

## Adoption and Impact of Insecticide Resistance Management Strategy in Cotton under Punjab Conditions

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### Abstract

To manage the problems arising due to the excessive use of pesticides for the control of insect-pests on cotton, a strategy based on four window programs was developed for disseminating among cotton growers of Punjab. The four windows of insecticide resistance management (IRM) strategy included cultivation of varieties/hybrids tolerant to sucking pests, no spray from sowing to first week of July, use of endosulfan / imidacloprid from second week of July to first week of August, use of organophosphatics / carbamates / synthetic pyrethroids in the mid to end of August, use of organophosphatics / new chemicals during September to October. For proper implementation of this strategy, the farmers were given training about identification of insect pests, when to spray, what to spray, for what to spray and how to spray, economic threshold levels. Three cotton growing districts i.e. Mansa, Ferozepur and Bathinda were covered under this program. Non-IRM villages were also selected for ascertaining the impact of adopted strategy. The number of villages selected under IRM project was 120 and 125, number of farmers was 10,044 and 10,127, and total area was 37,032 and 32,905 ha during 2005-06 and 2006-07 cropping seasons, respectively. It was observed that with the adoption of IRM strategy, there was less damage by the bollworms, less incidence of sucking pests, higher number of natural enemies, less number of insecticidal sprays, low cost of production and increase in net income. Due to less number of sprays, the population of natural enemies during early season remained high in cotton crop and thus helped in reducing the pest population and ultimately the damage done by these pests. This strategy helped the farmers to sustain the crop productivity and their prosperity.

**Key words :** Cotton insect-pests, Insect-pest management, Insecticide resistance management (IRM) strategy.

Agricultural development in the new century faces some unprecedented challenges with the steady growth in the world population, which is estimated to reach 10 billion in 2020. The intensification of agriculture to meet the need of the growing population has given birth to green revolution in India that resulted in use of improved varieties, increased consumption of fertilizers and pesticides (1). Cotton is an important commercial crop, which plays a vital role in social and monetary affairs of world. Though, India has the largest acreage under cotton in the world, productivity is low because of insect-pest damage at all the stages of crop growth. A large number of insect-pests have been found inflicting damage (30—80%) but major ones are jassid, *Amrasca biguttula* (Ishida), whitefly, *Bemisia tabaci* (Gennadius), and bollworm complex viz. American bollworm,

*Helicoverpa armigera* (Hubner) ; Pink bollworm, *Pectinophora gossypiella* (Saunders) and spotted bollworm, *Earias* spp. (2). The main thrust of Indian cotton growers so far is to depend heavily on unilateral use of synthetic insecticides to combat these pests (3). Almost 60% of the total pesticides are consumed in cotton crop alone. Due to excessive use of pesticides on cotton, there was development of resistance (4, 5), resurgence in insect-pests, depletion of natural enemies from cotton agro-ecosystem and on the other hand, the cost of cultivation increased tremendously. To overcome these problems, integrated pest management (IPM) arose in the second half of the century as the paradigm of choice for pest control, and stressed the need to incorporate basic ecological concepts in the implementation of pest control strategies (6). Proponents of IPM advocate

**Table 1.** Total number of villages, farmers and total area covered under IRM and non-IRM villages.

District	Total no. of villages covered		Total no. of farmers covered		Total area (ha) covered	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
<b>IRM</b>						
Mansa	40	40	3201	2925	8288	9548
Ferozepur	40	40	3480	3602	17121	13289
Bathinda	40	45	3363	3600	11623	10068
Punjab	120	125	10044	10127	37032	32905
<b>Non-IRM</b>						
Mansa	3	3	187	223	1209	441
Ferozepur	3	3	301	207	1317	922
Bathinda	4	3	516	400	1144	1200
Punjab	10	9	1004	830	3670	2563

the use of IPM systems to reduce or eliminate the use of chemical pesticides in agriculture (7). Although Bt cotton has become an important tool in IPM and significantly reduced the resistance problem in bollworms especially American bollworm, yet 20–30% of area, where water resources are not good, is still under non-Bt cultivation in Punjab. There is need to develop a strategy for managing the resistance problem in that area. An attempt was made to manage the arthropod fauna below economic threshold level, reduction in number of sprays, cost of cultivation and to increase the net-profit by adopting four window based insecticide resistance management (IRM) strategy in cotton crop system under Punjab conditions.

