Integrated Pest Management (IPM) Helps Reduce Pesticide Load in Cotton

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ABSTRACT

The adoption of Integrated Pest Management (IPM) strategy by farmers of Bathinda cotton belt of Punjab, India resulted in reduction of insecticidal applications. There was 3-4 times reduction in insecticidal applications in IPM villages (4.86-5.33) over the non-IPM villages (15.16-18.12). A general trend of reduced insecticidal applications of both conventional as well as new insecticides, in IPM villages as compared to non-IPM ones, was observed. However, the use of endosulfan was significantly more in IPM villages (1.07 and 0.85 applications) over non-IPM ones (0.49 and 0.32 applications) in 2002 and 2003, respectively. The use of the remaining insecticides was significantly less in IPM than in non-IPM villages. There was no application of non-recommended insecticides and mixtures in IPM villages while it was observed in non-IPM ones only. Further, farmers in IPM villages showed increased preference for relatively new insecticides (imidacloprid, acetamiprid, thiamethoxam, indoxacarb and spinosad) over the conventional group of chemicals. The adoption of IPM strategies resulted in significantly reduced pest incidence (32-75%), reduced plant protection and total input costs (17-34 and 15-21%, respectively) and an increase in net profit (54-88%) in addition to conservation of natural enemies (0.8-1.0 natural enemies/ plant in IPM over 0.4-0.7/ plant in non-IPM villages).

Keywords: Bollworms, Cotton, IPM, Natural enemies, Sucking pests.

INTRODUCTION

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 enemy fauna of cotton ecosystem and disturbed the so called natural control. Further, this unwise and indiscriminate use of insecticides has resulted in development of resistance in insects and resurgence of new pests (Mehrotra, 2000; Kranthi *et al.*, 2002) besides environmental pollution and public health hazards. Among these different pests *viz.* bollworms [Cotton bollworm, *Helicoverpa armigera* (Hübner), Spotted bollworms, *Earias vittella* (Fabricius) and *E. insulana* (Boisduval), Pink bollworm, *Pectinophora gossypiella* (Saunders)], and sucking pests [Jassid, *Amrasca biguttula biguttula* (Ishida), Whitefly, *Bemisia tabaci* (Gennadius) and Aphid, *Aphis gossypii* Glover], the cotton bollworm (CBW) *H. armigera* has emerged as the most devastating pest of cotton during the last two decades. During certain years when environmental conditions become favorable for its population development like rains in July and August, 25-30^{o}C temperature and high relative humidity, it emerges as a major pest, deciding the fate of cotton yield. It has developed high levels of resistance to most of the commonly used insecticides in the

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country (Mehrotra, 2000). About 50-60 percent loss of seed cotton is attributable to bollworms complex and sucking pests (Dhawan, 2004). The management of these pests needs judicious use of insecticides based on Economic Threshold Level (ETL).

At the global level, there is an increasing concern about the ill effects of the increased use of toxic insecticidal chemicals. According to WHO estimates, there are more than 20,000 fatal poisoning cases due to occupational pesticide exposure that occur annually worldwide (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 percent is used in agriculture sector especially cotton crop alone (Khauta and Gajaria, 1997). 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. Accoding to National Resource Defense Council (NRDC) of USA, one out of every 3,400 children between 1 and 5 years of age could one day get cancer because of pesticides they haphazardly ate as young children (NRDC, 1989). A recent study in cotton growing areas of India, focused on the chronic effects of pesticides on children, revealed that children have displayed lower abilities in cognition, memory, stamina, motor skills and concentration (Anonymous, 2003). The increased pesticide use has also resulted in pesticide residues in many food commodities. Surveys in India have indicated that many of the popular brands of soft drinks contained pesticides 34 times higher than the European Economic Community limit (Mathur *et al.*, 2003). At the India level, 55.1 percent samples of vegetables were found to be contaminated with pesticides, 9.5 percent of these above Maximum Residue Limit (MRL). Similarly, 86.7 and 89.7 per cent samples of milk were contaminated with DDT and HCH, respectively, out of which 43.4 and 77.8 percent were above the MRL (Agnihotri, 1999). Further, the increased use of a limited number of efficacious products year after year leads to loss of the chemicals owing to resistance development in insect-pests. The members of Insecticide Resistance Action Committee (IRAC) warned the European Union legislation against the use of a reduced number of pesticides as it leads to development of resistant pests (IRAC, 2008).

