



## Management strategy for pink bollworm (*Pectinophora gossypiella*) in cotton (*Gossypium hirsutum*) in farmers-participatory mode

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### ABSTRACT

Cotton (*Gossypium hirsutum* L.) in central India is witnessing increasing infestation of bollworm and sucking pests since 2016. In recent years, pink bollworm, *Pectinophora gossypiella* (Saunders) has emerged as a serious problem causing severe damage to cotton in several parts of our country. Farmers rely on chemical pesticides to control pest incidence that adversely affects naturally occurring predators and parasitoids in the crop ecosystems. The study was conducted by ICAR-National Research Centre for Integrated Pest Management, New Delhi during rainy (*khari*) season 2018–21 to implement IPM validation trials at Wakhari village of Jalna district, Maharashtra with a view to study the economic viability and feasibility of adaptable IPM technology in farmer participatory mode. IPM implementation significantly reduced the number of insecticidal sprays (49.74%) and increased the cotton yield (28.49%) against the farmer's practice (FP). Benefit to cost ratio was also higher in IPM fields (1.7, 2.4, 2.3 and 3.96) as compared to FP (1.3, 1.5, 1.74 and 2.97) during 2018, 2019, 2020 and 2021, respectively. It was evident that by adopting IPM strategy, pink bollworm in cotton can be successfully managed with minimum application of insecticides along with conservation of natural enemies and higher net return (42.6%) over farmer's practice. The technology will be helpful in increasing the seed cotton yield and improve quality especially in terms of reduced pesticides contents, thereby improving the socio-economic status of cotton growers of the country.

**Keywords:** Benefit cost ratio, Cotton, Natural enemies, Pink bollworm

Cotton (*Gossypium hirsutum* L.) is an important cash crop playing a pivotal role in sustaining economy of India and livelihood of the Indian farming community. Insect pests and diseases are the major constraints in cotton production. In India, 162 species of phytophagous insects have been recorded on the crop, of which 24 species have attained pest status and nine are key pests in one or more cotton growing zones of the country (Dhawan 2000). Farmers use heavy doses of chemical pesticides to control pest incidence that adversely affects naturally occurring predators and parasitoids in the ecosystems. Over-reliance on chemical pesticides has caused harm due to pesticide residue, resurgence, secondary pest outbreak and development of resistance against these chemical molecules. Many of the insect pests infesting cotton in different agro-climatic zones are common but some are more serious in particular zone due to the conditions favouring their buildup. Emerging pest problems like pink bollworm *Pectinophora gossypiella* (Saunders) (PBW)

threatened cotton production in the Central Zone of the country since 2016 onwards. The damage to lint is so severe that often the crop has to be abandoned from picking as the bad seed cotton has no market appreciation. This bollworm threatened farmers so much that integrated pest management (IPM) in cotton took off roots in order to suppress it smartly and with less cost. Pink bollworm has evidently come under increasing selection pressure to evolve resistance to Bt protein(s) produced in tissues of cotton plants. Secondly, even as an alternative control method, conventional insecticides have limited efficacy on PBW due to the internal feeding habit of the larvae within the developing cotton boll. The fruiting bodies formed in the later part of the season became prone to the attack of pink bollworm, therefore, the farmers apply chemical insecticides. Under these circumstances, there is a dire need for environmentally sound management practices against major pests of cotton including pink bollworm. Therefore, the present study aimed to develop and validate an adaptable IPM strategy for cotton with major emphasis on PBW.

### MATERIALS AND METHODS

Jalna (Maharashtra, India) is considered to be the hot spot of cotton pink bollworm. The present study was carried

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out by ICAR-National Research Centre for Integrated Pest Management, Pusa, New Delhi during rainy (*khariif*) season 2018–21 to implement IPM validation trials at Wakhari village (N 195146.3, E 761020.9) of district Jalna, Maharashtra. Cotton IPM validation trial was initiated in farmer's participatory mode in contiguous area of 24 ha covering 30 farmers in 2018, which was extended to 30 ha covering 45 farmers in 2019, 50 ha covering 60 farmers in 2020 and in 80 ha area with 83 farmers in 2021, respectively.

