Acta Phytopathologica et Entomologica Hungarica 50 (1), pp. 93–103 (2015)
DOI: 10.1556/038.50.2015.1.9

Economic Impact of Dissemination of Management Strategies for Sucking Insect Pests on Transgenic Cotton in Punjab, India

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(Received: 9 October 2014; accepted: 12 November 2014)

Integrated pest management (IPM) strategies for the management of sucking insect pests were disseminated in 36 villages of three districts of Punjab during 2008 to 2010. Adoption of IPM strategies led to reduction in the population of jassid, whitefly and mealybug in IPM villages. Mean population of jassid was 0.62 and 1.60 nymphs per three leaves, whitefly 1.11 and 2.53 adults per three leaves and mealybug 0.53 and 1.03 per 2.5 cm of central shoot in IPM and non-IPM villages, respectively. Mean population of spiders, chrysoperla, coccinellids and predatory bugs was 0.65, 0.13, 0.15 and 0.04 in IPM villages and 0.29, 0.09, 0.06 and 0.00 per plant in non-IPM villages, respectively. IPM strategies resulted in the 47.69 and 50.56 per cent reduction in number of spray and cost of spray in IPM villages over non-IPM villages. The average cost of cultivation was Rs. 21324 ha^{-1} in IPM villages, as compared to non-IPM villages (Rs. 23774.67 ha^{-1}). Average seed cotton yield in IPM villages was 2333 kg ha^{-1} in comparison to non-IPM villages (1959.67 kg ha^{-1}) and average net return in IPM villages was Rs. 57194 ha^{-1}, which was Rs. 15709 more than non-IPM villages.

Keywords: IPM, non-IPM, sucking insect pests, Bt cotton, economics.

Cotton (*Gossypium* spp.) is a major field crop in many countries, constituting a valuable cash crop for many smallholders in developing countries. Cotton, being the most important commercial crop plays a vital role in social and monetary affairs of India. Besides other causes, major bottleneck in cotton cultivation is biotic stresses due to attack of insect pests and diseases, which play a significant role in achieving optimum yield potential. At world level 1326 species of insects harbour cotton plants (Hargreaves, 1948) and in India, 162 insect species have been reported of which nine are of utmost importance inflicting significant losses in yield (Dhaliwal et al., 2004). In Punjab, there has been a change in pest scenario in the last decades. Besides increasing cost of production and environmental problems, the excessive and indiscriminate use of insecticides for the control of these insect pests has resulted in development of insecticidal resistance, decline in natural enemies population and resurgence of the insect pests like whitefly, *Bemisia tabaci* (Gennadius) and jassid, *Amrasca biguttula biguttula* (Ishida). Besides, these, other sucking pests like thrips, *Thrips tabaci* Lindeman hitherto occurring during May–June and aphids, *Aphis gossypii* Glover at fag end of the crop season are also gaining im-

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portance. During 2006, a new sucking pest, mealybug, *Phenacoccus solenopsis* Tinsley appeared in few pockets of Bathinda, Ferozepur and Muktsar districts of Punjab State and caused economic loss (Dhawan et al., 2007). Mealybug, a minor pest, which was earlier supposed to be suppressed with the use of insecticides, attained the pest status. In 2007, this pest wide spread to other parts of the state and became a menace of great challenge for cotton production. Mealybug because of its high reproductive potential, wide host range, powdery/waxy surface of its body and specific feeding behaviour on the apical and lower stem portion of plant is very difficult to control with insecticides only and there is a need of integrated pest management (IPM). Looking into the potential of these insect pests to cause economic losses and sustainability of cotton production, it becomes necessary to develop and disseminate management strategies. Keeping in view the above facts, our main emphasis was to disseminate IPM technologies for the management of sucking insect pests on cotton.

