was planted in an area of 328.62 lakh hectares during 2010–2017. India competes with China and ranks second in cotton production during the period as can be observed from the Figure 1.

Fig 1. Major countries in cotton production



Source: http://www.fao.org/faostat/en/#data/QC/visualize retrieved as on 20.01.2020

Cotton is the major fiber crop grown in India and plays a dominant role in agricultural and industrial sectors. Cotton contributes to 70 per cent of total fiber consumption in textile sector and 38 per cent of the country's export, fetching over ₹42,000 crore. The area and production of cotton during the year 2018–19 was 12 million hectare and 362 lakh bales (170 kg of each bale), respectively [6]. It can be observed from Table 1 that major cotton producing states are Gujarat followed by Maharashtra, Telangana, Madhya Pradesh, Andhra Pradesh, Rajasthan and others.

Table 1 Triennial average of area, production and yield of cotton of major states in India (2015–16 to 2017–18*)

States	Area (million hectares)	Production (million bales)	Yield (kg/ha)
Gujarat	2.57	10.21	672.67
Maharashtra	4.07	8.22	347.67
Telangana	1.69	3.95	397.67
Madhya Pradesh	0.59	1.91	551.00
Andhra Pradesh	0.59	1.83	527.67
Haryana	0.62	1.55	432.00
Rajasthan	0.50	1.50	506.00
Karnataka	0.56	1.41	419.67
Punjab	0.31	1.02	580.33
All India	11.85	32.49	468.00

Note: 1 Bale: 170 kg
**4th Advance Estimates*
Source: DES (2019) cotton - Major States. *Agricultural Statistics at a Glance 2018, retrieved as on 20.01.2020*

Rajasthan, with its diverse agro-climatic conditions, is richly endowed with the cultivation of a variety of crops and a strong animal husbandry sector. Agriculture in Rajasthan continues to be the backbone of the state's economy. Among 10 agro-climatic zones, Zone Ib is known as Irrigated North Western Plain region. Due to abundance of canal water irrigation, Zone Ib has today become the granary of Rajasthan. The total production as well as productivity level of all crops is relatively higher in this zone as compared to other parts of the state. It can be seen from Table 2 that, cotton is a major crop of Zone Ib in *Kharif* season. Zone Ib, comprising of two districts namely, Sri Ganganagar and Hanumangarh, covers a major area under cotton cultivation.

Table 2 Status of Zone Ib in agriculture of Rajasthan

Zone (Area)	Total area (million ha)	Districts Covered	Average Rainfall in millimeter	Temp (^{0}C)		Major Crops	
				Max	Min	*Kharif*	*Rabi*
Ib	2.10	Sri-Ganganagar, Hanumangarh	100–350	42.0	4.7	Cotton, Cluster-bean	Wheat, Mustard, Gram

Source: https://agriculture.rajasthan.gov.in/content/agriculture/en/Agriculture-Department-dep/Departmental-Introduction/Agro-Climatic-Zones.html retrieved as on 20.01.2020

Cotton is mostly harvested in northern Rajasthan. In the Ganganagar region, which comprises of Sri Ganganagar and Hanumangarh districts of Rajasthan, cotton is sown on an average of 2.386 lakh hectares with highest average production of 7.44 lakh bales, as shown in Table 3. Bt cotton has also been considered as an essential element of IPM technology. Due to the success rate of Bt cotton, the trend of Bt cotton cultivation is increasing.

Table 3 Cotton in Rajasthan region wise (average last five years ending 2016–17)

Regions	Area (lakh ha)	Regions	Production (lakh bales)
Ganganagar Region	**2.386**	**Ganganagar Region**	**7.440**
Bhilwara Region	0.608	Bhilwara Region	1.921
Sikar Region	0.550	Sikar Region	1.622
Jodhpur Region	0.365	Jodhpur Region	1.270
Bharatpur Region	0.267	Bharatpur Region	0.743
Jaipur Region	0.163	Jaipur Region	0.468
Udaipur Region	0.154	Jalore Region	0.403
Jalore Region	0.132	Udaipur Region	0.318
Bikaner Region	0.016	Bikaner Region	0.044
Kota Region	0.001	Kota Region	0.003
State	4.643	State	14.233

Note: 1 bale: 170 kilograms
Source: DOA (2019) Rajasthan Agricultural Statistics at a Glance 2017-18, Department of Agriculture, Rajasthan, retrieved as on 20.01.2020