**Baseline information:** The baseline information was collected by interviewing 60 cotton growing farmers of Wakhari, Kadegaon, Puneagaon and Pokalwadgaon in Jalna district of Maharashtra on major pests prevailing in cotton, pesticide use, cropping pattern, crop protection measures taken by the farmers, knowledge level of farmers about pests and natural enemies, sources of technical and crop protection inputs, existing agronomic practices and yield.

**Management interventions:** IPM strategy included sowing in June along with refugia, clean cultivation, border crop with bajra/maize/sorghum and intercrop with cowpea for natural enemy conservation, foliar application of 2% DAP and 2% potassium nitrate at flowering, pest monitoring at weekly interval by employing a field scout, installation of pheromone traps of PBW (5/ha) after 45 days of sowing, collection and destruction of fallen squares/flowers/bolls, installation of pheromone traps (40/ha) for mass trapping of PBW one week prior to flowering, release of parasitoid (supplied by ICAR-National Bureau of Agricultural Insect Resources, Bengaluru team collaborators) *Tricho grammatodea bactrae* Nagaraja (1.5 lakhs/ha) coinciding with the initiation of moth activity, need-based application of azadirachtin (1500 ppm @2.5 l/ha) against sucking pests and PBW, use of flonicamid 50 WG (150 g/ha) for jassids (economic threshold level (ETL) of two nymphs or adults/three leaves), use of diafenthiuron 50 WP (500 g/ha) against whitefly (ETL of eight adults/leaf) and thrips and spiromesifen 22.9 SC (500 ml/ha) for whitefly nymphs, spinetoram 11.7% SC (420 ml/ha) for thrips, [thiodicarb 75% WP (2 g/litre), quinalphos 20% AF (2 ml/litre), chlorpyrifos 20% EC (2.5 ml/litre) and fenvalerate 20% EC (1 ml/litre)] against PBW, termination of crop by end of December and destruction of crop residues.

Observations were recorded from 30 IPM fields and 10 farmer's practice (FP) fields. Observations on insect pests, viz. PBW (square, flower and green boll damage), sucking pests [whitefly, *Bemisia tabaci* Gen. (adults), jassid, *Amrasca biguttula* Ishida (nymphs and adults) and thrips, *Thrips* sp. (nymphs and adults) were recorded as number per three leaves, selected one each from top, middle and lower canopy of the plant. Natural enemies [ladybird beetle (adults), lacewing (adults) and spiders (adults and spider lings)] were recorded as number per plant at weekly interval. The damage to fruiting bodies (squares) was recorded based on the total number and damaged fruiting bodies in each plant. The fruiting bodies (square) both shed and intact on plants were taken into account for calculating the per cent damage. Similarly, the per cent green boll damage was recorded by

collecting 20 green bolls randomly (destructive sampling) from five different points per acre from total IPM area, were cut open to see the pink bollworm larvae. By counting the number of damaged bolls out of total number of bolls, per cent green boll damage was calculated. Farmer's field school (FFS) and awareness programmes were organized at 15–30 days interval in adopted villages during each crop season for dissemination of integrated pest management strategies. FFS included the training on identification of insect pests, diseases and beneficial, Economic Threshold Level (ETL) concept, use of biopesticides and bioagents and management tactics including safer pesticides.

**Statistical analysis:** Seed cotton yield of each plot was recorded over the three pickings. For economic analysis, number of chemical sprays, biopesticide sprays, cost of cultivation including plant protection, yield and benefit cost ratios were also computed. The weekly data of pests and natural enemies were subject to analysis under student 't' test.

