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Impact of Integrated Pest Management Technology Input and Yield Disparities on Cotton Crop in Vidarbha Region of Maharashtra: Principal Component Approach

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cotton is a significant crop that is farmed commercially, mostly in the Vidarbha region. It is planted with a focus on controlling insects and pests. In light of this notion, a study was conducted with the primary objectives of ascertaining the degree of adoption of recommended technology in cotton production, analyzing cotton's input utilization at different IPM adoption levels, and estimating the input and yield gap of cotton at different IPM adoption levels. The current study was conducted in the districts of Akola and Buldhana in the Vidarbha region of Maharashtra State, India. The primary data, which cover the years 2022–2023, were gathered using a straight forward random sample technique. Out of the 120 farmers which were surveyed for IPM adoption technology, 19 were classified as high adopters, meaning their percentage of technology adoption was above 78.11; 79 were classified as medium adopters, meaning their percentage of technology adoption was between 63.35 and 78.11; and 22 were classified as low adopters, meaning their percentage was below 63.34 percentage. The group with a high adoption level used the greatest amount of human labor as a result of input utilization. The highest use of farmyard manure is seen in the high adopter group (30.68 quintals per hectare), which is followed by the medium and low adopter groups (16.80 quintals per hectare and 14.05 quintals per hectare). With a yield per hectare of 16.64 quintals, the high adopter group had the highest yield, followed by the medium adopter group at 14.01 quintals, and the low adopter group at 12.71 quintals. In comparison to the yield gap in the low adopter group, a total of 2.29 quintals yield per hectare was discovered in the medium adopter group, 0.99 quintals per hectare in the high adopter group, and 1.64 quintals per hectare in the low adopter group. Thus, it was observed and proposed that the group with a high adoption level had the highest degree of adoption across all technologies as a result of this experiment. Moreover, there was very little use of trichograma, FYM, light, Pheroman, and yellow sticky traps among low adopter groups.

Keywords: IPM; principal component analysis; input gap; yield gap; composite index extent of adoption.

1. INTRODUCTION

The first IPM (Integrated Pest Management) initiative in India was the Operational Research Project (ORP), which was implemented in rice and cotton between 1974 and 1975 [1]. Promoting and assisting safe, efficient and environmentally responsible pest management is the primary goal of Integrated Pest Management Programme There are over 130 different kinds of insect pests that affect Indian cotton, and 12 of these arthropods need to be managed in order to increase cotton output.

Due to their propensity to multiply quickly and extensively within cotton plants, sucking pests such as aphids, jassids, whiteflies, and thrips are detrimental to the growth and development of cotton. While the early-season sucking pests' direct effects are seen as reduced production and poor crop stand, their late-season attacks—particularly those of aphids and whiteflies—indirectly lower the quality of cotton fiber by depositing honey dew on lint [2-4]. The bollworm complex, which is made up of the three genera of pink, American, and spotted bollworms, damages cotton crops during their reproductive period. The pests like, aphids (*Aphis gossypii*), and thrips (*Thrips tabaci* Lind) also cause economic loss to the crop. As a consequence of this, insecticide usage which had declined from Rs. 26223 million in 2002 to Rs. 24388 million in 2005, increased to Rs. 76836 million by 2010 [5]. Two key components make up a sustainable cotton production system, of which IPM is one consists of a number of actions that assist in preventing insect pests from reaching economic threshold levels (ETL). In addition to biological control and the use of botanicals, these control strategies also involve the use of natural control agents, host plant resistance, and the modification of agronomic variables such rotation, spacing, sowing time, and fertilizer inputs. Integrated Pest Management is a pest management system hat in the content of the associated environment and the pest population dynamics of the pest species [6,7,8]. Utilize all suitable techniques and methods in as compatible manner as possible and maintain the pest population at the level below these causing economic injury. This approach has been maintaining the agro-ecosystem [9-12]. It has more relevant due to advantage like safely to environment, pesticide-free food commodities, low input based crop production. In consideration of these factors, the study was designed and carried out with particular goals in mind: determining the degree of adoption of suggested technology in cotton production; examining the input utilization in cotton at varying IPM technology adoption levels; and estimating the input and yield gap in cotton at varying IPM technology adoption levels.