Materials and Methods

Thirty-six villages were adopted for dissemination of IPM strategies for the management of sucking insect pests in three districts *viz*. Muktsar, Bathinda and Ferozepur in cotton belt of Punjab State during 2008, 2009 and 2010. In each of the three districts, four villages were selected for dissemination of IPM strategies during all these years. In Muktsar district villages adopted were Goniana, Chak Tamkot, Chibbran wali, Khunde Halal, Kot Bhai, Lambhi, Khanne ki Dhab, Tharajwala, Kothemannwala, Bharu, Husner and Butter. In Bathinda district villages adopted were Jangi Rana, Pakka Khurad, Kot Guru, Mehma Sawai, Baho yatri, Beer Behane, Bajoana, Kalayan Sukha, Shekhpuara, Bhgwanpura, Lalewala and Nawan Pind. In Ferozepur district villages adopted were Jadnwala Kharta, Korian Wali, Aliana, Ghattian Wali, Mamukhera, Khandwaa Hazarkhan, Thliwala Jatta, Almgarh, Dharangwala, Roorianwali, Khatwan and Cholara. Twelve villages adjoining to IPM villages were kept as check and these constituted the non-IPM villages. Bt cotton (genetically modified cotton variety which expresses Bt genes and produces Bt Cry protein) crop was grown as per recommendation of Punjab Agricultural University, Ludhiana (Anonymous, 2009). All the selected villages were regularly visited twice a week from time of sowing till harvesting to disseminate the IPM strategies and to up scale the knowledge of farmers. Awareness campaign on weed eradication, removal of stacks from fields, sowing of barrier crops and other cultural practices were carried out in these villages. Farmers trainings were conducted to aware the farmers about the recommended varieties, fertilizer application and right use of insecticides. Farmers were given knowledge about spray techniques, judicious use of pesticides and ill effects of tank mixtures of pesticides. Farmers were guided about the benefits of recommended pesticides and harmful effects of unrecommended pesticides on cotton crop. Almost 100 per cent of farmers adopted spot treatment technology and used recommended insecticides for the control of mealybug in adopted villages. At least 50 farmers from each village were selected as a target group for dissemination of IPM strategies. The IPM module of cotton implemented in selected villages is as follows:

Window I (Till 60 days after sowing)
– Timely sowing of recommended Bt cotton cultivars resistant to bollworms and tobacco caterpillar
– Proper spacing and judicious use of fertilizers
– Eradication of weeds in or around the cotton fields to prevent multiplication of mealybug and whitefly
– Avoidance of insecticides for sucking pest in order to conserve the natural enemies, because population of these pests remains below economic threshold level in this period
– Trees and fruit plants near cotton fields harboring mealybug population should be sprayed with recommended insecticides
– Grow maize, pearl millet and sorghum as barrier crops, being least preferred hosts of mealybug

Window II (61–90 days after sowing)
– Regular surveillance and monitoring of insect pests
– Use of recommended insecticides at economic threshold level. For jassid imidacloprid @ 100 ml ha^{-1} or thiamethoxam 25WG @ 100 g ha^{-1}, for whitefly triazophos @ 1500 ml ha^{-1} or ethion @ 2000 ml ha^{-1} and for mealybug buprofezin 25EC or profenophos 50EC @ 1250 ml ha^{-1} can be used
– Do not spray against minor lepidopterans

Window III (91–120 days after sowing)
– Use of pheromone traps for monitoring of bollworm moths
– Scouting for whitefly and mealybug populations and need based application of insecticides
– Need based use of novaluron as first spray for the control of tobacco caterpillar and buprofezin for the control of mealybug as spot treatment
– Use of non-chemical methods for control of mealybug
– Avoid using synthetic pyrethroids after September 15 to minimize resurgence of whitefly

Window IV (Prevention of carryover of mealybug during off-season)
– Spray infested plants of cotton after last picking
– Dislodge the mealybug by shredding the infested sticks against ground and destroy them by burying deep in to the soil
– Remove the stacks of cotton stick from the fields and destroy the mealybug by burying them in the soil
– Do not stack the cotton sticks in the field and prevent the movement of sticks from the infested areas to the new areas

Results

Impact of IPM technology

IPM technology was disseminated in adopted villages in which approximately 10723 ha area was covered under cotton and about 2324 farmers followed IPM strategies to control different insect pests, reduce cost of cultivation and increase yield. Also, impact of technology was seen on sowing time and variety selection and all other agronomic practices. The area under cotton hybrids recommended by Punjab Agricultural University, Ludhiana and Genetic Engineering Approval Committee, Government of India was 83.61 and 82.33 per cent during 2008 and 2009. In 2010, area under recommended varieties decreased to 74.25 per cent because of non-availability of seed of recommended varieties. But overall, 80.06 per cent area was grown with recommended varieties in Punjab. The major achievement of this study was that there was negligible area under unrecommended hybrids like Gujrat Bt in the adopted villages.