The studies regarding cost and returns of cotton grown under different methods in different parts of India showed that IPM has always given higher returns as compared to Non-IPM practices. A study was conducted on the comparison between the IPM module developed by researchers and the recommended package of practices (RPP) on Bt cotton (RCH 134), at farmers' fields in Sirsa district of Haryana, during 2008 and 2009. The seed cotton yield (11.90 q/ha in IPM and 11.47 q/ha in RPP) and the cost benefit ratio (1:4.29 in IPM and 1:3.75 in RPP) were also noted to be higher in IPM, with reduction in the usage of insecticides to about 38 per cent (4.0 sprays In IPM and 6.5 in RPP) [5]. A comparative analysis was made between transgenic Bt cotton grown, under integrated pest management module, during 2007-08 and 2008-09 at Dharwad with that of Bt cotton grown under recommended plant protection practices and non-Bt grown under integrated pest management. Higher net returns were obtained from integrated pest management in Bt cotton, as compared to recommended plant protection in Bt cotton (₹67676 and ₹55403/ha) and integrated pest management for non-Bt (₹61155 and ₹43633/ha) also, for both consecutive seasons [9]. Under the front line demonstration of integrated pest management in cotton during 2008-09 to 2010-11 in two villages of Karimnagar district of Andhra Pradesh, IPM practices was found to be highly effective in managing aphids, spodoptera and mealy bugs, with better activity of beneficial insects in IPM fields, higher seed cotton yield (16.6 per cent), higher net returns (₹ 54217/ha in IPM, ₹ 40488/ha in non-IPM fields) and benefit to cost ratio (2.69 in IPM and 2.15 in non-IPM fields [3]. A research was conducted on the role of frontline training and demonstrations in augmenting yield of cotton as well as income of the people in tribal areas through integrated pest management and it was discovered that IPM led to higher returns and higher benefit to cost ratio [7]. During a study on impact of integrated pest management practices on pest complex and economics in Bt cotton in Sirsa district of Haryana, it was found that, there was reduction of pesticide sprays by 37.5 per cent in IPM when compared to non IPM practices. The IPM was accompanied with utilisation of recommended doses of pesticides in contrast to over utilization in non IPM fields. The IPM fields showed higher population of natural predators/plant (*Chrysoperla carnae*, spiders and coccinellids) with values of (1.14, 2.54 and 0.91, respectively) in comparison to non IPM programme (0.93, 2.34 and 0.74, respectively). The farms where IPM practices had not been implemented, showed higher cost of spray and cost of production (₹/ha) i.e. ₹ 5150 and 25466, respectively, when compared with IPM fields (₹ 3333 and 24583), the cost to benefit ratio of IPM fields and non IPM fields were 1:2.83 and 1:2.44, respectively. The farmers adopting IPM had an advantage of additional profit of ₹ 8083/ha over non IPM fields [12]. Studies were conducted in the Nagarkurnool district of Telangana, where front line demonstrations were organised by Krishi Vigyan Kendra (KVK), Palem in ten various locations from 2016 to 2018 for promotion and increasing farmers' knowledge of IPM in Bt cotton. The results from the frontline demonstration on IPM in Bt cotton indicated, better average three year yield (20.38 q/ha), better average cost to benefit ratio (1:1.33) and net returns (₹ 24691) as compared to farmers' practices (average yield: 18.33q/ha, average cost to benefit ratio: 1:1.09 and net returns: ₹ 7682). Due to the adoption of IPM module, the number of pesticidal sprays was reported to be reduced by five times, resulting in savings of about ₹ 6000 [10].

