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Large-scale IPM validation in whitefly *(Bemisia tabaci)*-prone cotton (*Gossypium* spp.) fields adjoining kinnow orchards

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ABSTRACT

Whitefly [*Bemisia tabaci* (Gen)] is a serious sucking pest of cotton in the north zone of India. Cotton (*Gossypium* spp.) fields adjoining kinnow orchards used to have a quite higher incidence of whiteflies compared to the fields away from orchards. Therefore, the study was carried out at ICAR-National Centre for Integrated Pest Management, New Delhi during 2017–19 to implement integrated pest management (IPM) validation trial in cotton fields located adjoining the kinnow orchards in the village Nihalkhera of district Fazilka, Punjab in farmers' participatory (FP). The IPM strategy consists of weed removal from orchards, timely sowing of recommended cotton hybrid, 4 foliar sprays of 2% potassium nitrate, use of azadirachtin 1500 ppm @5 ml/litre, conservation of natural enemies by avoidance of insecticides that are harmful (IOBC Class-4) to natural enemies and judicious use of safer pesticides (IOBC class1 and 2). The IPM adoption resulted in the successful management of whitefly and other sucking pests along with a two to three-fold increase in predator population compared to FP. IPM recorded a substantial reduction in the use of pesticide active ingredients (86%) and the number of sprays (58%) along with high parasitization (35.32–45.98%) of whitefly nymphs by *Encarsia* sp. IPM provided a significant increase in yield (23%), net return (57.5%) along with a high benefit cost (B:C) ratio of 2.65.

Keywords: Cotton, Conservation, IPM, Leafhoppers, Parasitization, Whitefly

Whitefly [*Bemisia tabaci* (Gen)] is a polyphagous sucking pest and feeds on thousands of plant species and is considered as a major sucking pest of cotton (*Gossypium* spp.) in the north zone of India. The whitefly epidemic of 2015 ravaged the 2/3rd of the cotton crop in Punjab and 15 farmers committed suicides (Varma and Bhattacharya 2015). Management of whiteflies in cotton fields adjoining to the kinnow (kinnow mandarin hybrid of cross *Citrus nobilis* × *Citrus deliciosa*) orchards remains a challenge for the farmers. There were always experts' recommendations to avoid cotton cultivation in and around orchards that suffer more from whitefly damage (Mohan *et al.* 2014). The microclimate formed by the orchards remains favourable for the survival of *B. tabaci* during heat waves. Although *B. tabaci* was not found feeding on kinnow, but the weed plants such as, *Sida* sp. *Abutilon indicum*, *Parthenium, Xanthium sp*. act as alternative host plants for the survival and multiplication of *B. tabaci* during off season (Kumar *et al.* 2020) which ultimately favour the early build-up of whitefly in cotton crop. Whereas the fields which are not in the vicinity of orchards and do not have preferred host plants of whiteflies in the off-season experienced less build-up or delay in the build-up of the whitefly population. Kinnow is the major fruit crop of Fazilka, Punjab and cotton is also a major cash crop of the district. The early build-up of the whitefly population in cotton fields near kinnow orchards creates havoc among the cotton growers. Most farmers rely on toxic-non-safer pesticides for the management of this serious sucking pest. The misuse of pesticides leads to ecological imbalance and environmental pollution. Therefore, IPM is important to grow a healthy crop with the least possible disruption of agro-ecosystems and encourages natural pest control mechanisms. In view of the above facts, a field experiment was conducted to validate the adaptive cotton IPM strategy in the cotton fields which are prone to whitefly attack, and located near orchards, with the major objective to test its efficacy and adaptability compared to farmers' practice (FP).

