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Validation of IPM strategy in Bt cotton in whitefly (*Bemisia tabaci*) hot spot of North-West India

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ABSTRACT

Bt cotton has witnessed the increasing infestation of sucking pests especially whitefly during last one decade. During 2015, whitefly (*Bemisia tabaci* Ishii) emerged as a serious pest in North India destroyed 2/3 of the cotton crop in Punjab. There was an urgent need to validate integrated pest management (IPM) strategy for management of whitefly in Bt cotton in hot spot area with farmer's participatory mode. To overcome the problem, ICAR-NCIPM initiated a trial on validation of IPM in cotton at Fazilka, Punjab in 2.5 ha during 2016, which was extended to 12 ha and 40 ha area in the year 2017 and 2018 respectively. The validated IPM strategy included timely sowing of recommended cotton hybrid, removal of weed as 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. IPM implementation resulted in successful management of whitefly and other pests with significant increase in population of natural enemies predators along with significant reduction in the number of insecticides spray (>68%) and amount of active ingredients (>84%) in IPM fields as compared to FP (Farmer's practice) fields. IPM implementation also brought > 18% increase in yield, > 17% reduction in input cost and >90% increase in net profit compared to FP. The benefit-cost ratio in IPM was 2.55 against 1.88 in FP.

Keywords: Cotton, IPM, Natural enemies' conservation, Sucking pests, Whitefly

Cotton is an important cash crop in India. Losses due to insect pests are the serious concerns of the farmers throughout the season. With the introduction of Bt cotton in 2002 in India the pest scenario has been changed. Bollworm complex, considered to be major pests have been reduced to minor, whereas the sucking pests have emerged as serious pests due to absence of genes tolerant to sucking pests. Bt cotton has witnessed the increasing infestation of sucking pests especially whitefly during last one decade. The whitefly (*Bemisia tabaci* L.) epidemic of 2015 ravaged the 2/3rd of cotton crop in Punjab on an estimated 1.38 lakh ha out of 4.36 lakh ha and 15 farmers committed suicides (Varma and Bhattacharya 2015). It has affected about two-thirds of standing cotton crop in Punjab causing an estimated loss of ₹ 4200 crore (Anonymous 2015). Indiscriminate and injudicious use of pesticides by farmers further deteriorates the pest situation. There was an urgent need to develop, validate and promote an eco-friendly technology for management of pests in farmers' participatory mode. With this view ICAR-NCIPM initiated a trial on validation of IPM strategy in whitefly hot spot in Fazilka (Punjab, India) in 2016 in collaboration with ICAR-CICR Regional Station, Sirsa and PAU Regional Research Station, Abohar. The IPM strategy was formulated based on information base available with ICAR-CICR, Nagpur.

MATERIALS AND METHODS

Fazilka (Punjab, India) is considered to be the hot spot of cotton whitefly (Central Team Survey Report 2016). Nihalkhera (30.230774 N, 74.116719 E) of block Khuiyan Sarwar of district Fazilka was selected for conducting trial during 2016–18.

Collection of baseline information: The baseline information was collected by interviewing 25 cotton growing farmers of Nihalkhera village 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 attained by the farmers.

IPM strategy: IPM module was based on the management strategy for Bt cotton by ICAR-CICR,