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 (IPM) strategy provides a reliable answer to the question of sustainable pest management. In rice, the adoption of IPM strategy resulted in 50-100% reduction in pesticide use and 6.2-42.1% increase in yield in IPM fields as compared to non-IPM fields during 1994-95 in major rice growing areas of India (Dhaliwal and Arora, 2006). Several strategies have been proposed for cotton pest management in India. However, such strategies have been demonstrated to be successful in localized conditions under scientific supervision and assured supply of inputs. Despite all the reports of successful demonstration of IPM, successful spread of eco-friendly cotton pest management is still far from reality at the farmer's level. Keeping this in mind, the Integrated Pest Management (IPM) program was followed in cotton to reduce selection for resistance based on rational use of insecticides, restriction of treatments and alternation of chemicals with different modes of action (Sawicki and Denholm, 1987). The impact of IPM strategy was evaluated by studying the pattern of insecticide use, reduction in number of sprays, damage by insect-pests, abundance of natural enemies as well as economic gains by farmers.

Table 1. Economic Threshold Levels (ETLs) of major insect-pests of cotton.

Insect-Pest	Economic Threshold Level
Jassid	2 nymphs per leaf or yellowing and curling of leaves along margins on 50% of plants.
Whitefly	6 adults per leaf or appearance of honey dew on 50% of plants.
Aphid	Appearance of honey dew on 50% of plants.
Bollworms complex (Pink, spotted and cotton bollworm)	5% damage in freshly shed fruiting bodies. Repeat spray at 10 day interval or 5 % damage in freshly shed fruiting bodies which so ever is earlier during boll formation period.

MATERIALS AND METHODS

The Integrated Pest Management (IPM) strategy was devised (PAU, 2002) and evaluated in farmer's fields of 10 villages at Bathinda district of Punjab, India during 2002 and 2003 crop seasons. Two villages were selected as control ones during the two years. Cotton crop in these two villages was grown by farmers at their own level with no supervision or guidance on the part of university scientists. Cotton crop in both IPM and non-IPM villages was sown in the second fortnight of April. All the practices for raising a good crop were followed (PAU, 2002). The different IPM strategies included:

- Choice of pest tolerant varieties/hybrids (tolerant to jassid/leaf hopper) (e.g. Ankur 651).
- Seed treatment with imidacloprid 70 WS (5 g kg^{-1} seed) or thiamethoxam 70 WS (3 g kg^{-1} seed) in case of varieties susceptible to jassid/ leaf hopper attack.
- Timely sowing in either April or first fortnight of May to escape bollworms infestation.
- No spray for the first 60 days after sowing.
- Field survey by farmers twice a week to take the necessary control measures against any untimely pest attack.
- Spray decisions based on Economic/Action Threshold Level (ETL) (Table 1).
- Spray of right chemical at the right time and proper dose (Table 2).
- Use of endosulfan as first spray. It is effective in early crop season as during this part of the crop season resistance levels in *Helicoverpa armigera* are low to almost all groups of insecticides. Furthermore it is relatively benign on beneficials (Kranthi *et al.*, 2000; PAU, 2002). Therefore, use of endosulfan is recommended in the early cropping stage against *H. armigera* and leaf hoppers.
- To avoid the use of insecticidal mixtures.
- Alteration of insecticidal sprays from different groups and modes of action.
- To avoid use of synthetic pyrethroids after mid September (PAU, 2002).
- To avoid the use of acephate spray during September as it leads to resurgence of whitefly (PAU, 2002).
- Getting the pesticide from an authorized dealer or source with the bill detailed with batch number, date of manufacture and date of expiry of chemical.

In order to make the IPM programme more successful, farmers in IPM villages were provided with facilities like:

Identification and introduction of insect-pests and natural enemies to the farmers through literature *viz.* colored charts, posters, pamphlets, books, folders, and insect collection boxes having the wet and dry insect specimens.

At village level by farmers' meetings at weekly intervals.

Field trials and demonstrations.

At district level farmers' training camps.

Table 2. Insecticides for the management of cotton insect-pests.