MATERIALS AND METHODS

Village Nihalkhera in Block- Khuian Sarwar of Fazilka district, Punjab was identified as a hot spot for whiteflies during the cotton field survey in 2016. In the same village, in the cotton fields adjoining kinnow orchards, the whitefly attack was higher compared to cotton fields away from it, throughout the season. Therefore, cotton fields adjoining the boundary of kinnow orchards in the village Nihalkhera

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(30°13'34.0"N,74°06'30.4"E; 30°14'11.8"N–74°07'05.7"E; 30°14'06.3"N–74°07'30.9"E), Fazilka, Punjab were selected for conducting cotton IPM validation trial in farmers' participatory mode. The area under IPM was 5 ha in 2017 which was extended to 20 ha and 40 ha during 2018 and 2019 respectively.

Collection of baseline information: The baseline information about the pest status was collected during field visits and information on crop condition, pesticides use pattern, 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 was collected through interaction with 25 farmers.

The IPM strategy: IPM module was based on the management strategy for Bt cotton for North Zone by ICAR-Central Institute for Cotton Research, Nagpur and ICAR-NCIPM, New Delhi (Mohan *et al.* 2014). IPM module comprises timely sowing up to 15th May with recommended BGII Bt hybrids (RCH 773, RCH 776), removal of weeds from bunds and orchards, pest monitoring at the weekly interval, installation of pheromone traps for the monitoring of moth emergence of american bollworm, spotted bollworm and *Spodoptera litura* Fabricius (2 trap/ha) and pink bollworm (1 trap/ha), 4 foliar sprays of 2% potassium nitrate at weekly interval started from the flowering stage, conservation of natural enemies by avoiding the injudicious application of harmful insecticides (IOBC class-4), use of safer pesticides (IOBC-class1 and 2) which includes azadirachtin 1500 ppm and need-based application of insect growth regulators (IGRs). Farmers' field schools (FFS) were conducted at regular intervals to educate farmers. IPM fields were compared with FP where farmers applied 6–9 sprays of chemical insecticides with tank mix of 2–3 chemicals at a time. In IPM fields, relatively safer chemical insecticides (Kumar *et al.* 2016, Khan and Ruberson 2017) mostly IGRs were used. One spray of each flonicamid 50 WDG @150 g/ha, diafenthiuron 50 WP @600 g/ha and buprofezin 25 SC @1000 ml/ha was done. The logic behind the selection of insecticides in IPM fields was based upon the mode of action of insecticides and the stage of the whitefly and the population of other sucking pests like leaf hoppers and thrips along with whitefly. Buprofezin was applied whenever only the nymphal population of whitefly was present in high numbers; if whitefly adults and nymphs along with the leafhoppers population were high, flonicamid was the choice; whenever the thrips population was high along with the whitefly and leafhoppers, diafenthiuron was applied. Decisions for pesticide application were taken when the pest population reached ETL (economic threshold level) (whitefly 6–8/leaf; leafhoppers 2/leaf; and thrips10/leaf up to 30 days crop).

Observation of pests and natural enemies: Populations of pests and natural enemies were recorded at weekly intervals from 5 spots per field of 1 acre and from each spot 5 plants were observed. Observations of the number of whitefly (adults/3 leaves), leafhoppers (nymph and adults/3 leaves) and thrips (nymph and adults/3 leaves) were recorded from 3 leaves, i.e. top middle and lower canopy of the plant, whereas for beneficial predators, i.e. coccinellids (adults/plant), chrysopids (eggs and larvae/plant) and spiders (adults and spiderlings/plant) whole plant was observed. The parasitization percentage of whitefly nymphs was recorded at monthly intervals from July–October. Cotton leaves infested with whitefly nymphs were collected from the field at regular intervals and observed under a stereomicroscope in the laboratory. The whitefly pupae with a circular exit hole or black/brown colour were considered parasitized and pupae with a 'T-shaped' exit hole or yellow coloured pupae were considered unparasitized (Flint 2015).

Statistical analysis: The weekly data of pests and natural enemies were subject to analysis under the Student's t test using the online software OPSTAT (Operational Statistics). The data on seed cotton yield, number of pesticides and cost of cultivation were recorded from IPM and FP fields, and economics were worked out.