In case of resource use efficiency of cotton cultivation, array of studies have been made. The resource use efficiency of small Bt cotton farmers of Punjab province, Pakistan, was examined by adopting the production function approach, where 150 Bt cotton farmers selected randomly through multistage sampling procedure were categorized into large, medium and small scale farmers. The average size of the farm possessed by the small farmers was 5 acres. From the regression analysis, the variables like fertilizer, number of sprays, irrigation acre-inches and labour cost were found to have major impact on Bt cotton production, whereas farm size showed no significant impact on production. The efficiency ratios i.e. MVP/MFC for inputs like fertilizer (Kg), labour cost (₹), irrigation (acre-inch) and number of sprays determined through resource use efficiency analysis were found to be 1.5, 1.27, 3.01, and 3.94, respectively. In case of small Bt farmers, the efficiency ratios were greater than unity, which signified under-utilization of production inputs, whereas production of Bt cotton had higher returns to scale, with elasticity of production valued at 1.27 [1]. A research was conducted in Haveri district of Karnataka to determine the resource use efficiency in Bt and non Bt cotton cultivation in that area. The outcomes of the study revealed that, the variables like fertilizers, seeds, human labour in case of Bt cotton, and variables like human labour and seeds in case of non-Bt cotton, gave significant regression coefficients, which indicated an increase in gross returns with the increase in value of the variables, whereas negative regression coefficients of plant protection chemicals in both Bt and non-Bt cotton indicated its insignificant economic importance. The results indicated that, 77 for every rupee expenditure on pesticides, there was a probability of ₹ 6.81 increase in gross returns of Bt cotton growers, in comparison to ₹ 1.29 for non-Bt cotton growers. In case of variables like seeds, machine labour, bullock labour, organic manure, seeds and human labour, the allocative efficiency was found to be higher than one, for both Bt and non-Bt cotton, denoting under utilization of resources in both cases [4]. For evaluating the resource use efficiency of Bt cotton in Hanumangarh district of Rajasthan, Cobb Douglas production

function was applied to determine the degree of utilization of various resource inputs involved in the cultivation of Bt cotton in that area. The various factors / resource inputs involved in the study were human labour, machine labour, seed, irrigation, plant protection chemicals, manure and fertilizer. From the findings of the study, the marginal value productivity (MVP) to marginal factor cost (MFC) ratio for human labour (1.44), irrigation (1.88), machine labour (5.07), and seed (12.76) were found to be more than unity [13]. This indicated under-utilization of these resources with potential scope for increasing the use of the resources, which could lead to benefits in gross income. So it was inferred that, cultivation and production of Bt cotton could be improved by optimum utilization of all the resources and by adopting new and improved technologies.
Cotton being the prime crop of the Zone Ib for *Kharif* season, its sustainability is a matter of concern for the study area. The problem of pest resistance has compelled the farmers to use more of pesticides in cotton crops and has led to the over reliance of conventional farmers on chemical pesticides. This research has made an attempt to uncover the production opportunities of IPM produces in the study area so that all stakeholders involved in the sustainable agriculture can be benefited. An effort has been made to study the resource use efficiency and cost and returns of cotton crops grown under different methods followed in the study area.

2. MATERIAL AND METHODS

For the study, the farmers were the respondents. Multistage stratified random sampling was followed for the research. Sri Ganganagar and Hanumangarh district of Irrigated North Western Plain Zone (Zone Ib) were purposively selected. Based on experts' opinion, villages were selected under three technologies viz. IPM, conventional and mix of both technologies for both the crops. The lists of farmers following IPM and mix of both technologies were collected from CIPMC, Sri Ganganagar and lists of farmers following conventional technology were collected from respective *gram panchayats*. The selection of farmers was based on probability proportional to size (PPS) method on the basis of their land holdings from each village (small: upto 2 hectare, medium: > 2 ≤ 4 hectare and large: > 4 hectare). Intermediaries were selected on the basis of experts' opinion and consumers were selected based on the researcher's convenience. Total number of respondents was 310 for two districts of Zone Ib and the sample comprised of 90 farmers (15 for each of the three categories of technology followed by cotton growers from each of the two districts). For collection of data based on the review of literature, schedules containing both open and closed ended questions were formed for farmers. Statistical tools used for the study are discussed as follows:

2.1 Net Return over Variable Cost

For the purpose of the study, only variable cost was considered. Net return over variable cost is the surplus after subtracting all the cost.
Net Return over variable cost = Gross return over variable cost per hectare - Total variable cost per hectare

2.2 Benefit-Cost Ratio

A Benefit–Cost Ratio (BCR) is an indicator that attempts to summarize the overall value for money of cultivating a particular crop. The higher the BCR is, the better the result.

$$\mathbf{BCR} = \frac{\mathbf{Gross\ Returns\ per\ hectare}}{\mathbf{Total\ Cost\ per\ hectare}}$$

Gross return per hectare was calculated over the variable cost. For total cost, variable cost per hectare was considered for the study.

2.3 Resource Use Efficiency

The Cobb-Douglas function was used to determine the resource use efficiency of farmers following different practices viz. IPM, conventional and mix of both practices. The form of Cobb-Douglas function used in the present study is as follows:

$$\mathbf{Y = \alpha . X_1^{\beta 1} . X_2^{\beta 2} . X_3^{\beta 3} . X_4^{\beta 4} . X_5^{\beta 5} . e_i}$$

Where, Y= Gross returns (₹/ha), α= Intercept, X_1= Expenditure on human labour (₹/ha), X_2= Expenditure on machine labour (₹/ha), X_3= Expenditure on seeds (₹/ha), X_4= Expenditure on fertiliser and manure (₹/ha), X_5= Expenditure on plant protection measures (₹/ha), e_i= Error term, β_{is}= Elasticities of respective factor inputs, i= 1, 2, …,5.