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Nagpur for North Zone and ICAR-NCIPM, New Delhi. IPM module included timely sowing of crop up to 15th May with recommended hybrids (RCH 773, RCH 776), pest monitoring at weekly interval, installation of yellow sticky traps (30×10cm) 40 per acre in the month of June, installation of pheromone trap for American bollworm, spotted bollworm and *Spodoptera litura* Fabricious (2 trap/ha) and pink bollworm (1 trap per ha), conservation of natural enemies by planting border row of bajra/sorghum, cowpea; avoiding injudicious application of harmful insecticides, use of bio-rational pesticides which includes neem and need based application of insect growth regulators (IGRs). Farmers' field schools were conducted at regular interval to educate farmers about the identification of pests and natural enemies, ETL of pests, judicious use of pesticides, balance plant nutrition which includes 4 spray of 2% potassium nitrate at weekly interval started from flowering stage etc. IPM fields were compared with Farmers' practice (FP) fields. In IPM fields relatively safer chemical insecticides (Kumar *et al.* 2016) mostly IGRs were used and only 3 sprays of chemical insecticides were sufficient to manage pest problems. During 2016 one sprays of each insecticides, viz spiromesifen 22.9 SC @ 600 ml/ha, diafenthiuron 50 WP @600 g/ha and ethion 50 EC @ 1000 ml/ha was required. During 2017 and 2018 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. In FP fields farmers has applied 6-13 sprays of chemical insecticides with mixture of 2-3 chemical as tank mix at a time. The logic behind the selection of insecticides for use in IPM field was based upon mode of action of insecticides and the stage of whitefly and population of other sucking pests like jassid and thrips along with whitefly. Spiromesifen/buprofezin was applied whenever only nymphal population of whitefly was present in high number; if whitefly adults, nymph along with jassid population was high flonicamid was the choice; whenever thrips population was high along with whitefly and jassid, diafenthiuron was applied.

The whole IPM strategy was validated in 2.5 ha, 12 ha and 40 ha area in the year 2016, 2017 and 2018, respectively. The area under IPM was gradually increased with increase in awareness and development of trust among the farming community about the success of IPM. IPM strategy adopted during second and third year was the same as first year except border row of jowar/bajra due to attack of stray animals. However, few farmers could grow 1-2 rows of cowpea as intercrop away from border inside the cotton fields. As per our protocol during 2017 and 2018 yellow sticky traps were installed in the selected designated fields of selected farmers and in rest of the fields whole IPM strategy was applied as per the mentioned IPM strategy except yellow sticky trap and border row of sorghum/maize/bajra to observe the effect of yellow sticky traps. The pests and predators were observed and monitored by the farmers themselves as per the procedure explained during farmers' field school. Decisions for pesticides application were taken as per our advice when the pest population reached ETL (whitefly 6-8/leaf and jassid 2/leaf). The data on number of pesticides applications and yields were recorded.

Observation of pests and natural enemies: Observations were recorded from three leaves, i.e. top middle and lower canopy of the plant for whitefly (adults/3 leaves), jassid (nymph and adults/3 leaves) and thrips (nymph and adults/3 leaves); and whole plant was observed for recording natural enemies predators coccinelids (adults/plant), chrysopids (eggs and larvae/plant) and spiders (adults and spiderlings/plant) at weekly interval. From each one acre field five spots were selected and from each spot five plants were observed.

*Statistical analysis***:** The weekly data of pests and natural enemies were subject to analysis under student't' test using online software OPSTAT.

RESULTS AND DISCUSSION

Baseline information: Baseline information indicated that the farmers were not aware with the concept of IPM, not able to identify pests and natural enemies. The source of plant protection information was mostly from pesticides dealers and only few farmers were in touch with department of Agriculture. Scheduled application of insecticides was done at weekly interval, sometimes twice a week. The total number of insecticides application during 2015 was varied from 15-20 sprays with cocktail of insecticides. Overdose and under dose and mix use of insecticides was common in the village, knowledge of safer/harmful insecticides was lacking. Pesticides poisoning case due to exposure during spray in every season was the common problem. Knowledge of impact of high dose of nitrogen and foliar spray of potassium nitrate, weed removal, timely sowing on pest problems in cotton was lacking. Whitefly and jassid were the important pest problems in the area.

Sucking pests: Results on population (mean of the season) of whitefly indicated low population in IPM as compared to FP and the differences were statistically significant during different SMW (Table 1). The pooled mean population of three years in IPM fields was 10.58, with range of 0.47-30.32 against 14.21 with range of 0.5 to 35.29 adults/3 leaves. Critical analysis of weekly population trend (Fig 1) of whitefly (average of 3 years) indicated that the population in IPM fields crossed ETL only twice in the season during SMW 28th (23.80±6.10) and 30th (22.06 ±2.73) SMW whereas 5 times, i.e. SMW 28, 29, 31, 32 and 38 in FP.

