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Validation of integrated pest management module for major pests of *Bt* cotton in north-west India

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ABSTRACT

Cotton (*Gossypium* spp.) is widely cultivated in the north-western states of India. Although *Bt* cotton provides resistance to bollworms, cotton cultivation in these regions continues to face challenges from various insect pests and diseases. The increasing infestation of pink bollworm and jassids, along with the incidence of boll rot, has led to severe yield losses and an over-reliance on chemical pesticides. The present study was carried out during rainy (*Kharif*) season of 2022–2024 in Bhainichanderpal village, Rohtak, Haryana to conduct a Integrated Pest Management (IPM) validation trial aimed to manage key pests, particularly jassids, pink bollworm, and boll rot, while reducing chemical dependence and promoting ecological balance. The IPM interventions included timely sowing, regular pest monitoring, seed treatment with *Trichoderma asperellum*, installation of yellow sticky traps, use of Specialized Pheromone and Lure Application Technology (SPLAT) for pink bollworm management, and need-based application of safer pesticides. The IPM module significantly reduced green boll damage by pink bollworm (12.95% in IPM vs. 19.75% in the farmers' practice) and minimized the incidence of boll rot (13.2% in IPM vs. 23.85% in the farmers' practice). There was a 21.05% increase in seed cotton yield under IPM compared to the farmers' practice, along with a higher benefit-cost ratio (2.15 in IPM vs. 1.65 in FP). Additionally, IPM led to a 33.5% reduction in pesticide applications compared to the control. These findings highlight the importance of IPM in enhancing cotton yield and profitability by reducing pesticide dependence and promoting natural enemies.

Keywords: Boll rot, Cotton, IPM, Pink bollworm, Predators

Cotton (*Gossypium* spp.) is a major global cash crop, playing a vital role in both the agricultural and industrial economies. India leads the world in cotton cultivation by area and production, with the crop widely grown across its northern, central, and southern regions (Directorate of Cotton Development 2017). Among these, the north-western states i.e. Punjab, Haryana, and Rajasthan are especially important for cotton production due to their warm, semi-arid climate, which is favourable for the crop. However, cotton cultivation in these areas faces persistent threats from various insect pests and diseases that significantly reduce yield and fiber quality. These include sucking pests, bollworms, and a range of fungal and bacterial pathogens. The introduction of *Bt* cotton has provided effective control against bollworm species such as American bollworm (*Helicoverpa armigera*), spotted bollworm (*Earias vittella*), and tobacco caterpillar (*Spodoptera litura*). Yet, it has not eliminated pest problems entirely. In recent years, several sucking pests, previously considered minor, have resurged as major threats. Among these, jassids (*Amrasca biguttula*), along with pink bollworm (*Pectinophora gossypiella*) and the boll rot disease complex, have led to significant yield losses in *Bt* cotton (Naik *et al.* 2018, Nagrare *et al.* 2019). Jassids damage plants by feeding on leaf undersides, causing yellowing, curling, and reduced photosynthesis, while bollworms directly damage developing bolls, lowering both yield and fiber quality. Boll rot, caused by a complex of fungal pathogens (*Fusarium moniliforme, Colletotrichum gossypii, Lasiodiplodia theobromae, Aspergillus flavus, Rhizopus nigricans, Nematospora nagpuri)* and bacteria *(Pantoea agglomerans, Pantoea dispersa, Erwinia uredovora, Bacillus pumilus*), further contributes to yield losses and fiber degradation (Sain *et al.* 2023). To combat these insect-pests and diseases, farmers often resort to excessive pesticide use. While this offers temporary relief, it disrupts ecological balance by harming beneficial predators and parasitoids. Overuse of chemical pesticides has also led to pest resurgence, resistance development, and environmental contamination. Given these challenges, there is an urgent need for sustainable, eco-friendly pest management strategies. To address this, ICAR-National Research Institute for Integrated Pest Management,

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New Delhi in collaboration with ICAR-Central Institute of Cotton Research, Regional Station, Sirsa, Haryana undertook a study to develop and validate an Integrated Pest Management (IPM) approach. This strategy aims to manage key pests, particularly jassids, pink bollworm, and boll rot, while reducing chemical dependence and promoting ecological balance.