## RESULTS AND DISCUSSION

**Baseline information:** The socio-economic baseline information indicated that 60% area is under cotton and rest of the area is under maize, bajra, urd, mung, groundnut, soybean, grapevine yard etc. About 80% of the cultivable area was rainfed. The source of irrigation was tube well with water table 20–25 mbgl (metres below ground level) (Central Ground Water Board Report 2013). Few farmers used drip irrigation systems for efficient use of limited water available. The average yield of the cotton crop varies with the irrigation facility. Normal seed cotton yield under rainfed, surface irrigated and drip irrigation condition was 5–7, 10–12 and 1–20 q/acre, respectively. It was also indicated that due to the attack of pink bollworm (PBW) during 2017, severe yield decline of about 60–65% was recorded and yield obtained was 1.5–2, 5–6 and 7–8 q/acre in rainfed, surface irrigated and drip irrigation conditions, respectively. Refugia seeds were not planted by most of the farmers except a few progressive farmers. Normal sowing of cotton in the area commenced from 10<sup>th</sup> June onwards and complete by the end of June depending upon the monsoon rain. Most of the farmers in the village apply 5–15 sprays (average 7–8) of insecticides (tank mix of two insecticides along with some growth hormone and foliar fertilizers) based upon the advice of pesticide dealers except a few farmers of the village.

**Sucking pests:** Lower incidence of sucking pests in IPM, as well as fields with farmer practices (FP), were noticed during the entire crop season. Comparison of population per leaf of sucking pests (average of 4 years) indicated lowest population of whitefly (adult), jassid and thrips (nymph and adult) in IPM module (0.22, 0.35, and 1.27) as compared to FP (0.48, 0.99 and 2.77) respectively (Fig 1). In IPM fields, application of azadirachtin 0.15% EC, flonicamid 50% WG for jassids, diafenthiuron 50% WP for whitefly and thrips and spinetoram 11.70% SC for thrips which provided protection from sucking pests. These findings are in agreement with the reports of previous study by various researchers (Patil

*et al.* 2014, Chandi *et al.* 2015, Birah *et al.* 2019, Kumar *et al.* 2021) revealed that the application of IPM components, clean cultivation, judicious use of insecticides and planting of maize/cowpea as border crop provided optimum conditions for multiplication and augmentation of natural enemies. Saravanan *et al.* (2015) also reported that IPM technologies like border cropping, use of 5% NSKE, use of recommended insecticides on economic threshold basis etc. were successful in managing the cotton pests.

*Pink bollworm:* Data shows that IPM fields registered significantly less fruiting bodies damage (squares and green bolls) compared to fields of FP indicating the suitability of effective IPM components (Table 1). Fruiting body (square) damage was found lower in IPM fields (4.60, 4.40, 4.20 and 5.80%) with a mean of (4.78± 3.07%) in IPM fields as compared to FP fields (9.11±5.78) during 2018, 2019, 2020 and 2021, respectively and was found statistically significant at  $P < 0.05$  during 32–52 standard meteorological weeks (SMW) except SMW 39 with average reduction of 47.53%. Similarly, green boll damage was found significantly lower in IPM fields (15.8, 11.0, 13.9 and 8.35%) with a mean of 12.62±5.62 as compared to farmer's practice fields (21.6, 25.2, 30.7 and 18.9%) with a mean of 23.88±8.44 and average reduction of 47.15% over FP during 2018, 2019, 2020 and 2021, respectively. During rainy (*khariif*) 2020, there was heavy rainfall at the end of crop season which lead to sufficient moisture for the summer winter (*rabi*) crop and thereby farmers timely terminated the cotton crop. Timely termination of the cotton crop may be the reason of overall reduction in moth population and lower green boll damage in 2021. Significantly higher population of natural enemies comprising coccinellids (*Coccinella septempunctata* and *Menochilus sexmaculatus*) and chrysopa (*Chrysoperla carnea*) and spiders were observed in IPM as compared to FP. The above results indicate that management of pink bollworm with merely chemical insecticides will not give satisfactory results. However, adoption of IPM along with, need based spray of recommended insecticides with proper dosages adopted on community basis effectively manages pink bollworm. The results obtained during field study were in corroboration with the findings of El-Hafez *et al.* (2000) who determined the role of augmenting *T. batrae* in the IPM programme for controlling *P. gossypiella* in Egypt. Adoption of IRM based IPM modules has resulted into reduction in population of sucking pests over recommended plant protection practices with lesser use of insecticides (Patil *et al.* 2011). The results demonstrated the superiority of IPM strategy over the present farmer's practice of unnecessary use of insecticides, and practically no monitoring where a significant increase in cotton yield was observed (Aggarwal *et al.* 2006). The efficacy of pheromone traps such as sleeve trap and yellow funnel was well demonstrated by some researchers (Sandhya *et al.* 2010), pheromones at higher dosages or frequency of lures can also be used in mass trapping and to confuse mating. Management of pink bollworm by way of mass trapping was also demonstrated by Maruti *et al.* (2020), present results are in confirmation