Similar trend of low population in IPM was recorded in jassids also throughout the study 2016–18 (Table 1, Fig 2). The differences were statistically significant at P=0.05% during 28-32, 34 and 38 SMW in 2016 and during most of the SMW in 2017 and 2018.

Thrips population (per three leaves) remained high during all the three years between 27 to 35 SMW in both IPM and FP fields with pooled mean of 44.64 (range 12.08-157.58) in IPM and 51.65 (9.92-158.50) in FP fields.

*Natural enemies***:** Among natural enemies predators (Table-1) Chrysopids were the dominant predators with 0.57 in IPM and 0.10 egg/larvae per plant in FP followed

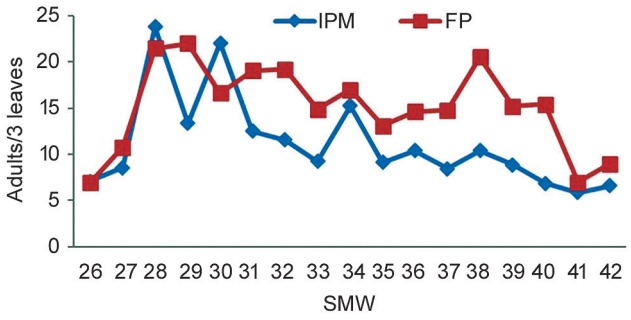

Fig 1 Weekly trend (average of 3 years) of whitefly in IPM and FP during 2016-2018.

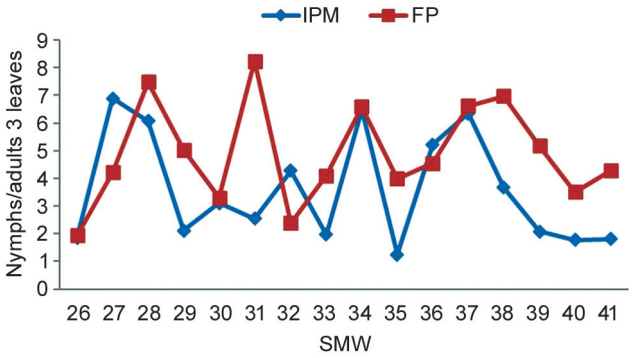

Fig 2 Weekly trend (average of 3 years) of jassid population in IPM and FP:2016-2018.

by the coccinelids (0.30 in IPM and 0.06 adult/plant in FP) and spiders (0.28 adult/young per plant in IPM and 0.11 in FP fields). Population of all predators was significantly higher in IPM fields compared to FP fields. Chrysopid was maximum during 27th to 30th SMW with 0.5 to 1.0 egg/larvae per plant in IPM fields, whereas in FP field population fluctuated between 0.00 to 0.25 per plant. Total sum of all three predators (chrysopid, coccinelid and spiders) indicated that in IPM field population fluctuated near about 1.0/plant during 27-36 SMW. Whereas, in FP fields population was <0.4 per plant and most of the time it was below 0.20 per plant. Tanwar *et al.* (2007) demonstrated that natural enemies predators also helps in reducing pest population in cotton.

During both years, while our personal fields visit, we could observe no visual difference in pest status and crop condition and the farmer's record revealed no difference in pesticides application and yield among the IPM fields with yellow sticky traps and IPM fields without yellow sticky trap. During both the years we found that yellow sticky traps

Table 1 Population of sucking insect pests and predators in Bt cotton in IPM and FP field