RESULTS AND DISCUSSION

Baseline information: Baseline information indicated that the farmers in the village were not aware of the concept of IPM. Most of the farmers were unable to identify and differentiate between pests and natural enemies. The source of information regarding crop protection was pesticides dealers and neighbouring farmers (92%) and a few farmers were in touch with the Department of Agriculture and PAU Regional Research Station, Seed Farm Road Abohar (8%). Application of insecticides was done at the weekly interval (100%), sometimes twice a week. Overdose and underdose and tank mix use of insecticides were common in the village (92%) and knowledge of safer/harmful insecticides was nil. Pesticides exposure related illness during spray in every season were a common problem (20%). Knowledge of foliar spray of potassium nitrate, weed removal and timely sowing on pest problems in cotton was nil. Whitefly and leafhoppers were the important pest problems in the area. Field visits in 2016 indicated that cotton fields near kinnow orchards or cotton intercropped in orchards suffered more whitefly attacks with the early build-up of the whitefly population compared to fields away from orchards. Farmers applied 10–15 sprays of insecticides with >10 kg active ingredient (insecticide) with a mixture of 2–3 chemicals as a tank mix at a time, which includes ethion, profenofos, monocrotophos, fipronil, acephate, lambda-cyhalothrin, imidacloprid, thiamethoxam, dinotefuran, spiromesifen, flonicamid, diafenthiuron, pyriproxyfen, etc. The average seed cotton yield was 15–18 q/ha.

Sucking pests: The population of whitefly was low in IPM as compared to FP and the differences were statistically significant (P=0.05) during most of the standard meteorological weeks (SMW) in 2017–19 (Table 1). During the years 2017–2019, a gradual increase in the average population was recorded in both IPM and FP. This could be due to the decrease in the number of pesticides application because of increased awareness about IPM and economic