2. METHODOLOGY

In the study on the effects of input and yield gaps of IPM technology on cotton production, which was suggested by Dr. PDKV, Akola, Maharashtra, India. The suggested technologies were taken into consideration after consulting with the cotton research unit and entomologists.

The Vidarbha region's Akola and Buldhana districts hosted the study. Primary data and cotton area cultivation form the basis of this study. Using the basic random sample technique, seven villages—Khambora, Madala, Kinkhed Pruna, Rambhpur, Sangrampur, Khiroda, and Varvat Khanderao—were chosen from the three tahsils, Akola, Akot, and Sangrampur based on the area under cotton cultivation. To gather the necessary data, a total of 120 cotton growers were chosen from the above cultivated areas of the three distrcts in the year 2022–2023.

Recommended IPM Technologies for Cotton by Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India are as follows.

List 1. Detail list of recommended technologies on Cotton crop by Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

Technology	Units	Recommendation
A. Cultural Control		
Grazing animals (Sheep,Goat etc)		End Dec. to Jan.
Ploughing		1
Burning of plat debris & Cleaning Campaign		Yes/No
Sowing time		Second week of June to First week of July
Resistant variety		PKV 5 PKV Suvarna, AKH 8828,
Seed rate	kg/ha	2.00 to 2.50 kg/ha
FYM	ql/ha	50 q/ha
Fertilizer		
N	kg/ha	60
P	kg/ha	30
K	kg/ha	30
Crop Rotation		Cotton – Soybean – Gram Cotton – Mung – Safflower Cotton – Udid – Safflower Cotton – Jowar – Gram
Inter cropping		Cotton +Mug/Udid(1:1) Cotton + Jowar + tur + Jowar(3:1:1:1) Cotton + Tur(8 to 10:1)
B. Mechanical Control		
Use of Proper Spacing between plant		90 x 45, 60 x 30 & 60 x 45
Removal of Rosette flower and removal of infested plant parts		Remove and destroy the pest affected plant/plant parts at the beginning when the infestation is very high.
Use Pheromone trap/Light trap/Yellow Sticky trap	Per/ha	P.T.: 4 per ha Y,S.T.: 25 per ha. L.T.: 1 per ha.
Installation of Bird perches	Per/ha	10-12 per ha
C. Biological control		
Use of Biological Sprey		Spray of NSE 5% or Azadirachtin formulation
Use of Trichogramma Card		40-50 DAS
D. Chemical Control		
Use of Pesticide		Ethion, Quinalphos, Fipronil, Chorpyrifos, Acephate etc. Combination of Insecticide

Source: Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi vidyapeeth, Akola, Maharashtra

2.1 Analytical Techniques

The extent of technology adoption, input utilization, input gap, and yield gap at various levels of IPM technology adoption were all considered in the Impact Assessment of Integrated Pest Management on Cotton Production technique suggested by Dr. PDKV, Akola.

2.1.1 To assess the extent of adoption of selected technologies

For the first objective of the study, the extent of adoption of technologies of Cotton crop following formulae was used,

$$\text{TAI} = \frac{1}{k}\left[\frac{AX_1}{RX_1} + \frac{AX_2}{RX_2} + \cdots + \frac{AX_K}{RX_K}\right] X\ 100$$

Where,
TAI = Technology Adoption Index
K = No. of technologies
AXi= Actual use of selected technology
RXi = Recommended use of selected technology.

For the purpose of creating a technological adoption index of technology adopted, the University's recommended primary components of technology for the cotton crop were expressed in terms of adoption scores (X1, X2, --------- Xn). The net adoption of all technology components with values ranging from 0 to 1 is represented by a single numerical number called the technological adoption index.

2.2 Development of Composite Index

To create a composite index of technology accepted, the University's suggested technology components for cotton crop were stated in terms of adoption scores (X1, X2,... X19). A composite index is a single number that represents the net adoption of all technology components with values between 0 and 1.