Table 1 Fruiting bodies damage along with population of beneficial in cotton (32–52 SMW)

Fruiting body damage and beneficials	2018			2019			2020			2021			Pooled mean		
	IPM	FP	SMW	IPM	FP	SMW	IPM	FP	SMW	IPM	FP	SMW	IPM	FP	SMW
Square damage (%)	4.60 ±3.63	8.50 ±3.39	32-38, 40-52	4.40 ±1.98	9.10 ±3.62	32-50, 52	4.20 ±1.05	9.70 ±2.19	34-52	5.80 ±1.80	8.90 ±2.10	33-42, 44, 46- 48, 50-52	4.78 ±1.07	9.11 ±3.78	34-50, 51
Green boll damage (%)	15.83 ±6.03	22.18 ±7.06	34-52	11.29 ±4.80	25.23 ±7.24	34-52	13.96 ±4.09	30.68 ±13.95	36-52	8.35 ±2.32	18.87 ±4.72	36-52	12.62 ±5.62	23.88 ±8.44	34-52
Spider	0.05 ±0.02	0.03 ±0.01	35-52	0.06 ±0.02	0.02 ±0.01	34-47, 50	0.12 ±0.20	0.03 ±0.01	34-35, 38-40, 42-52	0.37 ±0.09	0.16 ±0.03	34-52	0.15 ±0.1	0.06 ±0.03	35-52
Lady bird beetle (Coccinellids)	0.03 ±0.01	0.01 ±0.003	34-42, 45-47, 49-51	0.05 ±0.01	0.03 ±0.01	34-45, 47-52	0.14 ±0.04	0.04 ±0.02	35-49, 51-52	0.32 ±0.07	0.24 ±0.08	34-52	0.14 ±0.07	0.08 ±0.03	34-52
Green lacewing (Chrysopids)	0.09 ±0.03	0.05 ±0.02	34-47, 50-52	0.11 ±0.04	0.05 ±0.02	34-52	0.33 ±0.10	0.15 ±0.09	34-35, 38-49, 52	0.53 ±0.09	0.15 ±0.03	34-35, 37-52	0.28 ±0.04	0.11 ±0.03	34-52

IPM, Integrated pest management; FP, Farmer's practice; Coccinellid, Adult beetles/plant; Chrysopid, Adults and spiderlings/plant; \*SMW, Standard meteorological weeks means are significantly different with  $P < 0.05$  using t-test.