### Methods

The IRM strategy was disseminated in three south-west districts of Punjab i.e. Mansa, Ferozepur and Bathinda. For this purpose, from each district for both the years 40 villages were selected but during the second year the number of villages selected from Bathinda were increased to 45, with an over all total of 120 and 125 villages in Punjab during two crop seasons, respectively (Table 1). The total number of farmers and area during 2005-06 and 2006-07 crop season in Mansa, Ferozepur and Bathinda were 3,201, 3,480 and 3,363, and 8,288, 17,121 and 11,623 ha; and 2,925, 3,602 and 3,600; and 9,548, 13,289 and 10,068 ha, respectively, with over all total number of farmers

and area of 10,044 and 37,032 ha; and 10,127 and 32,905 ha, respectively for the same crop season (Table 1). For comparing its impact, non-IRM villages were also selected during each crop season in these districts. The cotton crop was grown following the recommended agronomic practices (8, 9). The four windows of IRM strategy (10) included cultivation of varieties / hybrids tolerant to sucking pests, no spray from sowing to first week of July, use of endosulfan / imidacloprid from second week of July to first week of August, use of organophosphatics (Ops) / carbamates / systemic pyrethroids (SPs) in the mid to end August, use of OPs/new chemicals during September to October (Table 2). For the effectiveness of this strategy, training was given to the farmers about the identification of insect-pests of cotton crop and natural enemies of these insect-pests. They were trained for spraying the insecticides, i.e. when to spray, what to spray and for what to spray. The literature having knowledge about insect-pests, their economic threshold levels (Table 3), and their control was distributed among the farmers. The insecticides of different groups were sprayed at economic threshold level (11), and attempt was made not to repeat same insecticide as far as possible. The data on the number of sucking pests (jassid and whitefly), tobacco caterpillar, grey weevil and natural enemies and bollworm complex (American bollworm and spotted bollworm) damage (%) were recorded at weekly intervals upto 140 DAS (days after sowing). The number and cost of insecticidal spray, cost of

**Table 2.** Insecticide resistance management (IRM) strategy.

<b>Window—I</b>	
1. <i>Sucking Pests Management (Sowing—First Week of July)</i>	
i.	Sow recommended varieties, which are resistant to sucking pests and cotton leaf curl virus to avoid early sprays.
ii.	Destroy alternate hosts of cotton leaf curl virus and whitefly.
iii.	Timely sowing, judicious use of fertilizers, irrigation, proper spacing and clean cultivation will prevent the early build up of pests and help conserve natural enemies.
iv.	Treat seed with Gaucho/Cruiser to control the cotton jassid in susceptible cultivars.
v.	Do not use any insecticide during this period to conserve natural enemies.
vi.	Do not spray against thrips and black semilopper, as they do not cause any economic damage to the crop.
<b>Window—II</b>	
2. <i>Sucking Pests and Bollworms Management (Second Week of July—First Week of August)</i>	
vii.	Use endosulfan for bollworms infestation, as it is less toxic to natural enemies. It gives moderate control of cotton jassid also.
viii.	Avoid the use of synthetic pyrethroids for the control of spotted bollworms (SBW). Use them only if endosulfan fails to give satisfactory control.
ix.	Avoid the use of nitroquadine compounds against jassid as these are toxic to natural enemies.
x.	Do not use organophosphates and carbamates against bollworms.
<b>Window—III</b>	
3. <i>Bollworms and Tobacco Caterpillar Management (Mid to End August)</i>	
xi.	Use profenophos/quinalphos/carbaryl in alternation with synthetic pyrethroids for the control of bollworms.
xii.	Prefer the use of acephate for the control of grown up larvae of American bollworm. It will also provide effective control of tobacco caterpillar.
xiii.	Use spinosad only in case of severe infestation of American bollworm.
<b>Window—IV</b>	
4. <i>Bollworms and Tobacco Caterpillar Management (September-October)</i>	
xiv.	Use profenophos / triazophos / quinalphos / thiodicarb for younger larvae of American bollworm. Prefer chlorpyrifos for grown up larvae. Chlorpyrifos, thiodicarb and quinalphos will also provide effective control of tobacco caterpillar.
xv.	Use indoxacarb / spinosad in case the American bollworm is serious.
xvi.	Use triazophos / ethion for the management of whitefly. It will also provide effective control of pink bollworm and spotted bollworms.