The process of creating the composite index involved the application of principle component analysis (PCA). The main components were calculated using a 19 x 19 co-relation matrix containing 19 technological components. A group of 19 fundamental elements that accounted for all of the variance in all of the suggested technology's components were taken into consideration.

Consider 19 eigen vectors in the form of 19 x 19 matrixes where rows represent variables and columns represent eigen vectors from which weight (wi) coefficient of component of technology say Σ was determined as under.

Wi = Mi / ΣMi

Where,

Wi = Weight
Mi = Maximum element in ith raw
ΣMi = Sum of maximum element in ith raw.

Cotton identified the components of the suggested technologies, and then the adoption level of each component by the farmer was stated in terms of adoption scores by the university, this information was then used to create a composite score for the adoption of the recommended technologies.

Using the following function, composite scores were calculated for each of the chosen farmers.

2.2.1 Development of composite Index (scores) of technology

The estimated composite adoption score (Si) is;

$$S_i = W_1X_1 + W_2X_2 + \text{-------------------} + W_{19}X_{19}$$

Where,

S_i = Composite Index of i^{th} farmers, X_1 = Grazing Animals, X_2 =Burning of Plant, debris and cleaning compaign,X_3= Ploughing,X_4= Sowing time,X_5 = Resistant variety,X_6 = Seed rate, X_7 =FYM,X_8 =Nitrogen,X_9 =Phosphorous,X_{10} = Potassium,X_{11}= Crop Rotation,X_{12}= Intercropping, X_{13} = Spacing between the plant,X_{14}= Removal of Rosette flower and removal of infested plant parts, X_{15} = Use of Phromane trap/Light trap/ Yellow sticky trap,X_{16} = Installation of Bird perches,X_{17} = Use of Trichhogamma card, X_{18} = Use of bio logical control, X_{19} = Use of pesticide, W_i = Use of weight given of i^{th} technology

Which provides adoption index (of all component of technologies) for each cultivators. The composite index obtained in the process lie in between 0 & 1.

The net adoption of recommended technologies expressed in terms of “Technological adoption Index” of the 120 farmers are classified as below.

Low adopter = Mean - SD

Medium adopter = Mean - SD to Mean + SD
High Adopter = Mean + SD

2.2.2 To study the input utilization at different level of adoption of IPM technology

The objective of the input utilization at different level of adoption of IPM technology were worked out by on the basis of level of adoption i.e. low, medium and high level of adoption of technologies.

2.2.3 To analyze the input gap and yield gap of Cotton at different level of adoption of IPM technology

Input Gap: Input Gap = Recommended Input - Actual Input used

1. Seed(Kg)
2. Organic Manures (qt)
3. Chemical Fertilizers N & P (kg)

Yield Gap: It was estimated by tabular method.

Yield gap I = Yp - Yd

Where,
Yp = Potential Yield
Yd = Demonstration yield
Yield gap II = Yd - Ya
Yd = Demonstration yield
Ya = Actual Yield
Total Yield gap I = Yp - Ya
Yp = Potential Yield
Ya = Actual Yield

3. RESULTS AND DISCUSSION

Appropriate approaches were employed to analyze the data with consideration for the study's aims. The study's findings have been presented and are subject to critical discussion.

3.1 Adoption Range of Different Adopter Group on the Basis of Composite Index

Table 1 displays the distribution of 120 farmers according to their level of adoption of suggested technology, as determined by the adoption index. The mean and standard deviation were used to estimate the technology adoption index for each recommended technology. Every technology was classified as having a low, medium, or high adoption level based on the calculated adoption levels.

Table 1 displays the distribution of farmers into low adoption group, with adoption index values less than 63.34 percent. Farmers in the medium group were those whose adoption index fell between 63.35 and 78.11 percent; farmers in the high level of adopters category were those whose composite adoption index was more than 78.11 percent. With a composite adoption index of between 63.35 and 78.11 percent, 79 farmers had a medium level of adoption, and 22 farmers had a low level of adoption, with a composite adoption index of less than 63.34 percent. Of the 120 farmers who were chosen, 19 farmers had a high level of adoption, exceeding 78.11 percent.