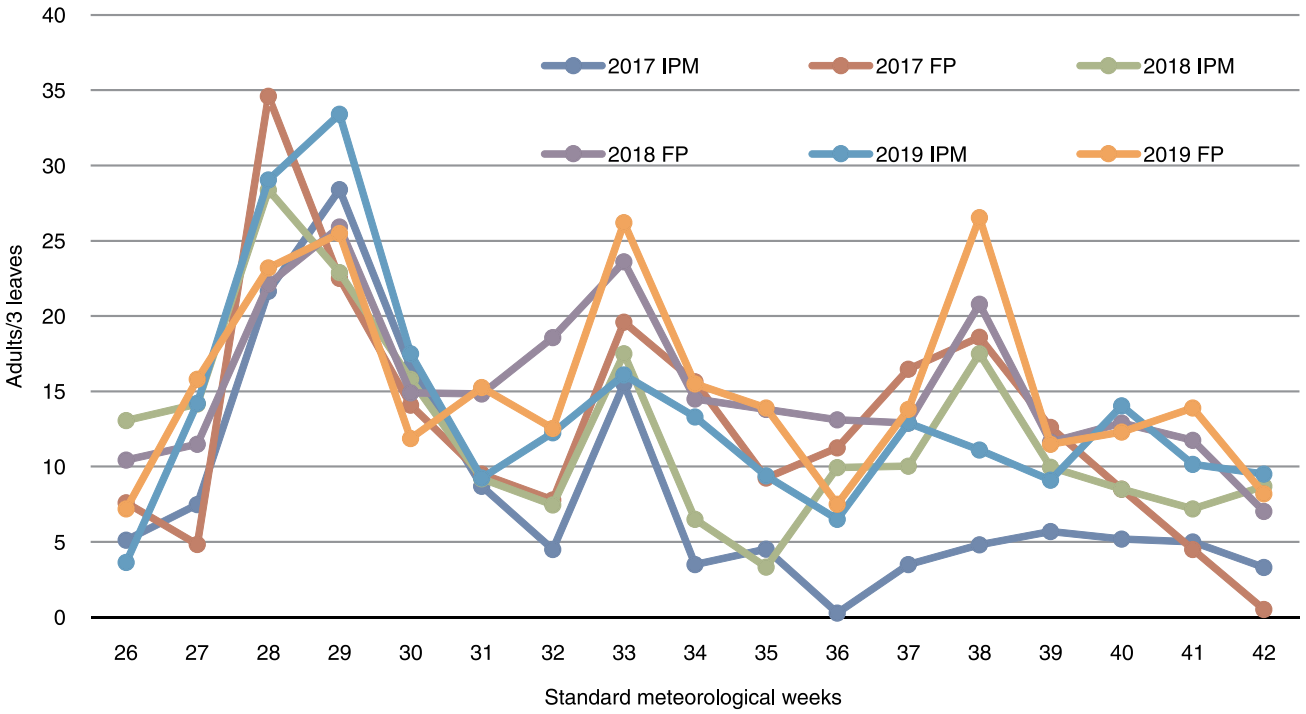

Fig 1 Weekly trend of whitefly in cotton IPM and FP during 2017–19.

threshold levels. Analysis of weekly trend (Fig 1) of the whitefly population indicated that the population in IPM fields crossed ETL (18/3 leaves) only twice in the season during SMW 28th and 29th SMW whereas 4 times, i.e. SMW 28, 29, 33, and 38 in FP. In IPM whitefly population was just below the ETL during SMW 30 and 33.

Similarly, population of leafhoppers in IPM was lower compared to FP and which was statistically significant (P=<0.05) during most of the SMW (Table 1). In contrast to whitefly, leafhoppers population showed a decreasing trend in 2017>2018>2019 both in IPM (2.81, 2.66, 2.09) and FP (4.36, 3.21, 2.93). This could be due to the reason that earlier farmers were mainly focusing on whitefly because of its fear and loose attention on leafhoppers population buildup and applied insecticides that were specific for whitefly control such as spiromesifen, pyriproxyfen and buprofezin. In the later years, farmers used insecticide flonicamid which was effective against both whitefly and leafhoppers.

Thrips population was high (>30 thrips/3 leaves) during all 3 years between 27–35 SMW with its peak (50–190/3 leaves) between 29–33 SMW in both IPM and FP. In contrast to leafhoppers, population (average of the season) of thrips (Table 1) showed gradual increasing trend during 2017<2018<2019 in both IPM and FP fields. This increasing trend in thrips population could be due to the favourable weather conditions and application of insecticides which are more effective against whitefly compared to thrips.

Moths of bollworms of all species including PBW were trapped during July–October in pheromones traps of respected species. But population was below ETL and no boll damage was found, however the leaf damage by *Spodoptera litura* was observed in traces.

Natural Enemies: Among natural enemies, predators *Chrysopids* was highest followed by the ladybird beetles and spiders. The population of all predators was significantly higher in IPM compared to FP during most of the SMW. Pooled data (average of 3 years) indicated that IPM fields recorded a significant increase in chrysopids (390%), spiders (366%) and coccinellid (207%) population over FP. Tanwar *et al.* (2007) demonstrated that natural enemies predators also help in reducing the pest population in cotton. Parasitization (average of 2 years) of whitefly nymphs by *Encarsia* spp was 35.32–45.98% in IPM whereas in FP it was 14.87–37.83%. Parasitization was at par in the month of July in both IPM (46%) and FP (38%). Thereafter, the parasitization in FP fields reduced significantly in September (IPM 56%, FP 21%) and October (IPM 35%, FP 15%) due to the indiscriminate application of insecticides. The population of natural enemies was higher in IPM compared to FP due to the avoidance of insecticides that are harmful to natural enemies and belongs to IOBC class 4 Kumar *et al.* (2016), which ultimately contributed to the regulation of pest population substantially. Similar to this study, Karut and Akdagcik (2006) noticed the highest nymphal parasitization, i.e. 77.6 by *E. lutea* on cotton crop. Recently, Rawal *et al.* (2018) recorded highest parasitization (32.1%) of whitefly nymphs on Bt cotton in the Hisar district. Contrary to present study, Sangha *et al.* (2018) reported comparatively lower parasitization by *Encarsia spp* on whitefly nymphs (5.20%) on cotton in Punjab.