cultivation and seed cotton yield were also recorded for calculating net profit and additional profit over non-IRM villages.

## Results and Discussion

### *Incidence of Insect-Pests*

*Sucking Pests.* Table 4 shows that the mean number of jassid nymphs per 3 leaves in Mansa, Ferozepur and Bathinda districts were 0.1, 0.3 and 0.4; and 0.3, 0.4 and 0.8, respectively, during 2005-06 and 2006-07 crop season in IRM villages, whereas in non-IRM villages, the mean numbers of jassid nymphs

per 3 leaves were 0.1, 0.4 and 0.4; and 1.2, 0.5 and 0.8, respectively, for these districts and crop seasons. Similarly, in whitefly adults per 3 leaves, the incidence was 0.1, 0.4 and 0.3 numbers of adult whiteflies in Mansa, Ferozepur and Bathinda districts during 2005-06 and the values for 2006-07 crop season were 0.8, 0.5 and 0.9 adults, respectively, in IRM villages. While in non-IRM villages, these values were 0.1, 0.6 and 0.4 for 2005-06 crop season and 1.4, 0.7 and 0.8 adults for 2006-07 crop season, respectively, for Mansa, Ferozepur and Bathinda districts. On the basis of over all means for 2005-06 and 2006-07 crop season in Punjab, the mean numbers of jassid nymphs and whiteflies adults in IRM were 0.3 and 0.5;

**Table 3.** Economic threshold levels of major insect-pests of cotton.

Insect pest	Threshold level
<b>American Cotton</b>	
Jassid	Appearance of second injury grade (yellowing and curling along leaf margins), on 50% plants
Whitefly	6 adults per leaf or appearance of honeydew on 50% plants
Aphids	Appearance of honey dew on 50% plants
Bollworm complex (Pink, Spotted and American bollworm)	Initiate spray at 5% incidence in shed fruiting bodies. Repeat spray at 10 days interval or 5% incidence in shed fruiting bodies which so ever is earlier during effective boll formation period
<b>Desi Cotton</b>	
Bollworm complex (Pink, Spotted and American bollworm)	Initiate spray when 25% plants start squaring. Repeat subsequent spray at 10 days interval or 5% incidence in shed fruiting bodies which so ever is earlier

and 0.3 and 0.7 per 3 leaves, respectively. Whereas in non-IRM, these values were 0.3 and 0.8 ; and 0.4 and 1.0 per 3 leaves, for 2005-06 and 2006-07 crop season, respectively.

**Bollworm Complex.** On the basis of the data obtained on per cent damage of fruiting bodies by bollworms (Table 4), there was 0.0, 1.3 and 0.1 ; and

0.0, 1.8 and 0.8% damage in intact and shed fruiting bodies, respectively, due to spotted bollworm during 2005-06 crop season in IRM, while during 2006-07, there was 0.0, 0.6 and 0.0 ; and 0.0, 0.7 and 0.0% damage in intact and shed fruiting bodies due to spotted bollworm in Mansa, Ferozepur and Bathinda districts, respectively. In non-IRM, these val-

**Table 4.** Impact of the adoption of IRM strategy on the incidence of insect-pests in Punjab. TC—Tobacco caterpillar, GW—Grey weevil, NE—Natural Enemies.