Insecticide	Dose per acre	Brand
I. For sucking pests management		
i) Jassid		
(a) Seed treatment at the time of sowing		
Imidacloprid 70 WS	5 g kg^{-1} seed	Gaucho
Thiomethoxam 70 WS	3 g kg^{-1} seed	Cruiser
(b) Spray		
Imidacloprid 200 SL	40 ml	Imidacel
Imidacloprid 17.8 SL	40 ml	Confidor
Acetamiprid 20 SP	20 g	Pride/Rapid
Thiomethoxam 25 WG	40 g	Actara/Extra Super
ii) Whitefly		
Triazophos 40 EC	600 ml	Hostathion
Ethion 50 EC	800 ml	Fosmite/E-mite/Volthion
II. For bollworms management		
i) Pink and spotted bollworms		
A. Synthetic pyrethroids		
Alphamethrin 10 EC	100 ml	Alphagaurd/Fastac/Merit Alpha
β-cyfluthrin 0.25 SC	300 ml	Bulldock
Cypermethrin 10 EC	200 ml	Ripcord/Bilcyp/Bullet/Ustad/ Cypergaurd
Cypermethrin 25 EC	80 ml	Cymbush/Cyperkill/Hillcyper/ Colt/Basathrin/Agrocyper/ Cypergaurd
Deltamethrin 2.8 EC	160 ml	Decis/Rukrain/Decicare
Fenvalerate 20 EC	100 ml	Sumicidin/Fenval/Agrofen/ Fenlik/Triumphcrd/Milfen
Fenpropathrin 10 EC	300 ml	Mesthrin
ii) Pink, spotted and younger larvae of cotton bollworm		
A. Organochlorine (Cyclodiene)		
Endosulfan 35 EC	1 litre	Thiodan/Endocel
B. Organophosphates		
Profenofos 50 EC	500 ml	Curacron/Carina/Profex/Celcron
Quinalphos 25 EC	800 ml	Ekalux/Quingaurd
Triazophos 40 EC	600 ml	Hostathion
Ethion 50 EC	800 ml	Fosmite/E-mite/Volthion
Monocrotophos 36 SL	500 ml	Nuvacron/Monocil/Monolik
C. Carbamates		
Carbaryl 50 WP	1 kg	Sevin/Hexavin
Thiodicarb 75 WP	250 g	Larvin
iii) Grown up larvae of cotton bollworm		
A. Organophosphates		
Acephate 75 SP	800 g	Orthene/Asataf/Starthene
Chlorpyriphos 20 EC	2 litres	Coroban/Dursban/Durmet/ Chlorgaurd/Radar/Lethal/Force
B. Naturalyte		
Spinosad 48 SC	60 ml	Tracer
C. Oxadiazine		
Indoxacarb 15 SC	200 ml	Avaunt
Indoxacarb 15 EC	200 ml	Avaunt
III. For tobacco caterpillar management		
A. Carbamate		
Thiodicarb 75 WP	250 g	Larvin
B. Organochlorinate		
Endosulfan 35 EC	1 litre	Thiodan/Endocel
C. Organophosphates		
Acephate 75 SP	800 g	Orthene/Asataf/Starthene
Chlorpyriphos 20 EC	2 litres	Coroban/Dursban/Durmet/ Chlorgaurd/Radar/Lethal/Force
Quinalphos 25 EC	800 ml	Ekalux/Quingaurd

Note: Insecticides for jassid management are also effective against aphids.

Street plays at village level to enhance farmers' knowledge concerning side effects of indiscriminate use of insecticides.

Setting up of Farmers' Information Centres at village level with placement of one scout per information centre.

Solution of farmers' problems on untimely pest attack, through field visits and meetings by university staff.

Solution of farmers' problems through phone calls.

From each of IPM and non-IPM villages, 10 farmers were selected by following simple random sampling method to record the data on pesticide use, incidence of insect-pests and damage, population of natural enemies and inputs used by them throughout the crop season. The data were taken from one acre field each at weekly intervals. The jassid and whitefly population was recorded by observing the number of nymphs and adults respectively, from three fully formed leaves in upper plant canopy from 12 randomly selected plants (three plants/quarter) in the one acre field. The data on bollworms damage in intact fruiting bodies were recorded on per plant basis from 12 randomly selected plants while that for shed fruiting bodies, 25 freshly shed fruiting bodies were collected from each quarter of field to record percent bollworms' damage. The data on population of various natural enemies were recorded on per plant basis from 12 plants selected at random. The pesticide application and other input use data from sowing till last picking were recorded from individual farmers. The whole cotton season was divided into window system i.e. up to first week of July (Window I), second week of July to mid August (Window II), second fortnight of August (Window III) and September-October (Window IV) (PAU, 2002). The mean number of insecticidal applications of different chemicals in each window and in the whole crop season, mean pest and natural enemies' population and total input costs were calculated. The data were subjected to analysis by Student's t test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Insecticide Use Pattern

During both the years i.e. 2002 and 2003, no spray of insecticide was used by farmers in either IPM or non-IPM villages in Window I (Table 3). However, sprays were used in the successive windows.

In organochlorines group, endosulfan is recommended as first spray since it is relatively safe to natural enemies. Its use was significantly more in IPM villages i.e. 1.07 and 0.85 sprays as compared to that in non-IPM villages i.e. 0.49 and 0.32 sprays, in 2002 and 2003, respectively. This reflects the increase in knowledge of farmers in IPM villages about the use of chemicals safe to natural enemies. For the control of sucking pests especially jassid, imidacloprid, thiamethoxam and acetamiprid were used. The total number of sprays of imidacloprid/thiamethoxam was significantly less being 0.20 and 0.88 in IPM as against 0.36 and 1.19 in non-IPM villages during 2002 and 2003, respectively. Acetamiprid was not used against jassid in 2002 in either of IPM and non-IPM villages, while in 2003, its use was significantly more (0.20 sprays) in non-IPM villages over the IPM ones (0.01 sprays).