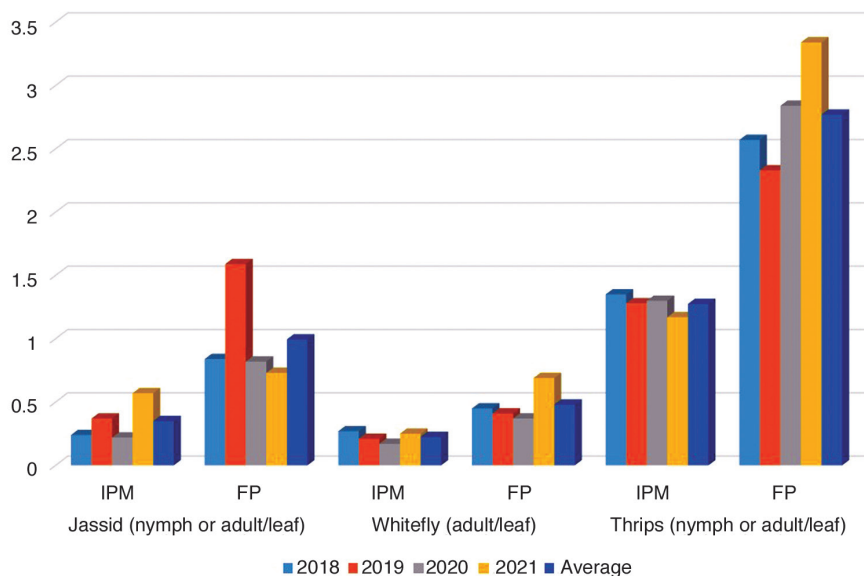


Fig 1 Trend of sucking pest population in IPM and FP fields during 2018–2021.

with the earlier studies, which reported that the adaptability of IPM module integrated with cotton proved superior by recording least percentage of pest or PBW infestation and higher seed cotton yield with more net returns (Patil *et al.* 2011).

**Beneficials:** Among beneficials, population of spiders remained higher in IPM (0.05, 0.06, 0.12 and 0.37 per plant) with the mean of 0.15±0.1 per plant as compared to FP (0.03, 0.02, 0.03 and 0.16 per plant) with the mean of 0.15±0.1 per plant during 2018, 2019, 2020 and 2021, respectively. Population of lady bird beetle also remained higher in IPM (0.03, 0.05, 0.14 and 0.32 per plant) with the mean of 0.14±0.07 per plant as compared to FP (0.01, 0.03, 0.04 and 0.24 per plant) with the mean of 0.08±0.05 per plant during 2018–20. Population of green lacewing also remained higher in IPM (0.09, 0.11, 0.33 and 0.53 per plant) with the mean of 0.28±0.14 per plant as compared

to FP (0.05, 0.05, 0.15 and 0.15 per plant) with the mean of 0.28±0.14 per plant during 2018–20 (Table 1).

**Economics of IPM:** The pooled data of four years on yield and economics revealed that IPM implementation resulted in >28% increase in yield and >42% increase in net profit compared to FP (Table 2). IPM implementation resulted in 49.74% reduction in number of insecticidal sprays against farmer’s practice. The benefit-cost ratio in IPM was 2.59, whereas in FP it was 1.87. The B:C ratio in the successive years increased gradually in both IPM and FP, because of increase in yield and thereby increase in net profit. Increase in yield in IPM fields was mainly because of good agriculture practices

which helped in maintaining plant vigour under insect pressure, thereby helped plant to compensate the damage done by the pests.

Farmer field schools were organized at regular interval and field day were also organized to create awareness and to develop the skill of the farmers about identification of pest and natural enemies, nature of damage and application of IPM components. Previous study by many researchers (Kumar *et al.* 2011, Dahiya *et al.* 2014, Patil *et al.* 2014, Chandi *et al.* 2015) revealed that the application of IPM components, clean cultivation, judicious use of insecticides and planting of maize/cowpea as border crop provided optimum conditions for multiplication and augmentation of natural enemies. This is in accordance with results of Dhawan *et al.* (2011) who reported 38.39% reduction in the number of sprays in IPM villages over non-IPM villages. Kumar *et al.* (2011) mentioned that insecticide usage can be