Incidence of sucking insect pests

The pest incidence in general was below economic threshold level (ETL) in IPM villages and comparatively lower than non-IPM villages. Mealybug was more in 2008 but its population decreased in coming years with the proper dissemination of technology for its management. Population of natural enemies including spiders, predatory bugs and ladybird beetle was more in adopted villages as compared to non-IPM villages during three years.

Mean jassid population was 0.62 nymphs per three leaves in IPM villages and was comparatively lower than non-IPM villages (1.60 nymphs/3 leaves). In IPM villages peak population of jassid was observed during the 31st standard meteorological week (SMW), whereas in non-IPM villages the peak was observed during the 35th SMW. Mean population of whitefly was 1.11 and 2.53 adults per three leaves in IPM and non-IPM villages, respectively. The peak population of whitefly in both IPM and non-IPM villages was observed in the 33rd SMW (Fig. 1). The mean population of mealybug per 2.5 cm of central shoot was 0.53 in IPM and 1.03 in non-IPM villages. Population of tobacco caterpillar was negligible in IPM villages due to the large scale adoption of Bollgard II cotton which provides protection against bollworms as well as tobacco caterpillar, however, in non-IPM villages its population was 0.28 larvae per plant. Population of natural enemies including spiders, chrysoperla, predatory bugs and ladybird beetles was more in IPM villages as compared to non-IPM villages. Among natural enemies, the mean population of spiders, chrysoperla, coccinellids and predatory bugs was 0.65, 0.13, 0.15 and 0.04 in IPM villages and 0.29, 0.09, 0.06 and 0 per plant in non-IPM villages, respectively (Fig. 2).

Survey for mealybug was carried out in adopted villages during 2008–2010. In all the three districts overall mean number of mealybug on weeds in and around cotton fields was 0.59 weed plant (Fig. 3). In districts Ferozepur, Bathinda and Muktsar mean number of mealybug per weed plant was 0.54, 1.03 and 0.19, respectively. Highest number (2.76) was found in district Bathinda during the 27th SMW. On weeds grown at wastelands,