In case of organophosphates, total number of sprays of triazophos/ethion targeted against whitefly and bollworms, was although significantly low (0.72) in IPM villages over non-IPM ones (0.93) in 2002, but in 2003 an opposite trend was observed. It may probably be due to untimely attack of spotted bollworms and whitefly in those villages. This opposite trend of increased use of sprays in IPM villages (0.60) over non-IPM ones (0.49) was also observed in case of monocrotophos in 2002, whereas in 2003, the total number of sprays remained significantly low (0.16) in IPM villages over non-IPM ones (0.40). The maximum use of

Table 3. Insecticide use pattern in Bathinda cotton belt of Punjab, India during 2002 and 2003 cotton crop seasons.

Insecticide group	Insecticide used	Target pest	Average number of sprays with different insecticides (during different periods)															
			IPM villages								Non-IPM villages							
			W-II [a]		W-III [b]		W-IV [c]		Total		W-II		W-III		W-IV		Total	
			2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Organochlorinated (OC's)	Endosulfan	BW complex	0.56	0.22	0.27	0.60	0.24	0.03	1.07	0.85	0.33	0.20	0.04	0.12	0.12	0.00	0.49	0.32
Chloronicotinoids	Imidacloprid/Thiamethoxam	Cotton leaf hopper/ Jassid	0.04	0.16	0.12	0.54	0.04	0.18	0.20	0.88	0.12	0.20	0.12	0.70	0.12	0.29	0.36	1.19
	Acetamiprid		0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.06	0.00	0.14	0.00	0.20
Organophosphates (OP's)	Triazophos/Ethion	BW [d]/Whitefly	0.00	0.06	0.24	0.15	0.48	0.15	0.72	0.36	0.00	0.06	0.60	0.06	0.33	0.00	0.93	0.12
	Monocrotophos	BW complex	0.08	0.07	0.33	0.07	0.19	0.02	0.60	0.16	0.00	0.10	0.08	0.00	0.41	0.30	0.49	0.40
	Quinalphos/Profenofos	BW complex	0.00	0.10	0.08	0.18	0.45	0.25	0.53	0.53	0.00	0.01	0.18	0.00	0.65	0.12	0.83	0.13
	Acephate/Chlorpyriphos	CBW [e]	0.00	0.00	0.12	0.05	0.56	0.24	0.68	0.29	0.00	0.08	0.48	0.18	0.67	0.28	1.15	0.54
Carbamates	Carbaryl/Thiodicarb	BW complex	0.00	0.00	0.00	0.00	0.04	0.02	0.04	0.02	0.00	0.00	0.08	0.00	0.00	0.00	0.08	0.00
Synthetic pyrethroids (SPs)	Cypermethrin/Alphamethrin /Deltamethrin/Fenvalerate	SBW [f]	0.12	0.05	0.48	0.32	0.12	0.07	0.72	0.44	0.12	0.08	0.34	0.76	0.42	0.41	0.90	1.25
Naturalite/Oxidiazine	Indoxacarb/Spinosad	CBW	0.00	0.00	0.12	0.17	0.18	1.62	0.30	1.79	0.00	0.00	0.24	0.45	0.33	1.41	0.57	1.86
Combinations	SP+Monocrotophos	CBW	--	--	--	--	--	--	--	--	0.67	0.50	0.18	0.25	0.96	0.16	1.81	0.91
	SP+Quinalphos/Profenofos	BW complex	--	--	--	--	--	--	--	--	0.20	0.15	0.67	0.58	0.45	0.80	1.32	1.53
	SP+Acephate/Chlorpyriphos	BW complex	--	--	--	--	--	--	--	--	0.67	0.40	0.67	0.35	0.86	0.45	2.20	1.20
	SP+Triazophos/Ethion	CBW	--	--	--	--	--	--	--	--	0.30	0.25	1.81	0.88	3.12	3.53	5.23	4.66
	SP+Endosulfan	BW complex	--	--	--	--	--	--	--	--	0.44	0.42	0.17	0.15	0.00	0.06	0.61	0.63
Miscellaneous (unrecommended)	Lambdacyhalothrin, DDBP, methomyl etc.	BW complex	--	--	--	--	--	--	--	--	0.25	0.26	0.48	0.40	0.42	0.06	1.15	0.72
Total			0.80	0.66	1.76	2.09	2.30	2.58	4.86	5.33	3.10	2.71	6.14	4.94	8.86	8.01	18.12	15.66
t ($p \leq 0.05$)			0.20	0.16	0.15	0.16	0.14	0.16	0.15	0.16								

[a] Window II; [b] Window-III; [c] Window-IV; [d] Bollworms; [e] Cotton bollworm, [f] Spotted bollworms.