Insect/pest	2005-06						2006-07									
	Mansa		Ferozepur		Bathinda		Punjab		Mansa		Ferozepur		Bathinda		Punjab	
	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM	IRM	Non-IRM
Jassid/3 leaves	0.1	0.1	0.3	0.4	0.4	0.4	0.3	0.3	0.3	1.2	0.4	0.5	0.8	0.8	0.5	0.8
White-fly/3 leaves	0.1	0.1	0.4	0.6	0.3	0.4	0.3	0.4	0.8	1.4	0.5	0.7	0.9	0.8	0.7	1.0
<b>Spotted Bollworm Damage (%) on Fruiting Bodies</b>																
Intact	0.0	0.0	1.3	1.8	0.1	0.0	0.5	0.6	0.0	0.1	0.6	1.1	0.0	0.0	0.2	0.4
Shed	0.0	0.0	1.8	3.1	0.8	0.0	0.9	1.1	0.0	0.0	0.7	1.4	0.0	0.1	0.2	0.5
<b>American Bollworm Damage (%) on Fruiting Bodies</b>																
Intact	0.0	0.0	0.8	0.9	0.0	0.0	0.3	0.3	0.0	0.0	0.3	0.7	0.0	0.0	0.1	0.2
Shed	0.0	0.0	1.2	2.0	0.0	0.0	0.4	0.7	0.0	1.0	0.5	1.3	0.0	0.1	0.2	0.5
TC/ Plant	0.1	0.1	0.3	0.6	0.1	0.2	0.2	0.3	0.0	0.0	0.2	0.1	0.3	0.3	0.2	0.1
GW/ Plant	0.1	0.1	0.4	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.6	0.5	0.5	0.4
NE/ Plant	0.2	0.2	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.4	0.4	0.3

**Table 5.** Adoption of IRM and knowledge gained by the cotton farmers in Punjab.

Strategies	Mansa	Ferozepur	Bathinda	Punjab
<b>Percent Farmers Adopted IRM Strategy</b>				
Recommended varieties / hybrids	69.5	73.6	70.1	71.1
Economic threshold level	61.2	63.4	58.5	61.0
Hand destruction of egg / larval masses of tobacco caterpillar	80.5	75.6	71.8	76.0
<b>Knowledge Gain in farmers Due to IRM (%)</b>				
Sowing from 15 Apr to 15 May	80.2	78.5	75.6	78.8
Recommended varieties / hybrids	81.5	80.7	81.3	81.2
No spray up to 1st week of Jul	70.7	75.4	72.1	72.7
Economic threshold level	75.5	72.8	69.9	72.7
Identification of insect-pests and Natural enemies	90.5	85.7	86.2	87.5
Use of recommended insecticides	80.0	82.5	79.6	80.7