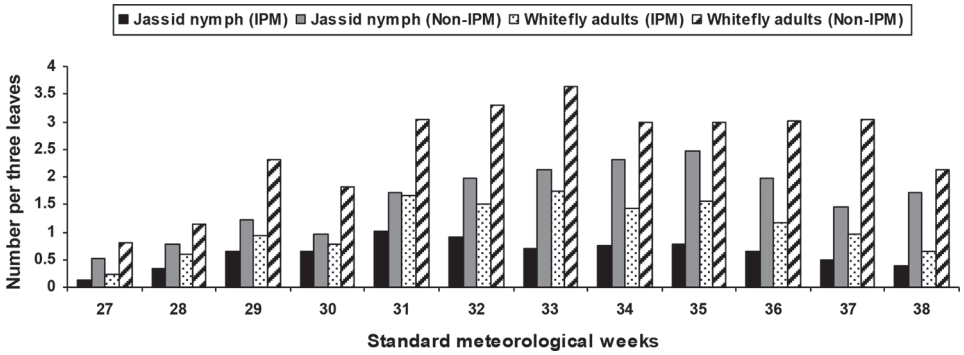

Fig. 1. Incidence of sucking insect pests in cotton during three years in Punjab

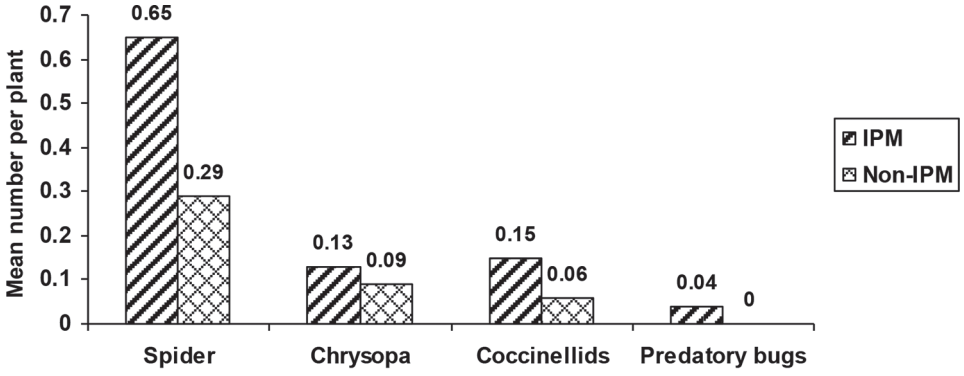

Fig. 2. Population of natural enemies in cotton during three years in Punjab

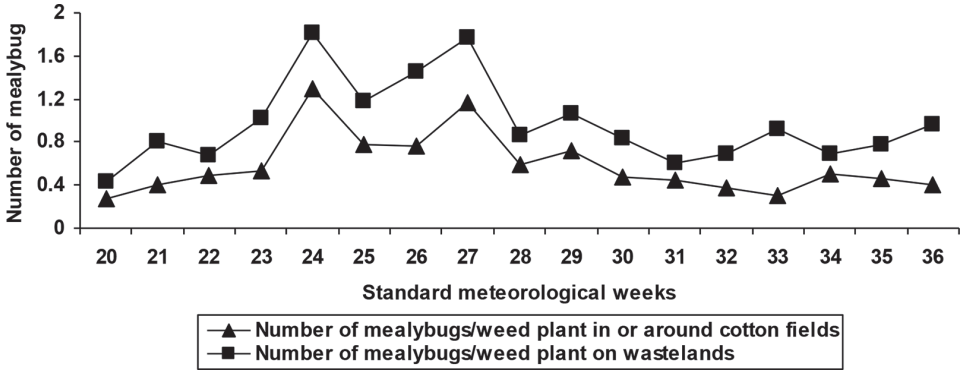

Fig. 3. Incidence of mealybug in IPM villages during three years in Punjab

mean mealybug population was 0.97 mealybugs per weed plant. In districts Ferozepur, Bathinda and Muktsar mean number of mealybug on wastelands was 0.65, 2.10 and 0.30 per weed plant, respectively. Mealybug incidence was reported on weeds like *Parthenium hysterophorus* (congress grass), *Trianthema portulacastrum* (itsit), *Xanthium strumarium* (gutputna), *Amaranthus viridis* (chulai), *Achyranthus aspera* (puthkanda), *Datura stramonium* (datura), *Sida* sp. (kanghi buti) and *Abutilon* sp. (peeli buti).

Number of sprays

Mean number of insecticide sprays for sucking pests, foliage feeders and bollworms were high in non-IPM villages than IPM villages. In Punjab, mean number of sprays were 3.50, 3.79 and 3.36 during 2008, 2009 and 2010, respectively, in IPM villages with overall mean of 3.55 sprays in the three years, whereas, in non-IPM villages mean number of sprays was 8.83, 6.25 and 5.58 during 2008, 2009 and 2010, respectively, with overall mean of 6.89 sprays (Table 1). In 2008, the number of sprays included 0.90 sprays for the control of mealybug but in next two years due to dissemination of mealybug management strategies in adopted villages, no spray was given by the farmers. Per cent reduction in number of sprays was highest in IPM village of Muktsar (48.21%) followed by Bathinda (46.73%) and Ferozepur (44.77%) over non-IPM villages. Mean per cent reduction of sprays was 47.69 in Punjab (Table 2).

Spray cost

Spray cost was also higher in non-IPM villages as compared to IPM villages (Table 2). It was highest in villages of Ferozepur i.e. Rs. 2150.67 and lowest (Rs. 1831.33) in IPM villages of Muktsar district. However, it was Rs. 4518 in villages of Ferozepur district in non-IPM villages. Overall, in three years, mean spray cost was Rs. 1972.33 in IPM villages and Rs. 4323 ha^{-1} in non-IPM villages. Per cent reduction in spray cost was highest in Muktsar (53.49) followed by Bathinda (49.41) and Ferozepur (49.17). In IPM villages of Punjab, per cent reduction in spray cost was 50.56 over non-IPM villages.