Expenditure on irrigation was not included as the study area was found to be irrigated by canals at free of cost. Cobb-Douglas production function was converted into log linear form and β values were estimated by employing Ordinary Least Square (OLS) method is given below:

$$\mathbf{Log\ Y = log\alpha + \beta_1 logX_1 + \beta_2 logX_2 + \beta_3 logX_3 + \beta_4 logX_4 + \beta_5 logX_5 + loge_i}$$

The regression coefficients, their significance, standard error, and coefficient of multiple determination (R^2) were worked out. Marginal Value Productivity (MVP) was worked out for each significant input. Given the technology, it is required to calculate the proper level of input use in production. To decide whether a particular input is used rationally or irrationally, its marginal value product was computed. If the marginal value product of an input just covers its acquisition cost it is said to be used efficiently.

The MVP was calculated at the geometric mean levels of variables by using the formula.

$$MVP_{Xi=}\ \beta_i \frac{\overline{Y}}{\overline{X_i}}$$

Where, MVP= Marginal Value Product, β_i= Regression coefficient of i^{th} independent variable, $\overline{Y}$= Geometric mean of the gross income, $\overline{X_i}$= Geometric mean of i^{th} independent variable, viz. expenditure on human labour, machine labour, seed, fertiliser and manure and plant protection measures.

In order to determine the resource use efficiency, the marginal value product (MVP) is divided by the marginal factor cost (MFC) which in this case is equal to unity as actual values of expenditure are taken into consideration. The criterion for determining optimality of resource used was,

MVP/MFP > 1: Under utilization of resource

MVP/MFP = 1: Optimal utilization of resource

MVP/MFP < 1: Over utilization of resource

3. RESULTS AND DISCUSSION

Cost and returns are part of the economics which deal with the cost of cultivation and returns of the production. Cost of cultivation comprises of cost of human labour, machine hours, seed, irrigation, micro and macro nutrients, plant protection chemicals, and others. Also, the efficiency of various inputs used in the crop is also considered to be essential in economic analysis. This research under reference took variable cost into account, which is meant by the cost, utilized in one time production process. In this objective, cost of cultivation, returns over variable cost, benefit to cost ratio and resource use efficiency have been measured for cotton.

Cost and returns analysis was done to determine and compare the profitability of cotton farmers. The aim of analyzing costs and returns was to determine the amount of profit earned by cotton farmers with the followed technology and investment. Resource use efficiency was further analyzed to have a clear picture about the efficiency of farm inputs and labour used in cotton. For cotton, the cost of human labour was analyzed by taking the prevailing wage rate in the study area (₹300.00 per man day). Machine labour was also calculated on hourly basis based on prevailing rate in the study area (₹200 per machine hour). The cost of seed was based on the fixed government rate for the crop year 2017-18. The cost of fertilizers, (excluding urea; ₹266 per 50 kg bag for the crop year 2017-18), manures and plant protection chemicals (including the cost of chemical as well as biological insecticides and other IPM inputs like traps, etc.) for cotton were based on the actual cost incurred by the farmers in the study area. There is no cost of irrigation, as the villages under the study area were found to be irrigated by canal. Interest on working capital was calculated on the basis of rate fixed by the local money lenders (12 per cent) for half of the crop period (3 months). Gross return was obtained by adding the total income received from the main product and by products per hectare. For calculation of total cost, only variable cost per hectare was considered for analysis. Return over variable cost per hectare was obtained by deducting total variable cost from the gross returns per hectare. B:C ratio was evaluated as gross income divided by variable cost per hectare. The tabular representation of the pertaining data is shown as follows:

Table 4 Cost and returns in cotton

Particulars	Per hectare			
	IPM N=30	**Conventional N= 30**	**Mix of both N= 30**	**Overall N= 90**
Human labour (Family and hired) (₹)	23213.17 (48.36)	18625.77 (37.93)	20615.33 (42.56)	20818.09 (42.91)
Machine labour (₹)	7975.97 (16.62)	8866.97 (18.06)	8874.13 (18.32)	8572.36 (17.67)
Seed (₹)	2960.00 (6.17)	2960.00 (6.03)	2960.00 (6.11)	2960.00 (6.10)
Fertilizer and manure (₹)	8539.90 (17.79)	9247.53 (18.83)	9016.70 (18.61)	8934.71 (18.42)
Plant protection measures (₹)	3914.63 (8.16)	7975.13 (16.24)	5564.83 (11.49)	5818.20 (11.99)
Interest on working capital (Half of the crop period) (₹)	1398.11 (2.91)	1430.26 (2.91)	1410.93 (2.91)	1413.10 (2.91)
Total average variable cost (₹)	48001.78 (100.00)	49105.66 (100.00)	48441.93 (100.00)	48516.46 (100.00)
Cotton yield (q)	26.13	22.04	24.11	24.09
By products yield (q)	23.10	23.87	23.33	23.43
Gross returns (₹)	106863.53	90732.60	98784.37	98793.50
Returns over variable cost (₹)	58861.76	41626.94	50298.07	50277.04
BC ratio	2.23	1.85	2.04	2.04

Figures in parentheses indicate the respective percentage to the total variable cost
Human labour cost at ₹300 per man-day, Machine labour cost at ₹200 per hour
Source: Researcher's computation from field data

It can be observed from Table 4 that in IPM method of cultivation, human labour acquires the highest share of variable cost i.e. ₹ 23213.17 (48.36 per cent) followed by the cost of fertilizer and manure i.e. ₹ 8539.90 (17.79 per cent), cost of machine labour i.e. ₹7975.97 (16.62 per cent), the cost of plant protection measures ₹ 3914.63 (8.16 per cent), the cost of seed i.e. ₹ 2960 (6.17 per cent) and the interest on working capital i.e. ₹ 1398.11 (2.91 per cent). In conventional method of cultivation, the cost of human labour i.e. ₹ 18625.77 (37.93 per cent) has been found to acquire the highest share of variable cost followed by the cost of fertilizer and manure i.e. ₹ 9247.53 (18.83 per cent), the cost of machine labour i.e. ₹ 8866.97 (18.06 per cent), the cost of plant protection measures i.e. ₹7975.13 (16.24 per cent), the cost of seed ₹ 2960 (6.03 per cent) and the interest on working capital i.e. ₹ 1430.26 (2.91 per cent). Likewise in mix of both technology category, highest share in variable cost is contributed by the cost of human labour i.e. ₹ 20615.33 (42.56 per cent), followed by the cost of fertilizer and manure i.e. ₹ 9016.70 (18.61 per cent), the cost of machine labour i.e. ₹ 8874.13 (18.32 per cent), the cost of plant protection measures i.e. ₹ 5564.83 (11.49 per cent), the cost of seed i.e. ₹ 2960 (6.11 per cent) and the interest on working capital i.e. ₹ 1410.93 (2.91 per cent).

The total variable costs for the cultivation of cotton per hectare are ₹ 48001.78, ₹ 49105.66 and ₹ 48441.93 for the farmers following IPM, conventional and the mix of both technologies, respectively. The yield of cotton was found to be more in case of farmers following IPM technology which was 26.13 compared to 22.04 in conventional method and 24.11 in mix of both technologies. The gross returns was found to be 106863.53 under IPM technology, 90732.60 under conventional method and 98784.37 under mix of both technologies. The returns over variable cost under IPM technology in cotton was 58861.76, compared to 41626.94 under conventional method and 50298.07 under mix of both technologies for cotton crops. The benefit to cost ratio in IPM was found to be the highest i.e. 2.23, whereas in mix of both technology the B: C ratio was 2.04, followed by the B: C ratio of 1.85 in case of conventional technology. It can also be observed that on an average, the overall cost of cultivation for cotton including all the three methods of pest contro is ₹ 48516.46 per hectare, out of which the cost of human labour i.e. ₹ 20818.09 (42.91 per cent) has the maximum share in the cost of cultivation, followed the cost of fertilizer and manure i.e. ₹ 8934.71 (18.42 per cent), the cost of machine labour i.e. ₹ 8572.36 (17.67 per cent) , the cost of plant protection measures i.e. ₹ 5818.20 (11.99 per cent), the cost of seed 2960 (6.10 per cent) and the interest on working capital of ₹ 1413.10 (2.91 per cent).