ues of per cent intact and shed fruiting damage were 0.0, 1.8 and 0.0; and 0.0, 3.1 and 0.0% in 2005-06 crop season; and 0.1, 1.1 and 0.0; and 0.0, 1.4 and 0.1% in 2006-07 crop season for Mansa, Ferozepur and Bathinda districts, respectively. On the basis of per cent damage due to American bollworm in cotton, there was 0.0, 0.8 and 0.0; and 0.0, 0.3 and 0.0% damage in intact fruiting bodies during 2005-06 and 2006-07 crop season, respectively, and 0.0, 1.2 and 0.0; and 0.0, 0.5 and 0.0% damage in shed fruiting bodies respectively in IRM villages of Mansa, Ferozepur and Bathinda districts. In non-IRM villages, these values were 0.0, 0.9 and 0.0; and 0.0, 0.7 and 0.0% in intact and 0.0, 2.0 and 0.0; and 1.0, 1.3 and 0.1% damage in shed fruiting bodies during 2005-06 and 2006-07 crop season, respectively, in the Mansa, Ferozepur and Bathinda districts. On the basis of over all means for 2005-06 and 2006-07 crop season in IRM villages, there was 0.5 and 0.2; 0.3 and 0.1% damage in intact fruiting bodies due to spotted and American bollworm, respectively in Punjab. The per cent damage in shed fruiting bodies during these crop seasons was 0.9 and 0.2; and 0.4 and 0.2%, respectively due to spotted and American bollworm, respectively in Punjab under IRM. In non-IRM, there was 0.6 and 0.4; and 1.1 and 0.5% damage due to spotted bollworm in intact and shed fruiting bodies, respectively, for 2005-06 and 2006-07 crop season. While in American bollworm, the per cent damage in intact and shed fruiting bodies was 0.3 and 0.2; 0.7

and 0.5%, respectively, for these crop seasons.

*Other Insect-Pests Per Plant.* In Mansa, Ferozepur and Bathinda districts, the mean population of tobacco caterpillar was 0.1, 0.3 and 0.1; and 0.0, 0.2 and 0.3 per plant during 2005-06 and 2006-07 crop seasons in IRM, with over all mean of 0.2 and 0.2 per plant in Punjab, respectively (Table 4). While in non-IRM, these values were 0.1, 0.6 and 0.2; and 0.0, 0.1 and 0.3 per plant, individually for Mansa, Ferozepur and Bathinda districts, and with over all mean of 0.3 and 0.1 per plant in Punjab, respectively for 2005-06 and 2006-07 crop seasons. In grey weevil (Table 4), the population per plant in these districts was 0.1, 0.4 and 0.3; and 0.3, 0.5 and 0.6, respectively, for 2005-06 and 2006-07 crop season in IRM, individually for Mansa, Ferozepur and Bathinda districts, respectively, and with over all mean of 0.3 and 0.5 per plant for Punjab, whereas in non-IRM, these values were 0.1, 0.5 and 0.3; and 0.3, 0.5 and 0.5, respectively, for the same districts individually, and with over all mean of 0.3 and 0.4 per plant for Punjab during 2005-06 and 2006-07 crop season, respectively.

*Natural Enemies Per Plant.* As natural enemies are one of the important biotic factors in IPM programs for lowering the pest population below economic threshold level up to some extent, their presence in the cotton agro-ecosystem under the pesticide umbrella is important. In IRM, the number of natural enemies (lady bird beetles, big-eyed bug,

**Table 6.** Impact of IRM strategy on the economics of plant protection and production in cotton in Punjab. MSP for 2005-06 and 2006-07 was Rs 1885/- and Rs 2100/- for 100 kg seed cotton. \* Figures in parentheses are per cent reduction over non-IRM. \*\* Figures in parentheses are per cent increase over non-IRM.

Inputs/Outputs	Mansa	2005-06			Punjab
		Ferozepur	Bathinda		
<b>IRM</b>					
Number of Sprays*	3.1 (41.5)	4.4 (37.1)	2.7 (15.6)	3.4 (34.6)	
Cost of spray (Rs/ha)*	1669 (29.7)	2378 (43.9)	1333 (17.0)	1793.33 (34.6)	
Cost of cultivation (Rs/ha)*	13993 (8.81)	14338 (15.4)	13841 (5.0)	14057.33 (10.03)	
Seed-cotton yield (kg/ha)**	2395 (9.2)	2421 (9.4)	2540 (10.2)	2452 (9.6)	
Net profit (Rs/ha)**	31158 (20.9)	31228 (27.6)	33254 (15.2)	31880 (20.9)	
Additional profit (Rs/ha)	5377	6735	4398	5509	
<b>Non-IRM</b>					
Insecticide use	5.3	7.0	3.2	5.2	
Cost of spray (Rs/ha)	2375	4243	1607	2741.66	
Cost of cultivation (Rs/ha)	15346	16952	14577	15625	
Seed-cotton yield (kg/ha)	2194	2212	2304	2236.66	
Net profit (Rs/ha)	25781	24475	28856	26370.66	