It is determined that over 88.37 percent represented the highest percentage of technology adoption. It indicates that some high adoption level categories y did not fully implement the suggested technology.

3.2 Extent of Adoption Technology

With the aid of suggested technologies created by Dr. P.D.K.V. Akola, the actual degree of adoption of each technology by farmers was determined. Every technology's efficiency was computed. Every efficiency score was reduced to a range of 0 to 1. Since the soil types of all the chosen farms were essentially the same, the suggestion about soil type was disregarded.

Table 2 shows that, of all the suggested technologies at every level, the use of resistant variety has been accepted at a rate of 100.00 percent for the IPM's cultural control technology. The recommended level—90.91%, 91.14%, and 100 percent for low, medium, and high adopter groups, respectively—was adhered to during the sowing period. Cotton growers utilized seed rates of 89.97%, 96.97%, and 99.47 percent in their respective categories.

Table 1. Adoption range of different adopter group in cotton

Particulars	Low adopter	Medium adopter	High adopter
Total number of farmers	120		
Adoption Range (%)	Below 63.34	63.35 to 78.11	Above 78.11
No. of farmers	22	79	19
Percentage to number of farmer	18.33	65.83	15.84

Table 2. Extent of adoption of technology

Particular	Extent of Adoption (%)		
	Low adopter (N = 22)	**Medium adopter (N = 79)**	**High adopter (N = 19)**
Cultural Practices			
Farm preparation (Grazing, Burning of Plant debris & Field Pre.)	86.36	93.67	94.74
Sowing time	90.91	91.14	100.00
Short & Medium duration variety	100.00	100.00	100.00
Seed Rate	100.00	100.00	100.00
FYM	25.37	33.61	38.01
Fertilizers			
N	111.48	109.70	104.43
P	140.60	136.16	136.58
K	139.55	115.85	112.51
Inter cropping	45.45	73.42	84.21
Crop Rotation	77.27	88.61	100.00
Mechanical Control			
Proper Spacing	86.36	91.14	94.74
Removal of Rosette flower and removal of infested plant parts	27.27	64.56	89.47
Use Pheromone trap/Light trap/Yellow Sticky trap	9.09	21.52	52.63
Installation of Bird perches	18.18	40.51	63.16
Biological Control			
Biological Spray	4.55	31.65	47.37
Use of Trichogramma Card	0.00	10.13	31.58
Chemical Control			
Use of Pesticide	100.00	72.15	57.89

When comparing the three adoption levels, it was found that none of the three categories had the recommended amounts of potassium, phosphorus, and nitrogen used. It indicates that farmers used fertilizers more frequently and at the recommended levels in all three categories. Farm yard manure application had the lowest adoption rates, with 25.37%, 33.61%, and 38.01 percent in the low, medium, and high adopter groups, respectively. Farmers only used FYM from their owned farms, which resulted in a low application rate.

The most often used mechanical IPM method in both high and medium adopter categories was the appropriate spacing and removal of rosette flowers as well as the removal of infected plant components. The biggest percentage of high adopters—52.63%—used pheromone traps, followed by medium and low adopters—21.52% and 9.09%, respectively.

Within the high adoption group, 78.95% of IPM technology has been implemented for biological control. when the biological control method is not applied to a low adopter group. It indicates that farmers were ignorant about biological control. Chemical control was applied 100% to the low adopter group, 72.15% to the middle adopter group, and 578.89% to the high adopter group.

The overall analysis found that the group with high adoption level had the highest adoption of all 18 technologies. Furthermore, the low adopter group uses relatively little of the following technologies: biological control, resistant variety use, trichoderma use, FYM, and sowing timing technology. It resulted from a lack of understanding of the significance and appropriate technology knowledge.

3.3 Input Utilization

The information about per hectare physical input used by selected farmer according to their adoption of recommended technology level is shown in Table 3.