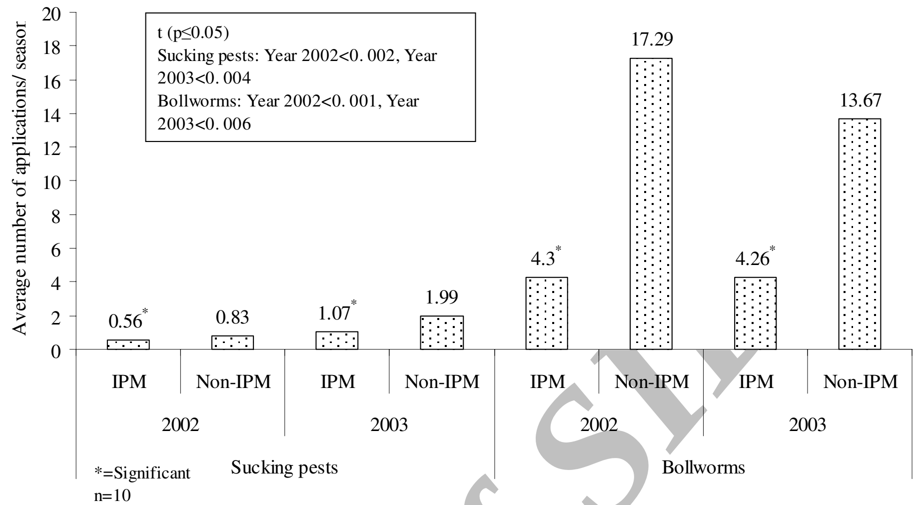

Figure1. Number of insecticidal applications against sucking pests and bollworms in IPM and non-IPM villages during 2002 and 2003.

quinalphos/ profenofos was observed in September-October (Window IV) for the control of bollworms (*Earias* spp. and *H. armigera*). Again, the number of sprays in IPM villages remained significantly lower (0.53) than those in non-IPM villages (0.83) in 2002. Almost similar trend of less number of sprays of acephate/chlorpyriphos in IPM villages over non-IPM ones was observed as in other insecticides for the CBW, *H. armigera*. An opposite trend of increased use of quinalphos in IPM villages (0.53 applications) (Table 3) over non-IPM (0.13) villages was reported in 2003. It is important to mention here that the use remained similar to that in 2002 (0.53 applications), however, it declined in non-IPM as farmers shifted to acephate/chlorpyriphos (0.54 applications) in 2003 than in IPM (0.29 applications). Similar reasons can be assigned to increased use of monocrotophos in 2002 in IPM villages (0.6 applications) whereas more number of sprays of acephate/chlorpyriphos (1.15) were applied in non-IPM villages.

In carbamate group, carbaryl and thiodicarb were employed against bollworms and tobacco caterpillar, *Spodoptera litura* (Fabricius). Here again, a similar trend of less number of sprays in IPM villages was observed, as in other chemicals, except in 2003 where no use was recorded in non-IPM villages.

Synthetic pyrethroids were employed for the control of spotted bollworms (SBW, *Earias* spp.). Their maximum use was recorded after mid August i.e. in Window III and IV. The total number of sprays of these chemicals was 0.72 and 0.44 in IPM villages being significantly less than those in non-IPM villages i.e. 0.90 and 1.25 in 2002 and 2003, respectively.

The new chemicals i.e. indoxacarb and spinosad were preferred more by farmers for the control of CBW over conventional groups. Their maximum use was reported in Window III and IV in both years of the study. In 2002, there were 0.3 sprays in the IPM villages as against a significantly more number of sprays (0.57) in the non-IPM villages. A similar trend was observed in

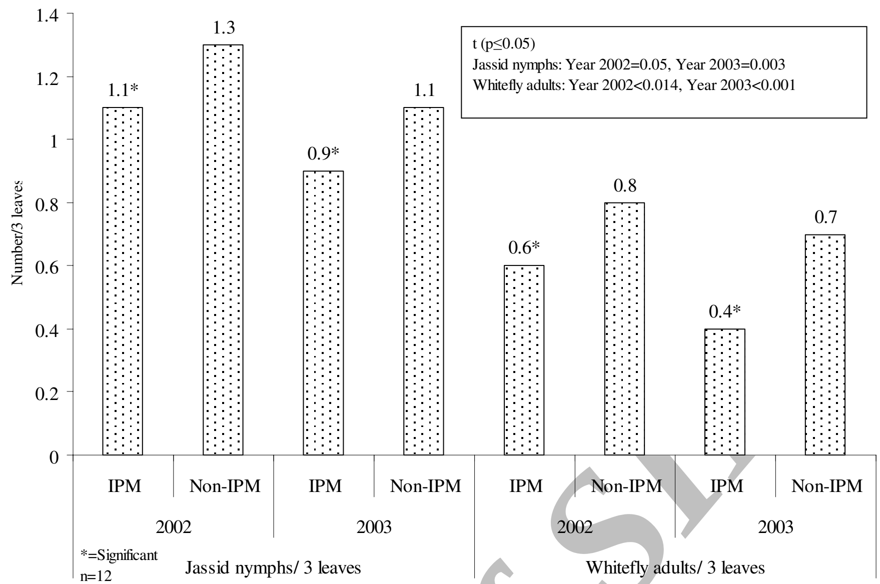

Figure2. Incidence of sucking pests in IPM and non-IPM villages in 2002 and 2003.