Table 2 Economic analysis and insecticidal sprays in IPM and FP during 2018–21

Parameter	IPM				FP				Average		% Inc/dec in IPM over FP
	2018	2019	2020	2021	2018	2019	2020	2021	IPM	FP	
No. of insecticide sprays	2.8	2.9	2.9	3.2	5.7	5.6	5.9	6.3	2.95	5.87	49.74
Seed cotton yield (q/ha)	12.0	22.5	17.24	18.74	8.80	15.0	11.50	15.10	17.62	12.6	28.49
Cost of cultivation* (₹/ha)	42500	46000	41720	42550	39500	47000	37080	45750	43192	42332	1.99
Gross income** (₹/ha)	72000	112500	96544	168660	52800	75000	64460	135900	112426	82040	27.03
Net profit (₹/ha)	29500	66500	54824	126110	13300	28000	27380	90150	69233	39707	42.64
Benefit-cost ratio	1.70	2.4	2.3	3.96	1.30	1.5	1.74	2.97	2.59	1.87	27.80

IPM, Integrated pest management; FP, Farmer’s practice; \*Cost of seed, pesticide, fertilizer, irrigation and labour cost for sowing, weeding, hoeing, pesticide and fertilizer application, collection and destruction of fallen squares/flowers/bolls, installation of Tricho cards, installation of pheromone traps for mass trapping etc. Average cost of pesticides was ₹8267/ha in FP and ₹8352/ha in IPM; Labour cost was ₹22050/ha in FP and ₹25835/ha in IPM. \*\*Average market price of seed cotton were ₹6000, 5000, 5600, 9000/q during 2018, 2019, 2020 and 2021, respectively.

reduced by adopting IPM module. It has been reported that neem seed kernel extract is safe to parasitoids and predators (Tanwar *et al.* 2007). These results are in accordance with our study as in the present study sowing of bajra as border crop for conservation of natural enemies along with sprays of azadirachtin were successful in managing the sucking pest population. Kumar *et al.* (2021) also reported that IPM technologies like timely sowing of recommended cotton hybrid, removal of weed as an alternate host, proper plant nutrition along with foliar spray of 2% potassium nitrate, use of neem based pesticides, conservation of natural enemies by avoidance of insecticides which are harmful to natural enemies, and judicious use of safer pesticides were successful in managing the cotton pests.

**Impact:** The team conducted Farmer's Field School (FFS) and awareness programmes at regular intervals about importance of IPM in cotton in Wakhari village of Jalna district. With the influence of IPM farmers, other farmers of Wakhari village and other nearby villages adopted the validated IPM technology. In 2020, the same IPM strategy was accepted and implemented in 500 ha across five adjoining villages, viz. Dharkalyan (150 ha), Wadgav (80 ha), BajiUmrad (120 ha), Somnath (100 ha) and Jalgav (50 ha). In 2021, it was horizontally spread to 2208 ha across two blocks in 15 adjoining villages, viz. Wakhari (280 ha), Dharkalyan (150 ha), Wadgav (80 ha), BajiUmrad (120 ha), Somnath (100 ha), Jalgav (50 ha), Wanadgoan (169 ha), Salegoan (147 ha), Pinegoan (150 ha), Wadiwadi (160 ha), Khanepuri (180 ha), Nirkheda (125 ha) and Brahmankheda (150 ha) villages of Jalna block and Kadegoan (180 ha), Matrewadi (167 ha) of Badnapur block of Jalna district.

Wide scale validation of cotton IPM for four years in farmer's participatory mode, provided better yield with minimum input, minimum pesticides application along with conservation of natural enemies with high benefit-cost ratio. The overall conclusion of the study is that by adopting integrated pest management (IPM) strategies in cotton, pink bollworm can be efficiently managed. Relying on chemical insecticides alone for the management of pink bollworm is not sustainable and increases cost of cultivation and reduces net returns. The validated IPM strategy is ecologically safe, economically viable and adoptable under farmer's field conditions and is highly effective in managing pink bollworm and other pests with conservation of natural enemies in cotton in the central zone of the country.

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