MATERIALS AND METHODS

The present study was carried out during rainy (*Kharif*) season of 2022–2024 in Bhainichanderpal village (29°00'05.6" N, 76°18'32.4" E), Rohtak, Haryana. The trial initially covered 40 ha with 15 progressive farming families in 2022–23 and was expanded to 48 ha with 20 families in 2023–24. Population and incidence of major pests were compared with farmers' practices (FP) and untreated control plots (10 m × 10 m). In addition, the number of pesticides sprays and seed cotton yields were recorded.

Baseline information collection: Baseline data were collected by interviewing 30 cotton growing farmers from Bhainichanderpal village. The survey focused on cropping patterns, agronomic practices, key pests affecting cotton, farmers' knowledge of pests and natural enemies, crop protection practices, number of pesticides sprayed, sources of technical and crop protection inputs, and the seed cotton yields obtained by the farmers.

IPM module: IPM strategy included timely sowing of crop up to 15^{th} May with recommended hybrids (RCH 773, RCH 776, US-51); seed treatment with *Trichoderma asperellum* (NCIPM/ T-9) @10 g/kg of seed; pest monitoring at weekly interval; installation of yellow sticky traps (30 cm × 15 cm) @100/ha in June; installation of pheromone traps for *Helicoverpa armigera*, *Spodoptera litura* and *Earias vittella* @5 traps/ha each for monitoring purpose; use of bio-rational pesticides such as neem oil (Azadirachtin 1500 ppm) mixed with 0.5% laundry detergent emulsion, and need based application of insect growth regulators (IGRs) i.e. Flonicamid 50 WG (200 g/ha) to manage jassid. Destructive sampling (20 bolls from a field) during the boll formation stage and need based spray of copper oxychloride 50 WP @25 g/10 L of water to manage boll rot. For management of pink boll worm, Specialized Pheromone and Lure Application Technology (SPLAT) based formulation [Gossyplure 4% RTU (CREMIT-PBW)] was used @125 g/acre/application and was applied four times at monthly intervals (August–November). The ready-to-use formulation, available as paste was applied in the form of small dollops (peanut size) at the primary branch axil (below 3–4 inches from crop canopy) at 400–500 spots/acre 3 m apart in a zigzag pattern. In addition, for optimal nutrition 3–4 foliar applications of potassium nitrate fertilizer (NPK 13:0:45) @2% during flowering to boll formation stage at a weekly interval were also done. Farmers' Field Schools (FFS) were held at fortnight intervals to educate farmers on pest and predator identification, economic threshold levels (ETL) of pests, safe and judicious use of pesticides, balanced plant nutrition, awareness of pink bollworm vs. boll rot damage, and demonstration of SPLAT formulation. In the IPM fields, relatively safer chemical insecticides, mainly IGRs, were used, with pesticide applications limited to 3–4 sprays in both cropping seasons. In contrast, farmers in the FP fields applied 6–10 pesticide sprays, often using a mixture of 2–3 chemicals as a tank mix.

Observation of pests and predators: For recording pest and predator populations, famers' field were considered as replications, with five replications per treatment. In each one-acre field, five spots were selected, and five plants were observed per spot. Observations were made weekly from three leaves (top, middle, and lower canopy) of plants for whitefly (adults/3 leaves), jassid (nymph and adults/3 leaves) and thrips (nymph and adults/3 leaves). The entire plant was taken into consideration for counting population of the predators (natural enemies), such as lady bird beetle (adults/plant), lacewing (eggs and larvae/plant) and spiders (adults and spiderlings/plant). The percentage of green boll damage was assessed by destructive sampling i.e. randomly collecting 20 green bolls from five different points/acre. The bolls were cut open to check for the presence of pink bollworm larvae. Similarly, boll rot incidence was determined by collecting 20 cotton bolls and inspecting them for internal or external boll rot symptoms. The percentage of green boll damage and boll rot incidence was calculated by counting the number of damaged or infected bolls out of the total bolls observed multiplied by hundred.