2003, however, there was an increase in number of sprays in IPM (1.79) and non-IPM villages (1.86). The lesser number of sprays in 2002 were due to a very less population build up of CBW as it was a drought year.

Farmers in non-IPM villages used various mixtures of insecticides for the control of different insect-pests of cotton. However, no such insecticidal mixture was used in IPM villages, as use of mixtures is not recommended in Punjab. Similarly, there was no spray of un-recommended insecticides in IPM villages while these were used in non-IPM villages.

The mean number of insecticidal sprays targeted against sucking pests and bollworms are presented in Figure 1. There were 0.56 and 1.07 insecticidal applications against sucking pests in IPM villages as compared to 0.83 and 1.99 in non-IPM villages in 2002 and 2003, respectively. The respective reduction in number of sprays was 32.53% and 46.23% in IPM over non-IPM villages in 2002 and 2003. A similar trend was observed for insecticidal sprays targeted against bollworms with 4.30 and 4.26 sprays in the IPM villages as compared to 17.29 and 13.67 in the non-IPM ones in 2002 and 2003, respectively. There was 75.13 and 68.83 percent reduction in number of sprays in the IPM over non-IPM villages in 2002 and 2003, respectively.

Pest and Natural Enemies' Incidence

Despite the reduced number of insecticidal applications in IPM villages, the incidence and damage by sucking pests and bollworms remained lower than that in non-IPM villages (Figures 2 and 3). The population of sucking pests i.e. jassid and whitefly was significantly lower in the IPM villages than that in the non-IPM villages in both years. Mean jassid population in crop season was 1.1 and 0.9 nymphs/3 leaves in the IPM villages as compared to 1.3 and 1.1 nymphs/3 leaves in the non-IPM villages in 2002 and 2003, respectively (Figure 2). Similarly, the incidence of whitefly was lower (0.6 and 0.4 adults/3 leaves) in IPM villages than in non-IPM ones (0.8 and 0.7 adults/3 leaves) in 2002 and 2003,

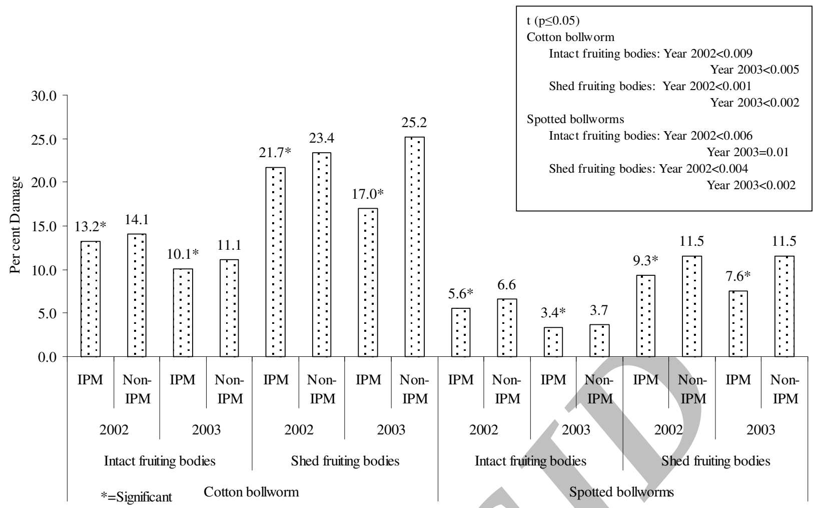

Figure 3. Percent damage by bollworms in intact and shed fruiting bodies in IPM and non-IPM villages during 2002 and 2003.

respectively. A similar trend was observed with respect to percent damage by cotton bollworm and spotted bollworms in intact and shed fruiting bodies for both years wherein significantly lower damage was reported in IPM than for non-IPM villages (Figure 3). On the other hand, the population of natural enemies was higher in the IPM than in the non-IPM villages. Among the different natural enemies *viz.* spiders, predatory bugs, coccinellids (*Coccinella septempunctata* and *Cheilomenes sexmaculatus*) and *Chrysopa*, spiders (*Oxyopus* sp., *Neoscona* sp.) were the dominant predators of sucking pests and small larvae of bollworms as well as *Spodoptera litura* throughout the crop season. In the IPM villages the mean incidence was 0.8 and 1.0 of natural enemies/plant, higher than that observed in