Table 3. Input utilization at different level of adoption of IPM technology (Per hectare)

Input Utilization	Unit	Low adopter (N = 22)	Medium adopter (N = 79)	High adopter (N = 19)
Male Labour	Days	32.60	34.53	31.86
Female Labour	Days	73.59	75.17	81.34
Total HumanLabour	Days	106.19	109.70	113.20
Bullock Labour	Days	7.66	7.36	7.59
Machine Labour	hrs	24.21	27.54	32.09
Seed rate	kg/ha	2.34	2.30	2.26
FYM	q/ha	14.05	16.80	30.68
Fertilizer				
N	kg/ha	66.89	65.82	62.66
P	kg/ha	42.18	40.85	40.97
K	kg/ha	41.87	34.76	33.75

Table 3 showed that the group's small, medium, and high levels of labor utilization—106.19, 109.70, and 113.20 days, respectively—were observed per hectare. It was found that the group with the highest adoption level utilized the most human labor. In all three groups, the recommended per-ha seed rate of 2.00 kg to 2.50 kg per hectare was applied. It demonstrates that the seed rate was at the recommendation level for all three adoption levels.The group with the highest machinery charges, the high adopters, had 32.09 hours per hectare, whereas the medium adopters had 27.54 hours per hectare.

The maximum amount of farm yard manure—30.68 quintal per hectare—was used in the high adopter group. This was followed by medium adopters (16.80 qtl/ha) and low adopters (14.05 qtl/ha). The low adopter category demonstrates the minuscule use of FYM. Due to a scarcity of cattle, farmers only apply FYM on their owned farms, which explains the low application of FYM.

The nitrogen fertilizer application rates for the low, medium, and high adopter groups were, respectively, 66.89 kg/ha, 65.82 kg/ha, and 62.66 kg/ha. Additionally, 42.18 kg, 40.85 kg, and 40.97 kg of phosphorus per hectare were adopted for the low, medium, and high adopter groups, respectively. For the low, medium, and high adopter groups, respectively, 41.87 kg, 34.76 kg, and 33.35 kg of potassium fertilizer were applied per acre. The fertilizer application findings indicate that NPK was applied more frequently and at the acceptable level in each of the three categories.

3.4 Input Gap and Yield Gap of Cotton

The per hectare input gap and yield gap on the sample farm were estimated using the university's guidelines, taking into account the per hectare input utilized by a selected group of farmers as well as the overall amount of input used. When the potential yield and demonstration yield are contrasted with the actual yield of the low, medium, and high adopter groups, the yield gap is estimated. Tables 4 and 5 display the yield gap and input gap per hectare due to the varying degrees of suggested technology adoption.

3.5 Input Gap at Different Level of Adoption of IPM Technology

The input gap, which is displayed in Table 4, was calculated by subtracting the actual input used from the suggested level of input. With the aid of a comparison with the real technologies that Dr. P.D.K.V. Akola advised, the input gap was computed at the various stages of IPM technology adoption. The input gap was computed by comparing the actual and recommended uses of the input by various adopter levels. This led to the results that demonstrate the varying input gaps for varying IPM technology adoption levels. These gaps relate to the following inputs.

Table 4 shows that a seed rate of 2.00 to 2.5 kg per hectare was the optimum dose. The input gap resulted in 2.34 kg/ha, 2.30 kg/ha, and 2.26 kg per hectare for the usage of seed rate in relation to suggested use for low, medium, and high adopter group gaps, respectively. It indicates that the recommended level of seed rate was applied.

For the three IPM technology adoption levels, the FYM input gap is extremely large. The fact that farmers can only use FYM from their own farms prevents anyone from fully adopting the appropriate level of FYM dosage. Regarding fertilizer, additional fertilizer was applied in accordance with prescribed levels for all three categories by applying doses of phosphorus, potassium, and nitrogen. The crop's productivity levels have demonstrated this.

3.6 Yield Gap of Selected Farmer at Different Level of Adoption

The productivity level of the chosen sample is directly related to the input gaps. Table 5 presents the findings.

Table 5 shows that the actual yield per hectare for the low, medium, and high adopters categories was 12.71 quintals, 14.01 quintals, and 16.64 quintals per hectare, respectively; the potential yields for the same variety of cotton (BT Cotton) were 15 quintal per hectare, and the demonstration yield of the same variety was 22.00 quintals per hectare on University farms; the yield gap I, or difference between the potential yield and demonstration yield, was 7 quintal per hectare. The result indicates that the demonstration yield was greater than the potential yield, and as a result it shows in negative value.