Statistical analysis: The data related to pests and natural enemies were analysed using OPSTAT. The Shapiro-Wilk normality test showed the data were normally distributed, therefore one-way analysis of variance (ANOVA) was performed. The treatment means were compared using the least significant difference (LSD) test at $p<0.05$.

RESULTS AND DISCUSSION

Baseline information: Baseline information revealed that chemical pesticides were the primary method of pest management in the village, and farmers lacked awareness of the IPM concept. Pesticide applications were based solely on recommendations from pesticide dealers, with sprays typically applied on a weekly basis. Farmers used to spray 6–12 pesticide applications, often using insecticide cocktails. Pesticide poisoning due to exposure during spraying was a common issue each season. Farmers had limited knowledge of the effects of high nitrogen doses, foliar potassium nitrate sprays, weed control, timely sowing, and an ETL-based approach to plant protection. Key pest problems in the area included jassid, resurgence of pink bollworm over the past 2–3 years, and boll rot.

Jassid: The incidence of jassids in cotton over the *kharif* seasons of 2022–2023 and 2023–2024 showed significant variations between the different treatments. In both years, the IPM approach generally resulted in lower jassid incidences compared to the FP and control treatments. The jassid population was highest in the control plots, followed by the FP treatment, with the IPM treatment showing consistently lower infestations. Over the two seasons, the mean jassid

Table 1 Dynamics of major insect-pest and disease in cotton under IPM and FP fields in *kharif* 2022–2023

SMW	Jassid population (nymphs and adults/3 leaves)						Per cent boll rot incidence						Per cent green boll damage by PBW					
	IPM		FP		Control		IPM		FP		Control		IPM		FP		Control	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
25	2.2	2.2	2.8	2.8	3.2	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	2.8	2.8	4.2	4.2	4.9	4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	3.7	3.9	5.3	5.3	5.9	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	4.8	5.8	6.2	5.9	6.8	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	5.6	6.3	7.4	6.5	7.6	6.8	14.0	3.0	16.0	5.0	20.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
30	6.6	1.0	6.4	7.4	7.1	7.6	21.0	8.0	26.0	11.0	30.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
31	6.1	1.3	5.6	1.1	6.4	7.4	37.0	15.0	41.0	22.0	48.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.9	1.8	1.0	1.6	5.9	5.6	15.0	34.0	48.0	34.0	52.0	37.0	0.0	0.0	0.0	0.0	0.0	0.0
33	1.3	2.5	1.5	2.5	4.9	5.7	12.0	16.0	53.0	44.0	55.0	45.0	0.5	0.7	1.4	1.4	2.1	1.4
34	1.8	4.1	2.5	4.3	4.0	5.9	10.0	9.0	28.0	28.0	48.0	51.0	0.7	0.7	2.9	2.1	4.3	2.9
35	2.3	4.9	2.9	5.1	3.3	6.2	7.0	7.0	20.0	13.0	36.0	36.0	1.4	1.4	5.8	3.6	7.1	4.3
36	3.9	5.7	4.3	6.1	2.9	6.4	5.0	5.0	13.0	13.0	29.0	29.0	2.1	2.9	8.4	6.4	9.9	7.1
37	4.4	3.9	4.6	1.9	2.1	5.4	5.0	5.0	11.0	11.0	18.0	20.0	3.3	3.6	10.7	11.4	16.4	15.0
38	2.6	3.2	3.0	3.0	3.5	4.7	7.0	7.0	14.0	16.0	25.0	25.0	5.9	5.7	14.3	14.3	25.3	22.1
39	1.7	2.8	2.8	3.5	3.1	4.1	17.0	11.0	25.0	20.0	38.0	30.0	7.8	8.6	17.5	26.4	32.7	35.7
40	1.5	1.9	1.7	3.7	2.0	3.8	24.0	13.0	31.0	22.0	45.0	34.0	12.7	9.3	20.6	29.3	36.0	43.6
41	1.2	1.1	1.3	1.7	2.1	2.0	20.0	16.0	28.0	28.0	39.0	35.0	14.2	10.7	25.0	32.1	45.0	44.3
42	0.5	1.0	0.8	1.2	0.8	2.1	16.0	12.0	21.0	25.0	32.0	31.0	16.2	12.9	30.6	35.0	46.2	46.4
Mean ± SE	3.1 ± 0.1	3.2 ± 0.1	3.7 ± 0.1	3.9 ± 0.1	4.5 ± 0.2	5.4 ± 0.2	14.9 ± 0.8	11.5 ± 0.7	27.2 ± 1.4	20.5 ± 0.8	37.2 ± 1.6	29.5 ± 1.2	5.4 ± 0.3	4.8 ± 0.2	11.8 ± 0.4	14.1 ± 0.6	19.9 ± 1.0	19.6 ± 0.9
CD at $p<0.05$			0.26	0.67					0.78	1.90					1.90	3.67		