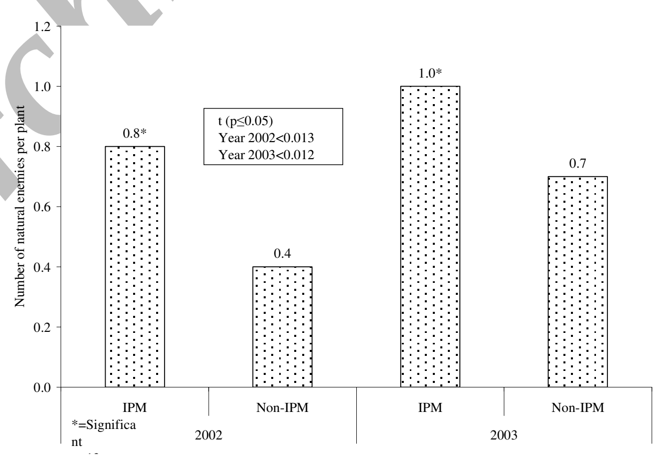

Figure 4. Population of natural enemies in IPM and non-IPM villages in 2002 and 2003.

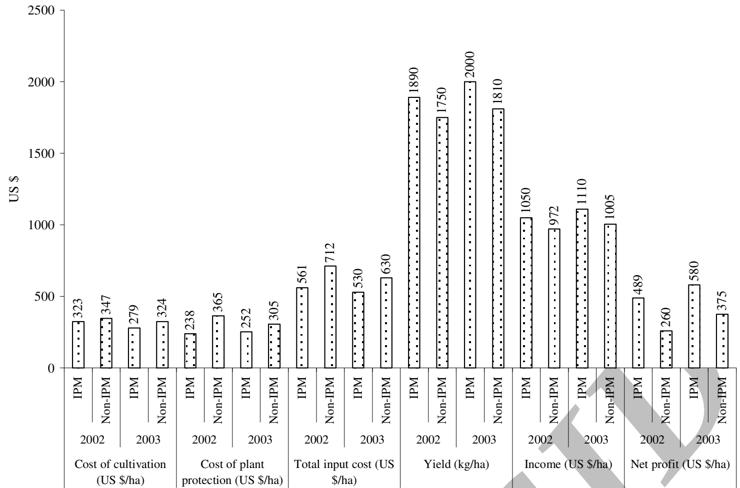

Figure 5. Comparative input costs, yield and net profit in IPM and non-IPM villages in 2002 and 2003.

the non-IPM villages (0.4 and 0.7 natural enemies/plant) in 2002 and 2003, respectively (Figure 4).

Economics

Total input and plant protection costs from sowing to picking was lower in IPM than in non-IPM villages in both years of the study. Input costs included seed cost, cost of sowing, irrigations, fertilizers, cultivation, weeding, plant protection costs and cost of picking. There was 21.20 and 15.87 percent reduction in total input costs in IPM over non-IPM villages in 2002 and 2003, respectively (Figure 5). The respective reduction in plant protection costs was 34.80 and 17.40 percent.

In spite of the reduced input costs including plant protection costs, farmers in the IPM villages were able to obtain higher yields than farmers in the non-IPM villages. There was 8.00 and 10.50 percent increase in yield, hence net income, in IPM over non-IPM villages in 2002 and 2003, respectively. The respective increase in net profit was 88.10 and 54.66 per cent in 2002 and 2003. The environmental cost of the community was difficult to evaluate due to manipulation of the product and its dissemination in soils and water. Thus farmers in IPM villages obtained higher yields and returns than those in non-IPM villages and effectively managed the pest populations in their fields besides using less number of insecticides.

All the above mentioned strategies are simple and easy to adopt. Thus, these can be easily incorporated in the pest management program with high efficacy. The introduction of new molecules in pest management strategy helped the farmers a lot in diverting from the non-recommended insecticidal mixtures and from the use of chemicals at doses greater than the recommended ones.

Thus, with the adoption of IPM strategy 3-4 times decline in the use of insecticides was reported. There was 73.18 and 66.00 percent reduction in insecticidal applications and 140 and 190 kg ha^{-1} increase in yield in IPM villages as compared to non-IPM ones in 2002 and 2003, respectively. Similar results were obtained in China by adoption of IPM strategy whereby there was 3-4 times reduction in insecticidal application and 80 kg ha^{-1} increase in lint cotton yield (Wei *et al.*, 1996). In an earlier study in Punjab, the implementation of Operational Research Project (ORP) from 1976 to 1989 resulted in

73.7 and 12.4 per cent reduction in number of sprays against sucking pests and bollworms, respectively after the adoption of supervised pest management technology. Properly timed sprays along with a number of cultural and mechanical practices resulted in 38.5 percent reduction in bollworms incidence in ORP area as compared to adjoining non-ORP area. In spite of reduced plant protection expenditure, the ORP farmers obtained 23.2 per cent higher yield and 31.7 per cent higher income (Simwat, 1994).