Sucking pests and predators	2016			2017			2018			Pooled Mean	
	IPM	FP	SMW*	IPM	FP	SMW*	IPM	FP	SMW*	IPM	FP
Whitefly	8.93 (2.67-27.46)	11.40 (1.88-25.21)	26-32, 34, 35, 37-40, 42	8.37 (0.47 -29.06)	13.77 (0.5-28.15)	30,32-34,36-43	14.44 (9.21-30.7)	17.47 (9.18-35.29)	28-31, 33,35,37	10.58 (0.47 -30.7)	14.21 (0.5-35.29)
Jassid	2.30 (0-6.7)	2.40 (0.25-11.50)	28-32, 34, 38	2.76 (0.26-16.96)	3.46 (0.12-14.14)	24-29, 31, 34, 36, 38-42	3.22 (0.68-15.2)	5.41 (0.60-15.61)	28-31, 33-36, 38, 39, 41-43	2.76 (0-16.9)	3.75 (0-15.61)
Thrips	42.12 (12.83-157.58)	63.55 (9.92-158.50)	26, 28-40	37.47 (12.08-104.0)	37.66 (13.26-108.7)	27-28, 30-33, 35-36, 38-39	54.34 (14.18-113.5)	53.73 (14.77-128.1)	29, 32-35	44.64 (12.1-157.5)	51.65 (9.92-158.50)
Coccinelid	0.40 (0.04-1.13)	0.06 (0-0.42)	30, 33, 34, 35	0.35 (0.01-1.39)	0.06 (0-0.39)	29, 31-43	0.16 (0-0.43)	0.08 (0-0.23)	26-27, 29, 31-33, 35, 40	0.30 (0.04-1.4)	0.06 (0-0.42)
Chrysopid	0.47 (0.06-2.0)	0.11 (0-0.38)	27	0.36 (0.05-1.04)	0.06 (0.0-0.33)	28-43	0.39 (0.08-1.2)	0.15 (0-0.61)	25-27, 29-33, 35-36, 38-39, 41-42	0.57 (0.05-2.0)	0.10 (0-0.61)
Spider	0.42 (0.04-0.71)	0.15 (0-0.17)	26, 28, 29, 33, 34, 35	0.29 (0-1.4)	0.04 (0.00-0.18)	30-43	0.15 (0-0.3)	0.08 (0-0.39)	29-30, 32-33, 36, 39-39, 41	0.28 (0-1.4)	0.11(0-0.39)

Whitefly: adults/3 leaves; jassid: nymph and adults/3 leaves; thrips: nymph and adults/ 3 leaves; Coccinelid: adult beetles/plant; Chrysopid: eggs and larvae/plant; Spider: adults and spiderlings/per plant; *SMW: Standard Metrological week when mean are significantly different with $P<0.05$ using t-test. Values in the bracket are range throughout the season; mean values are the average of 24 to 64 observations.

also attracted number of parasitoids and predators, besides adult whiteflies. Due to avoidance of insecticides which are harmful to natural enemies, population of predators was higher in IPM fields compared to FP fields, which ultimately contributed in regulation of pest population density substantially, resulted in further reduction in need of pesticides application, input cost and increased in net profit.

Socio-economic analysis: IPM implementation resulted in significant reduction (average of 3 years) in the number of insecticides (Table 2) spray (>68%), amount of active ingredients (>84%) and reduction in pesticides cost (65.74%) in IPM fields compared to FP (Farmers practice) fields. If we look at the year wise pesticides use by IPM and FP farmers, which indicated that in IPM fields number of sprays were almost remained same (3) in all the three years, whereas in FP number of sprays and amount of active ingredient reduced to a great extent in successive years with 13 sprays in 2016, 9 in 2017 and 6 in 2018. The important reason behind this is increased awareness among the FP farmers as well, about the cotton IPM and whitefly management through horizontal learning, availability of quality pesticides and awareness created by the ICAR, State Agriculture Department and SAU.

The pooled (3 years average) data on yield and economics (Table 2) revealed that IPM implementation resulted in >18% increase in yield, >17% reduction in input cost and >90% increase in net profit compared to FP. The benefit-cost ratio in IPM was 2.55, whereas in FP it was 1.88. The BC ratio in the successive years increased gradually in both IPM and FP, this was because of reduction in input cost due to better and judicious use of inputs and increase in cotton price.

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 helped plant to compensate the damage done by the pests. Bala *et al.* (2018) reported that high levels of potassium enhance secondary compound metabolism, reduce carbohydrate accumulation and plant damage from insect pests. It was observed that plants infected with ClCuD virus were also found to recover by the application of 2% potassium nitrate and produced flower and fruit like normal healthy plants. Pervez *et al.* (2007) found that the mild intensities of CLCuV disease in cv. NIAB-Karishma at day 30, 60 and 90 after sowing were negatively correlated with increasing doses of potassium fertilizer.