Cost of cultivation

In three years, the cost of cultivation was higher in non-IPM villages than IPM villages (Table 1). In Bathinda, it was 21383 ha^{-1} followed by 21330 ha^{-1} in Muktsar and 21260 ha^{-1} in Ferozepur in IPM villages. During three years, cost of cultivation was highest in 2010, because most of the farmers wanted to grow Bollgard II and they purchased seed at high cost, and also in this year attack of whitefly was more and farmers used costly insecticide for the control of this pest which ultimately raised the cost of cultivation (Rs. 26463 ha^{-1}). In Punjab, it was Rs. 21324 ha^{-1} in IPM villages as compared to Rs. 23842 ha^{-1} in non-IPM villages. The per cent reduction in cost of cultivation was 11.31.

Table 1

Impact of cotton IPM technology on economics and net returns in Punjab

District	Years	Total area under cotton (ha)	Number of sprays/ha				Total number of sprays	Cost of sprays (Rs/ha)	Seed cotton yield (kg/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)
			SP	TC	BW	MB*					
IPM											
	2008	365.28	1.60	1.13	0	0.90	3.38	2031.00	2317.00	15865.00	50110.25
Bathinda	2009	1901.00	3.65	0.08	0	0	3.73	1729.00	2451.00	22140.00	55090.13
	2010	1141.50	2.00	1.10	0.40	0	3.40	2054.00	2205.00	26145.00	66476.00
Mean		3407.78	2.42	0.77	0.13	0.30	3.50	1938.00	2324.33	21383.33	57225.46
	2008	336.30	1.93	1.08	0	1.10	4.10	2507.00	2357.00	15028.00	48175.00
Ferozepur	2009	3115.00	3.81	0.11	0	0	3.92	1773.00	2327.00	21630.00	51686.25
	2010	1321.00	2.30	1.30	0.10	0	3.60	2172.00	2329.00	27122.00	70449.00
Mean		4772.30	2.68	0.83	0.03	0.37	3.87	2150.67	2337.67	21260.00	56770.08
	2008	384.84	1.50	0.83	0	0.75	3.00	1604.00	2387.00	15807.00	51042.50
Muktsar	2009	1530.00	3.65	0.08	0	0	3.73	1767.00	2435.00	22063.00	54639.50
	2010	632.00	2.00	1.00	0.10	0	3.10	2123.00	2190.00	26122.00	67089.00
Mean		2546.84	2.38	0.64	0.03	0.25	3.28	1831.33	2337.33	21330.67	57590.33
Non-IPM											
	2008	66.40	3.00	1.60	0.20	3.90	8.70	5680.00	1825.00	21890.00	31047.00
Bathinda	2009	261.00	6.00	0.34	0	0	6.34	3713.00	2042.00	23195.00	41144.00
	2010	366.80	2.20	2.77	0.49	0	5.46	2953.00	1866.00	26955.00	51406.00
Mean		694.20	3.73	1.57	0.23	1.30	6.83	4115.33	1911.00	24013.33	41199.00
	2008	72.50	2.90	1.50	1.20	4.10	9.70	6589.00	1965.00	20268.00	32338.00
Ferozepur	2009	407.00	5.97	0.30	0	0	6.27	3699.00	2089.00	23989.00	41819.00
	2010	449.60	2.22	3.31	0.38	0	5.91	3266.00	1896.00	27377.00	52273.00
Mean		929.10	3.70	1.70	0.53	1.37	7.29	4518.00	1983.33	23878.00	42143.33
	2008	59.60	3.20	1.20	0.20	3.50	8.10	6209.00	2035.00	19962.00	30890.00
Muktsar	2009	288.00	5.86	0.28	0	0	6.14	3629.00	2120.00	24305.00	42487.00
	2010	374.80	2.08	2.80	0.51	0	5.38	3267.00	1831.00	26646.00	50244.00
Mean		722.40	3.71	1.43	0.24	1.17	6.54	4368.33	1995.33	23637.67	41207.00