A shift in the use of insecticides was observed in 2003 from 2002. There was a decline observed in the number of applications of all the conventional groups in 2003 except synthetic pyrethroids, while farmers showed increased preference for new chemistries (imidacloprid, acetamiprid, thiamethoxam, spinosad and indoxacarb) as evident from increased applications of these compounds. Inclusion of new chemicals in the IPM strategy is a healthy sign as it will lead to the reduced selection pressure on the limited number of efficacious products (Murray *et al.*, 2005). Further, indoxacarb will help in managing pyrethroid resistant populations of cotton bollworm, *H. armigera*, as it exhibits negative cross resistance between indoxacarb and pyrethroids (Gunning and Devonshire, 2003). However, optimized use of new insecticides through monitoring field pest tolerance is needed to prolong their lifespan (Horowitz *et al.*, 1992).

CONCLUSIONS

The Insecticide Resistance Management Programme was found to be successful because of its simplicity and straightforward nature of the strategies which do not include any component that is either less effective or unavailable. There was a lack of proper guidance to the farmers due to which they resorted to untimely and unnecessary spray applications either as a part of routine practice or under peer pressure. The major problems concerning the insecticide use in this part of the country were:

- Lack of decision making about the correct time of application, resulting in badly timed sprays.
- Use of inappropriate chemicals at incorrect doses.
- Mixing of two or more chemicals.
- Use of substandard chemicals or even spurious insecticides mostly with the advice of local pesticide dealers.

Moreover, farmers showed great reluctance to make any special effort to consult a specialist before making pesticide applications. However, when such service was available at their doorsteps, they showed keen interest and actively participated with the scientists and followed their advice. Even after five years of its implementation, farmers in those villages are still using the IPM strategies. They have included Bt cotton hybrids in the strategy which has further resulted in reduction in pesticide applications specifically targeted against bollworms. Thus, the implementation of IPM programme was highly successful and sustainable in this part of the country for cotton pest management.

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تأثیر مدیریت تلفیقی آفات در کاهش میزان آفت‌کش در پنبه

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چکیده

استفاده زارعین محدوده کمربند پنبه بتهیندای پنجاب هند از مدیریت تلفیقی آفات باعث کاهش میزان مصرف حشره‌کش‌ها گردیده است. تعداد دفعات سمپاشی در روستاهایی که مدیریت تلفیقی بکار گرفته بودند (۴/۸۶-۵/۳۳) سه تا چهار نوبت کمتر از روستاهای بدون مدیریت تلفیقی (۱۵/۱۶-۱۸/۱۲) بوده است. در مقایسه روستاهای با مدیریت تلفیقی نسبت به روستاهای بدون مدیریت تلفیقی، روند عمومی کاهش تعداد دفعات سمپاشی هم در مورد سموم قدیمی و همچنین سموم جدید مشاهده گردید. با این وجود تعداد دفعات مصرف اندوسولفان طی سال‌ها ۲۰۰۲-۲۰۰۳ میلادی، به ترتیب، در روستاهای با مدیریت تلفیقی (۱/۰۷ و ۰/۸۵ نوبت) نسبت به روستاهای بدون آن (۰/۴۹ و ۰/۳۲نوبت) بیشتر بوده است. مصرف سایر سموم در روستاهای با مدیریت تلفیقی به صورت معنی‌داری کمتر از روستاهای بدون آن بوده است. برخلاف مناطق بدون مدیریت تلفیقی، هیچ نوع استفاده‌ای از حشره‌کش‌های توصیه نشده و یا مخلوط آنها در مناطق با مدیریت تلفیقی مشاهده نگردید. به علاوه زارعین روستاهای با مدیریت تلفیقی یک افزایش ترجیح برای استفاده از سموم نسبتاً جدید، از قبیل امیداکلوپرید، استامیپرید، تیومتوکسام، ایندوکساکارب و اسپینوساد نسبت به گروه‌های رایج از خود نشان دادند. کاربرد ساز و کارهای مدیریت تلفیقی باعث کاهش معنی‌دار مصرف آفت‌کش‌ها (۳۲-۷۵٪)، کاهش هزینه حفاظت گیاهی و هزینه‌های کلی (به ترتیب ۱۷-۳۴ و ۱۵-۲۱ درصد) و افزایش سود خالص (۵۴-۸۸٪)، همچنین حفظ دشمنان طبیعی (۰/۸-۱/۰ دشمن طبیعی در مناطق با مدیریت تلفیقی نسبت به ۰/۴-۰/۷ به ازای هر بوته) گردیده است.