Farmer's field school organized at regular interval in the village helped in developing strong linkages among farmers, scientists and extension workers and enabled farmers to identify the pests and natural enemies, understand the role of monitoring, role of field sanitation and weed removal in whitefly management, concept of ETL and need based application of safer pesticides. Previous study by various workers (Patil *et al.* 2014, Chandi *et al.* 2015 and Birah *et al.* 2019) revealed that the application of IPM components, clean cultivation, balance 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. Dhawan *et al.* (2011) 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 reduced by adopting IPM module. Saravanan *et al.* (2014) also reported that IPM technologies like border cropping, setting up of yellow sticky traps, use of 5% NSKE, use of recommended insecticides on

Table 2 Pesticides application and economics of IPM and FP in Bt cotton

Particulars	2016			2017			2018			Pooled mean		
	IPM	FP	% difference in IPM over FP	IPM	FP	% difference in IPM over FP	IPM	FP	% difference in IPM over FP	IPM	FP	% difference in IPM over FP
Pesticides sprays (Number)	3	13	-84.61	3	9	-66.66	2.8	6	-53.33	2.93	9.33	-68.20
Pesticides active ingredient used (kg/ha)	1.20	10.61	-88.68	0.537	5.625	-90.45	0.49	1.88	-73.94	0.74	6.04	-84.36
Seed cotton yield kg/ha	3521	2842	23.89	3083	2500	23.32	2965	2725	8.81	3190	2689	18.67
Gross income ₹/ha(in thousands)	176.05	142.08	23.91	154.16	125	23.33	163.08	149.88	8.81	164.43	138.99	18.68
*Total cost ₹/ha (in thousands)	77.7	107.24	-34.79	63.11	72.15	-12.53	55.36	58.05	-4.63	65.39	79.15	-17.32
Net income ₹/ha (thousands)	98.35	34.84	182.29	91.05	52.85	72.28	107.72	91.82	17.32	99.04	59.84	90.63
Benefit-cost ratio	2.27	1.32	71.97	2.44	1.73	41.04	2.94	2.58	13.95	2.55	1.88	42.32

Price of cotton @ ₹ 50/kg in 2016, 2017 and ₹55/kg in 2018. *Total cost includes: Cost of seed, fertilizers, land preparation, sowing, irrigation, pesticides, intercultural operations, weeding, spraying, transport, labour for cotton picking, spraying, fertilizer application, sowing, stalk removal, loading unloading.

economic threshold basis etc. were successful in managing the Bt cotton pests. However, the fact came out from this study that fields with yellow sticky trap and without yellow sticky traps recorded no difference in pest population, insecticides spray and yield. This may be due to the fact that yellow sticky trap besides whitefly also attracted natural enemies' parasitoids and predators and cause mortality of both. Hoelmer *et al.* (1998) demonstrated *Eretmocerus eremicus*, a parasitoid of whitefly strongly attracted to the yellow sticky cards. Yellow sticky traps caught the greatest number of other arthropods; these included thrips, flies, cotton leaf perforator (*Buccalatrix thurberiella* Busck) moths; small beetles, and other parasitic wasps. Otherwise these natural enemies might have played role in reducing whitefly population equal to the number whitefly numbers killed by the yellow sticky trap. In the present study Flonicamid 50 WDG was found very effective in managing whitefly and jassid population below ETL with conservation of natural enemies, which is in accordance of finding of Naik *et al.* (2017) who reported Flonicamid as a safer and most effective insecticide for sucking pests of cotton.

Wide scale validation of cotton IPM for three 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 the validated IPM strategy which includes timely sowing of recommended *Bt* hybrids, removal of weed, proper plant nutrition along with foliar spray of 2% potassium nitrate, use of neem based pesticides, avoidance of insecticides which are harmful to natural enemies, judicious use of safer pesticides, is ecologically safe, economically viable, adoptable under farmers field conditions and is highly effective in managing whitefly and other pests with conservation of natural enemies in cotton in North Zone of the country with high net return.

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