By deducting the actual yield from the theoretical yield of cotton, the total yield gap was calculated. The low adopter group showed the largest overall yield gap of 2.29 quintals per hectare, followed by the medium adopter group with a yield gap of 0.99 quintals per hectare, and the high adopter group with a yield gap of 1.64 quintal per hectare more than potential output. In light of this, it may be said that adopting advised technology lowers the yield gap and, eventually, raises net returns for high adopter groups.

Table 4. Input gap of cotton crop (Per hectare)

Particulars	Units	Recommended	Low adopter (N = 22)	Medium adopter (N = 79)	High adopter (N = 19)
Seed rate	kg/ha	2.00 to 2.50	0 (2.34)	0 (2.30)	0 (2.26)
FYM	q/ha	50	- 35.95 (14.05)	- 33.20 (16.80)	- 19.32 (30.68)
Fertilizer					
N	kg/ha	60	6.89 (66.89)	5.82 (65.82)	2.66 (62.66)
P	kg/ha	30	12.18 (42.18)	10.85 (40.85)	10.97 (40.97)
K	kg/ha	30	11.87 (41.87)	4.76 (34.76)	3.75 (33.75)

Note: Figures parenthesis indicates the actual use of Input.

Table 5. Yield Gap of selected farmer in cotton crop production (quintals per hectare)

Particulars	Units	Low adopter (N = 22)	Medium adopter (N =79)	High adopter (N = 19)
Actual Yield	q/ha	12.71	14.01	16.64
Potential Yield	q/ha	15		
Demonstration Yield	q/ha	22		
Yield Gap	q/ha			
Yield Gap I (Yp – Yd)		07		
Yield Gap II (Yd – Ya)		9.21	7.99	5.36
Total Yield Gap I (Yp – Ya)		2.29	0.99	-1.64
Maximum Yield	q/ha	13.72	15.37	18.23
Maximum Yield Gap (Actual Yield – Maximum Yield)	q/ha	1.01	1.36	1.59

4. CONCLUSIONS

Among 120 farmers surveyed, 19 farmers were observed under high level of adoption group i.e. above 78.11 percent, 79 farmers were reported under medium level of adoption group i.e. above 63.35 to 78.11 per cent while 22 farmers were observed under low level of adoption group i.e. below 63.34 per cent in technology adoption range. The group with high adoption level had the greatest extent of adoption across all technologies. Furthermore, in low adopter groups, the employment of trichograma, FYM, light, Pheroman, and yellow sticky traps is negligible. The group with the highest adoption level had the highest utilization of human labor as a result of input utilization. Seed rates were used at the recommended level in all three adoption levels, and farmers chose short and medium duration varieties. Farm yard manure was used at the highest rate in the high adopter group (30.68 quintal per hectare), followed by the medium adopter group (16.80 q/ha) and the low adopter group (14.0 5 q/ha). The results of the application of fertilizer (NPK) indicated that more was used at the recommended level in all three categories. The results of fertilizer application (NPK) showed that more was used at the recommended level in all three categories. 7. Per hectare yield was highest in the high adopter group (16.64 quintal), followed by the medium adopter group (14.01 quintals), and lowest in the low adopter group (12.71 quintals).Regarding the input gap, the amount of FYM used was observed to be 35.95 kg, 33.20 kg, and 19.32 kg per hectare for the low, medium, and high adopter groups, respectively. This indicates that no farmer is able to fully adopt the recommended level of FYM dose because they can only apply FYM from their owned farms. The reason for the lower use of FYM is the shortage of cattle population. Regarding input utilization, the results indicate that fertilizer application was used more at the recommended level in all three categories. The lowest total yield gap, 2.29 quintals per hectare, was observed in the low adopter group, followed by 0.99 quintals per hectare yield gap in the medium adopter group and comparatively higher yield was observed, 1.64 quintals per hectare.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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