SMW, Standard Meteorological Week; IPM, Integrated Pest Management; FP, Farmers' Practice; PBW, Pink boll worm.

population in the IPM treatment was 3.1 and 3.2 per three leaves in the two years, respectively, compared to 3.7 and 3.9 in the FP, and 4.5 and 5.4 in the control (Table 1). The trend in jassid infestation over the two cropping seasons showed a significant increase in population levels, with populations exceeding the Economic Threshold Level (ETL) between Standard Meteorological Week (SMW) 28–31 across different treatments. The IPM approach helped delay the buildup of jassid populations compared to traditional farming practices (FP and Control). This delay in reaching the ETL under IPM suggests its effectiveness in managing pest populations, potentially reducing the need for early chemical interventions, and promoting more sustainable pest control strategies. Similar findings reported by Ameta *et al.* (2006) found that IPM practices significantly reduced insect-pest populations compared to farmers' practice, which relied on 9–10 insecticide sprays. The IPM approach, notably decreased the numbers of aphids (*Aphis gossypii*), jassids (*A. bigutulla*), whiteflies (*Bemisia tabaci*), and thrips (*Thrips tabaci*), demonstrating its advantages over FP. Birah *et al.* (2019) studied the impact of non-pesticide farming practices (NIFP) and IPM on pest populations in *Bt* cotton in Jind district, Haryana. The IPM module resulted in the lowest populations of whitefly (7.18), jassid (3.37), and thrips/3 leaves (7.17). Moreover, NIFP showed slightly higher populations, and FP had the highest pest numbers.

Pink bollworm: Green boll damage due to pink bollworm was significantly higher in the control plots compared to both IPM and FP treatments. During both seasons, the green boll damage was lowest in the IPM. In the 2022–2023 season, the percentage of green boll damage was highest in the control treatment (37.2%), with the IPM plots exhibiting only 14.9% damage. Similarly, in the 2023–2024 season, the green boll damage remained consistently lower in IPM plots (11.5%) compared to FP plots (20.5%) and control plots (29.5%) (Table1). The per cent green boll damage was first observed in 33 SMW and continued to increase at a slower rate in IPM plots compared to FP and control plots across both cropping seasons. This suggests that the IPM approach effectively minimized green boll damage. Srinivas *et al.* (2019) studied the use of SPLAT, in Raichur district, Karnataka, during *kharif* 2017 and showed that SPLAT at 500 g/acre reduced damage to rosette flowers (8.23%), green bolls (7.36%), and locules (8.41%) compared to farmers' practices. In an advanced study, CREMIT-PBW (a SPLAT based formulation) effectively reduced bollworm incidence and increased cotton yields, with minimal damage to rosette flowers (11.76%) and green bolls (10.20%). Compared to conventional insecticide use, SPLAT demonstrated superior pest management, providing a promising alternative with higher yields and reduced pest damage (Srinivas *et al.* 2022).