* Spray for mealybug was spot treatment only; SP – sucking pests, TC – tobacco caterpillar, BW – bollworms and MB – mealybug

Table 2

Per cent reduction in sprays, sprays cost, cost of cultivation and per cent increase in yield

District	Years	Number of sprays			Spray cost (Rs/ha)			Cost of cultivation (Rs/ha)			Yield kg/ha			Additional profit over non-IPM	
		IPM	Non-IPM	% reduction	IPM	NIPM	% reduction	IPM	NIPM	% reduction	IPM	Non-IPM	% increase	Rs/ha	%
Bathinda	2008	3.38	8.70	61.14	2031	5680	64.24	15865	21890	27.52	2317	1825	21.23	19063	38.04
	2009	3.72	6.34	41.32	1729	3713	53.56	22140	23195	4.54	2451	2042	20.02	13946	33.89
	2010	3.40	5.46	37.73	2054	2953	30.44	26145	26955	3.05	2205	1866	15.37	15070	22.66
Mean		3.50	6.83	46.73	1938.00	4115.33	49.341	21383.33	24013.33	11.70	2324.33	1911.00	18.87	16026.33	31.53
Ferozepur	2008	4.10	9.70	57.73	2507	6589	61.95	15028	23989	37.35	2357	1965	16.63	15837	32.87
	2009	3.92	6.27	37.48	1773	3699	52.06	21630	23989	9.83	2327	2089	11.39	9867	23.59
	2010	3.60	5.91	39.09	2172	3266	33.49	27122	27377	1.00	2329	1896	18.59	18176	25.80
Mean		3.87	7.29	44.77	2150.67	4518.00	49.17	21260.00	25118.33	16.06	2337.67	1983.33	15.54	14626.67	27.42
Muktsar	2008	3.00	8.11	63.00	1604	6209	74.16	15807	19962	20.81	2387	2035	14.74	20152	39.48
	2009	3.73	6.14	39.25	1767	3629	51.30	22063	24305	9.22	2435	2120	14.85	12152	28.60
	2010	3.10	5.38	42.38	2123	3267	35.01	26122	26646	1.00	2190	1831	16.39	16845	25.10
Mean		3.28	6.54	48.21	1831.33	4368.33	53.49	21330.67	23637.67	10.34	2337.33	1995.33	15.33	16383.00	31.06
Punjab	2008	3.50	8.83	63.98	2047	6159	66.76	15567	20706	24.81	2354	1941	17.54	18350	36.86
	2009	3.79	6.25	39.36	1754	3649	51.93	21944	23626	7.12	2404	2074	15.91	11988.33	28.95
	2010	3.37	5.58	39.73	2116	3162	32.98	26463	26992	2.00	2241	1864	16.78	16697	24.52
Mean		3.55	6.89	47.69	1972.33	4323.33	50.56	21324.67	23774.67	11.31	2333.00	1959.67	16.74	15709.00	30.11

Seed cotton yield

Seed cotton yield was higher in IPM villages than non-IPM villages (Table 2). In Punjab yield was highest in the year of 2009 (2404 kg ha^{-1}) followed by 2354 kg ha^{-1} in the year 2008 and was lowest in 2010 (2241 kg ha^{-1}). In 2010, yield was low due to dry spell in the beginning and heavy rainfall at flowering stage which ultimately reduced the yield. Per cent increase of yield in IPM villages over non-IPM villages was highest in 2008 (17.54%) followed by 2010 (16.78%) and 2009 (15.91%). Overall in Punjab, yield in IPM villages was 2333 kg ha^{-1} as compared to 1959 kg ha^{-1} in non-IPM villages and per cent increase in seed cotton yield in these villages was 16.74 per cent in three years.

Net profit

Net profit was higher in IPM villages than non-IPM villages (Table 2). It was highest in 2010 (Rs. 68004 ha^{-1}) followed by 2009 (Rs. 53805 ha^{-1}) and 2008 (Rs. 49775 ha^{-1}). Per cent increase in net profit was highest in 2008 (36.86%) and lowest in 2010 (24.52%) over non-IPM. In Punjab, net profit was Rs. 57194 ha^{-1} in IPM villages as compared to Rs. 41485 ha^{-1} in non-IPM villages. Addition profit was Rs. 15709 ha^{-1}. The percent increase in additional profit in Punjab was 30.11.