The cost and returns in cotton indicate that the IPM technology in cotton is economical, with low cost of cultivation and higher returns over the variable cost. The benefit to cost ratio is also highest under IPM technology in cotton. As in the present context; there is high requirement of inputs like machine labour, fertilizers, pesticides, etc. for the increasing yield, identifying the inputs that are efficiently used, is a matter of concern. Therefore, it has become very essential to know about resource use efficiency to evaluate the efficiency of farm inputs. For resource use efficiency, Cobb-Douglas function was applied to find out the coefficients of the variables. With the help of such model, the ratio of marginal value product (MVP) and marginal factor product (MFP) was calculated. MVPs were calculated at geometric levels. MFP for all these inputs are same as unity because all input and output values have been taken in monetary terms. Variables with significant ‘P’ values were selected for analysis. The resource use efficiency for cotton is presented in Table 5 as follows:

Table 5 Resource use efficiency in cotton

	Particulars	Coefficient	t value	MVP/MFP
IPM	Intercept	3.54 (1.33)	2.65*	
	Human labour	0.54 (0.24)	2.25*	2.47
	Machine labour	-0.22 (0.08)	-2.62*	-2.92
	$R^2 = 0.77$			
Conventional	**Particulars**	**Coefficient**	**t value**	**MVP/MFP**
	Intercept	6.47 (0.14)	45.94**	
	Machine labour	-0.38 (0.04)	-10.74**	-3.92

	Particulars	Coefficient	t value	MVP/MFP
	R^2 = 0.80			
Mix of both	**Particulars**	**Coefficient**	**t value**	**MVP/MFP**
	Intercept	1.32 (0.39)	3.43**	
	Human labour	0.85 (0.09)	9.51**	4.08
	R^2 = 0.76			

MVP: Marginal Value Product and MFP: Marginal Factor Product
Figures in parentheses indicate the respective standard errors
**Significant at five per cent level of probability*
***Significant at one per cent level of probability*
Source: Researcher's computation from field data

Variables having significant '*P*' values of maximum 5 per cent level of probability were selected for analysis. Stepwise regression was followed to filter out the non significant variables. The values of R^2 (coefficient of multiple determination) indicated that 77, 80 and 76 per cent of the variation in the income of cotton production was explained by variables included in the model for IPM, conventional and mix of both technologies followed by farmers, respectively. As seen in Table 5, in case of IPM, additional rupee invested in human labour would bring additional return of ₹ 2.47, suggesting that there is further scope for increasing the usage of this variable to attain optimization of resources. For farmers following IPM technology in the study area, it is not advisable to invest more on machine labour as its MVP value is coming negative (-2.92). Seed, fertilizer and manure and plant protection measures, in case of IPM practice, showed a non-significant '*P*' value and were discarded through the stepwise linear regression. In the conventional practice, it is not advisable to invest more in machine labour as its MVP value is also coming negative (-3.92). Other variables like human labour, seed, fertilizer and manure and plant protection measures were found non-significant in step wise regression analysis. In case of mix of both technologies, data showed that an additional rupee invested in human labour, will result in an additional return of ₹ 4.08, suggesting its high scope for its use to increase returns. In mix of both technologies, variables like machine labour, seed, fertilizer and manure and plant protection measures were non-significant for the analysis. Machine labour in both IPM and conventional method of cultivation showed negative MVP value, indicating overutilization of the resource. Therefore, it may be suggested that identified available resources should be optimally used for higher profitability.

4. CONCLUSION

The economic analysis of aspects like total variable cost, gross returns, yield and B:C ratio revealed IPM as comparatively more cost efficient and profitable technology, in comparison to farmers following conventional and mix of both technologies in cotton. The total average variable cost of cotton in case of IPM farmers was valued at ₹ 48001.78, which was less compared to that of farmers following conventional (₹ 49105.66) and mix of both technologies (₹ 48441.93). Out of the three technologies, IPM farmers received the highest yield of 26.13 quintals and highest gross returns of ₹ 106863.53 per hectare, as compared to the other two technologies. The benefit-cost ratio was 2.23 in case of IPM, whereas in case of conventional farmers, it was 1.85 and for mix of both technologies, it was 2.04. The Cobb-Douglas function was used to estimate the resource use efficiency of cotton cultivation, which revealed the over-utilization of machine labour with MVP/MFP value of -2.92 and -3.92 in case of IPM and conventional technology, respectively. In case of IPM (MVP/MFP: 2.47) and mix of both technologies (MVP/MFP: 4.08), human labour was under-utilized. Therefore from the results, it can be suggested to ensure effective utilization of the identified available inputs as some inputs have further scope of utilization to attain optimum benefits.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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