Boll rot: The incidence of boll rot, was notably higher in the control plots across both seasons, with the disease incidence increasing significantly in the absence of management practices. In the 2022–2023 season, boll rot incidence was 37.2% in control plots, compared to 14.9% in IPM plots, and 27.2% in FP. In the 2023–2024 season, boll rot incidence continued to follow a similar pattern, with the control showing the highest incidence (29.5%), followed by FP (20.5%) and IPM (11.5%) (Table 1). The incidence of boll rot began to rise significantly in SMW 30 and 31, with IPM plots showing lower levels of damage compared to FP and control plots across both the season. Mahmood *et al.* (2015) studied the effectiveness of Mancozeb, Cupravit 50 WP, and Streptomycin against cotton boll rot and found that Cupravit 50 WP (copper oxychloride) was the most effective in controlling the disease under both *in vitro* and *in vivo* conditions. Similarly, Perane *et al.* (2015) reported that propiconazole (0.1%), copper oxychloride (0.3%), and streptocycline (100 ppm) were effective in managing boll rot diseases in cotton.

Population of predators: The study revealed significant differences ($p<0.05$) in the population of natural enemies (lacewing, lady bird beetle and spiders) among the three treatment practices with maximum number in untreated control, followed by IPM and FP. The population of lacewings were higher in control plots (0.94 and 0.88) followed by IPM (0.50 and 0.55) and FP (0.23 and 0.19) per plant during both years of study (Fig.1). Similarly, the ladybird beetle population was higher in control plots (0.48 and 0.46) as compared to IPM (0.18 and 0.22) and FP (0.08 and 0.08) per plant during 2022–2023 and 2023–24, respectively. The trend of population of spiders was also same, it was higher in case of control (0.83 and 0.77) and IPM (0.45 and 0.49) as compared to FP (0.15 and 0.17) per plant during both the years (Fig.1). These findings suggest

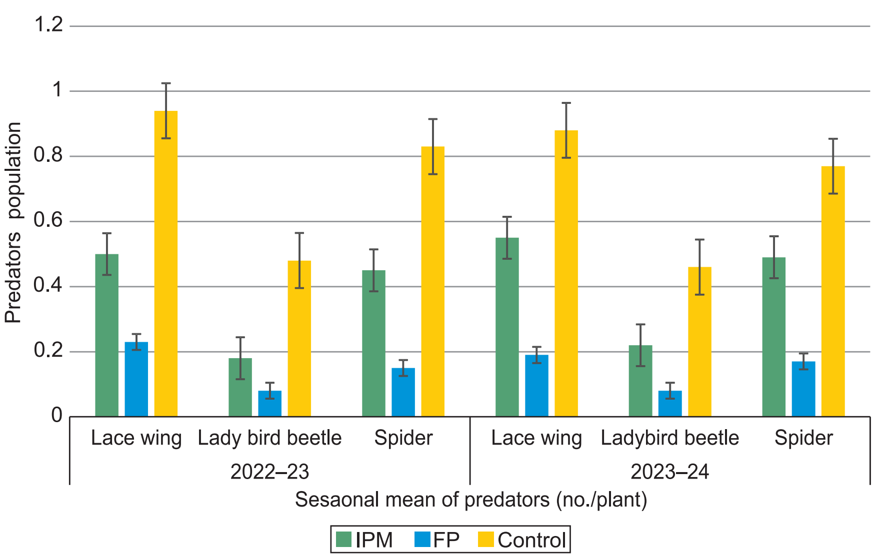

Fig. 1 Mean population of predators in cotton under integrated pest managment (IPM) and farmers' pratise (FP) fields during *kharif* 2022–2024.