Socio-economic analysis: IPM implementation resulted in a significant reduction (average of 3 years) in the number of insecticides (Table 2) spray (>58%) and active ingredients (>86%) in IPM fields compared to FP fields. Analysis of the

Table 1 Pest and beneficial scenario in cotton IPM and FP fields close to kinnow orchards

Sucking pest and predator	2017			2018			2019			Pooled mean		Per cent change in IPM over FP
	IPM* (range)	FP* (range)	SMW with P=<0.05	IPM* (range)	FP* (range)	SMW with P=<0.05	IPM* (range)	FP* (range)	SMW with P=<0.05	IPM*	FP*	
Pests												
Whitefly	8.46 (0.28–28.39)	12.58 (0.51–34.61)	26–40, 42–43	11.94 (3.33–28.37)	15.25 (7.03–25.91)	26–28, 31–37, 39–43	12.92 (1.13–33.40)	16.43 (5.25–26.55)	26, 28–30–31, 33–35, 38,40, 41	11.11	14.75	-24.7
Leafhopper	2.81 (0.16–18.19)	4.36 (0.52–23.89)	26, 26–31, 35–36, 38–40, 42–43	2.66 (0.49–11.52)	3.21 (0.89–9.03)	26, 28, 30 33, 35–38	2.09 (0.00–11.95)	2.93 (0.15–11.9)	26–31, 33–36, 38–42	2.52	3.50	-28
Thrips	33.95 (11.18–107.54)	33.43 (4.1–94.63)	27, 29–31, 33, 35, 37–40	53.67 (15.27–139.14)	59.56 (14.91–130.93)	31	75.92 (0.00–188)	80.04 (0.00–191.5)	26, 37	54.51	57.68	-5.5
Predators												
Chrysopid	0.33 (0.10–0.55)	0.01–(0.00–0.11)	28–43	0.45 (0.06–1.82)	0.21 (0–0.90)	29, 31-32, 34–39	0.50 (0.15–1.0)	0.12 (0.00–0.4)	29-43	0.33	0.07	390
Lady bird beetle	0.23 (0.00–0.44)	0.02 (0.00–0.06)	29–43	0.15 (0–0.41)	0.07 (0–0.26)	28, 30–35	0.05 (0.00–0.35)	0.05 (0.00–0.25)	31–43	0.14	0.05	207
Spiders	0.17 (0.00–0.49)	0.01 (0.00–0.03)	28-43	0.15 (0–0.31)	0.07 (0–0.55)	26, 30, 31–32, 34, 36–41	0.24 (0.00–1.10)	0.04 (0.00–0.2)	26, 30, 31–35, 37–43	0.19	0.04	366

*Figures are the average of the season 18 weeks (26–43 SMW) with 80 observations per week; Values in the bracket are range throughout the season; **SMW, Standard Metrological Week when mean are significantly different with P<0.05 using t-test; Whitefly, adults/3 leaves; leafhoppers, nymph and adults/3 leaves; thrips, Nymph and adults/3 leaves; Coccinelid, adult beetles/plant; Chrysopid, egg and larvae/plant; Spider, Adults and spiderlings/per plant.

Table 2 Pesticides use and economics of IPM and FP in cotton at Fazilka, Punjab

Variable	2017		2018		2019		Pooled mean (average of 3 years)		Per cent change in IPM over FP
	IPM	FP	IPM	FP	IPM	FP	IPM	FP	
Number of chemical pesticides sprays	3	9	3.20	7	2.71	5.29	2.97	7.1	-58.14
Active ingredient (kg/ha)	0.537	6.071	0.75	3.07	0.352	2.787	0.54	3.97	-86.25
Seed cotton yield (q/ha)	30.00	22.5	30.30	26.67	27.5	22.5	29.26	23.89	22.50
Gross Income (₹ lakh/ha)	1.500	1.125	1.666	1.466	1.512	1.237	1.55	1.27	22.20
Cost (₹lakh /ha)	0.618	0.674	0.554	0.621	0.618	0.620	0.59	0.63	-6.52
Net Income (₹lakh/ha)	0.882	0.450	1.112	0.845	0.894	0.616	0.96	0.63	51.12
B:C Ratio	2.43	1.67	3.00	2.36	2.45	1.99	2.62	2.00	30.89