Discussion

Over the last two decades cotton crop has witnessed a diverse array of pest problems. The problem has arisen primarily because of the increasing trend on the part of the growers to depend mainly on toxic pesticides for pest management. This has exerted a severe impact on the natural enemies' fauna of cotton ecosystem. Further, indiscriminate use of insecticides has resulted in development of resistance in insects and resurgence of new pests besides environmental pollution and public health hazards (Mehrotra, 2000; Kranthi et al., 2002). Insecticide resistance in cotton pests has emerged as a key area of concern in cotton pest management in India. The problem of resistance has rendered insecticides a less useful and reliable tool. If cotton pest management is to be effective, it is necessary to address the problem of resistance to insecticides and devise appropriate proactive management strategies to ensure that it does not continue to impair pest management in the field and management of these insect pests needs judicious use of insecticides based on economic threshold level. At the global level, there is an increasing concern about the ill effects of the increased use of toxic insecticidal chemicals (Dhaliwal and Koul, 2007). India is the largest consumer of pesticides in the South Asian countries and third largest in the world (Dhaliwal et al., 2006). Of the total pesticides used in the country, more than 60 per cent is used in agriculture sector especially cotton crop alone. The consumption of technical grade pesticides is more than 800 g ha^{-1} in Punjab, Haryana, Delhi and Pondicherry, much higher than in the other states of the country (Agnihotri, 2000). This increased use of insecticides has resulted in increasing cost of pest management in addition to environmental pollution and public health hazards. Thus, at present there is a

need to explore the possibility of developing new strategies so that the sole dependence on conventional insecticides can be reduced and sustainability of pest management be maintained. The adoption of an integrated pest management strategy provides a reliable answer to the question of sustainable pest management. Our study showed that with the adoption of IPM strategies, there was less incidence of sucking pests and foliage feeders, higher number of natural enemies in IPM villages as compared to non-IPM villages. There was also reduction in number of sprays, spray cost and cost of cultivation and increase in yield and ultimately the net profit. This is in accordance with results of Kranthi et al. (2000), who reported that with the adoption of IPM strategies, number of sprays for sucking pests and bollworm complex were reduced in North India with 90 per cent reduction in sprays while seed cotton yield increased up to 59 per cent and plant protection cost reduced by 25–60 per cent. Similarly, Dhawan et al. (2011) reported 38.39 per cent reduction in the number of sprays in IPM villages over non-IPM villages with an additional profit of Rs. 14056 per hectare. Surulivelu et al. (2004) also reported 63 per cent reduction in number of sprays at Coimbatore and Theni districts of Tamil Nadu with mean of 2.7 sprays in project villages as compared to 7.3 sprays in the control villages. Similar reports were also given by Rajak et al. (1997) with 30–50 per cent reduction in pesticides consumption in insecticide resistance management (IRM) adopted fields and 21–27 per cent increase in yield. Results of present investigations also conform with Dhawan et al. (2009) who reported that adoption of IRM strategies helped in reduction of cost of spray up to Rs. 1217 ha^{-1}, cost of cultivation up to Rs. 1620 ha^{-1} and overall additional profit of Rs. 5435 ha^{-1} in adopted villages. Dahiya et al. (2014) reported that population of leafhopper, whitefly and thrips throughout the season was (2.36, 6.91 and 8.13 respectively) more in non-IRM villages as compared to IRM villages (1.87, 5.95 and 6.46, respectively). The insecticide usage was more in non-IRM villages compared to IRM villages. However, seed cotton yield, net profit and cost benefit ratio was more in IRM villages as compared to non-IRM villages. Thus, our study showed that with proper dissemination and implementation of IPM technologies in cotton, natural enemies can be conserved, incidence of sucking insect pests can be minimized with reduction in number of sprays, cost of spray. Further dissemination of IPM technologies to other areas is needed to increase the income of farmers with additional benefit of environment conservation.

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