Table 2 Economic analysis of cotton under IPM and FP fields during *kharif* 2022–2023

Particulars	IPM			FP			Per cent increase (I) or Per cent decrease (D) in IPM over FP		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
Pesticide spray (nos.)	4.1	3.8	3.95	5.8	6.1	5.95	29.3 (D)	37.7 (D)	33.5 (D)
Seed cotton yield (q/ha)	18.5	19	18.75	14.5	16.6	15.55	27.6(I)	14.5 (I)	21.05 (I)
Cost of cultivation (₹/ha)	56,250	57,100	56675	57,300	63,400	60350	1.9 (D)	9.9 (D)	5.9 (D)
Gross income (₹/ha)	1,18,030	1,25,780	121905	92,510	1,09,892	101201	27.6(I)	14.5 (I)	21.05 (I)
Gross income (₹/ha)	61,780	68,680	65,230	35,210	46,492	40,851	75.5 (I)	47.7 (I)	59.7 (I)
Benefit cost ratio	2.1	2.2	2.15	1.61	1.7	1.68			

IPM, Integrated Pest Management; FP, Farmers' practices.

that using IGR group insecticide (Flonicamid 50 WDG) in IPM practices helped sustain a higher population of natural enemies, which played a crucial role in controlling sucking pest populations (Naik *et al.* 2017). In contrast, lower natural enemy populations were observed in FP. The higher populations in the control plots can be attributed to the absence of chemical interventions, which likely allowed these beneficial species to thrive (Tanwar *et al.* 2007). According to Birah *et al.* (2019) also, natural enemy populations were higher in non-insecticidal farmer practice and IPM as compared to FP. Kumar *et al.* (2021) reported that IPM successfully managed whitefly and other pests, with a significant increase in natural enemy populations.

Economic impact: The pooled data from *kharif* 2022–23 and 2023–24 on cotton yield and economic analysis indicated IPM led to a significant increase in seed cotton yield (21.0%) along with a reduction in pesticides application (33.5%) over FP. IPM also helped in reduction of cost of cultivation (6.0%) which resulted in high benefit-cost ratio (2.15) and higher net profit (59.7%) over FP (Table 2). These gains reflect the economic and yield benefits of IPM, driven by sustainable pest management practices. In line with the findings, Dhawan *et al.* (2011) observed a 38.39% reduction in spray frequency in IPM villages compared to non-IPM villages. Surulivelu *et al.* (2004) found a 63% reduction in sprays in Theni and Coimbatore districts of Tamil Nadu, with an average of 2.7 sprays in IPM villages compared to 7.3 sprays in FP villages. Saravanan *et al.* (2015) also reported that IPM practices such as border cropping, yellow sticky traps, 5% neem seed kernel extract (NSKE) application, and insecticide use based on economic thresholds were successful in managing *Bt* cotton pests. The increased yield in IPM fields compared to FP can be attributed to effective agricultural practices, such as the foliar application of potassium nitrate (NPK 13:0:45) (Birah *et al.* 2019, Kumar *et al.* 2021). Bala *et al.* (2018) demonstrated that elevated potassium levels boost secondary metabolism, reduce carbohydrate accumulation, and minimize pest-induced plant damage and higher yield.

In conclusion, the IPM approach successfully minimized pest damage, delayed pest buildup, and reduced pesticide applications, resulting in higher cotton yields and increased profitability, along with reduced pesticide costs. Moreover, the reduced chemical usage in IPM fields helped sustain populations of beneficial insects such as coccinellids, chrysopids, and spiders. With adequate extension support, farmer capacity building, and policy measures, such as incentives for biocontrol agents and pheromone-based technologies, IPM module can be scaled up across cotton-growing regions.

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