Market price of seed cotton @ ₹5000/qt in 2017 and ₹5500/qt in 2018 and 2019.

year-wise pesticides used by IPM and FP farmers indicated that in IPM fields number of sprays were almost remained the same (3 sprays) in all the 3 years except in 2019 (2.71) whereas in FP number of sprays and amount of active ingredient (kg/ha) reduced to a great extent in successive years with 9 sprays in 2017; 7 in 2018 and 5.29 in 2019. The important reason behind this is increased awareness through horizontal learnings about the cotton IPM and whitefly management among the FP farmers as well as the availability of quality pesticides and awareness created by the ICAR-National Centre for Integrated Pest Management, State Agriculture Department, and SAU. During the meeting, farmers informed that pesticide exposure-related illness case of agriculture workers in the villages has been reduced by >90%. This was due to the increased awareness about the harmful effect of pesticides and safe handling of pesticides through the IPM programme.

The pooled (3 years average) data on yield and economics revealed that IPM implementation resulted in a >22% increase in yield, >5.5% reduction in input cost and >51% increase in net profit compared to FP. The benefit cost (B:C) ratio in IPM was 2.62 whereas in FP it was 2.00. Overall IPM farmers earned ₹33000/ha extra income over FP.

The increase in yield in IPM fields was mainly because of good agriculture practices including foliar application of potassium nitrate (NPK 13:0:45) which helped in maintaining plant vigour under insect pressure, thereby helping the plant to compensate the damage done by the pests. Bala *et al*. (2018) and Kumar *et al.* (2021) also reported that high levels of potassium enhance secondary compound metabolism and reduce carbohydrate accumulation, and plant damage from insect pests. It was also observed that traces of plants infected with cotton leaf curl disease virus with severity grade 1–2 recovered by the application of potassium nitrate (2%) and produced flower and fruit like normal healthy plants. Pervez *et al.* (2007) reported that the mild intensities of Cotton leaf curl virus disease in cv. NIAB-Karishma at day 30, 60 and 90 after sowing were negatively correlated with increasing doses of potassium fertilizer.

Organization of Farmer's field school (FFS) at regular intervals in the village enabled farmers to identify the pests and natural enemies, understand the role of pest monitoring, weed removal, the concept of ETL and need-based application of safer pesticides for whitefly management. FFS also helped in developing strong linkages among farmers, scientists and extension workers. The previous studies by various workers Kumar *et al.* (2011), Chandi *et al*. (2015), Birah *et al*. (2019), Kumar *et al.* (2021) revealed that the application of IPM components, clean cultivation, balanced use of fertilizers, 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 the 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) reported that, insecticide usage can be reduced by adopting the IPM module. It has been reported that neem seed kernel extract is safe to parasitoids and predators (Tanwar *et al*. 2006). Saravanan *et al*. (2015) also reported that IPM technologies were successful in managing the Bt cotton pests. In the present study, flonicamid 50 WDG was found very effective in managing whitefly and leafhoppers population below ETL with conservation of natural enemies, which is in accordance of the finding of Naik *et al.* (2017) who reported flonicamid as a safer and most effective insecticide for sucking pests of cotton.

Large scale validation of IPM in cotton fields prone to whitefly attack in the vicinity of kinnow orchards for 3 years in farmers' participatory mode, concluded that the validated integrated pest management strategy is highly effective in managing whitefly and other pests problems along with conservation of natural enemies with high benefit cost (B:C) ratio and is adoptable under farmers field conditions in north zone of the country.

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