**Table 6.** Continued.

Inputs/Outputs	Mansa	2006-07			Mean for two years for Punjab	Mean reduction (-) / Increase (+) in IRM over non-IRM for Punjab
		Fer-ozepur	Bathinda	Punjab		
<b>IRM</b>						
Number of Sprays*	2.7 (44.9)	3.9 (42.6)	2.5 (30.5)	3.0 (41.2)	3.2 (37.86)	-1.95
Cost of spray (Rs/ha)*	2053 (43.2)	2170 (48.9)	1844 (30.4)	2022.33 (42.4)	1907.84 (38.95)	-1217.50
Cost of cultivation (Rs/ha)*	16735 (11.44)	16941 (9.57)	17029 (5.89)	16901.66 (9.01)	15479.45 (9.47)	-1620.88
Seed-cotton yield (kg/ha)**	2526 (4.3)	2355 (6.6)	2692 (10.6)	2524.33 (7.2)	2488.16 (8.39)	+192.67
Net profit (Rs/ha)**	36309 (14.1)	32507 (18.1)	39503 (20.1)	36106.33 (17.4)	33993.16 (19.03)	Value Rs 3814.5
Additional profit (Rs/ha)	4491	4998	6601	5363	5435	
<b>Non-IRM</b>						
Insecticide use	4.9	6.8	3.6	5.1	5.15	
Cost of spray (Rs/ha)	3617	4244	2666	3509	3125.33	
Cost of cultivation (Rs/ha)	18897	18735	18095	18575.66	17100.33	
Seed-cotton yield (kg/ha)	2421	2208	2434	2354.33	2295.49	
Net profit (Rs/ha)	31818	27515	32902	30745	28557.83	

spiders and green lace wing) recorded per plants was 0.2, 0.6 and 0.5; and 0.4, 0.4 and 0.5 per plant in Mansa, Ferozepur and Bathinda districts during 2005-06 and 2006-07 crop seasons, respectively (Table 4).

In non-IRM, this number was 0.2, 0.5 and 0.5; and 0.3, 0.3 and 0.4 in Mansa, Ferozepur and Bathinda districts during the same crop seasons, respectively. On the basis of over all mean for Punjab, there was

0.4 and 0.4 mean number of natural enemies recorded in the cotton agro-ecosystem in IRM during 2005-06 and 2006-07 crop seasons, respectively, while in non-IRM, there was 0.4 and 0.3 numbers of natural enemies recorded in cotton agro-ecosystem during the same crop season, respectively (Table 4).

#### *Adoption and Impact*

On the basis of over all mean of two crop seasons, the per cent adoption of IRM strategy was calculated and it showed that in Mansa, Ferozepur and Bathinda districts (Table 5), 69.5, 73.6 and 70.1% of farmers sown recommended varieties / hybrids, respectively. About 61.2, 63.4 and 58.5% of farmers followed economic threshold levels, respectively in these districts and 80.5, 75.6 and 71.8% of farmers followed the practice of destruction if egg/larval masses of tobacco caterpillar by hand in Mansa, Ferozepur and Bathinda districts, respectively. By taking over all mean, there was 71.1, 61.0 and 76.0% farmers in Punjab followed IRM strategy of sowing of recommended varieties/hybrids, economic threshold levels, destruction if egg/larval masses of tobacco caterpillar by hand, respectively.

On the basis of over all mean for three districts, in Punjab (Table 5), there was 78.8, 81.2, 72.7, 72.7, 87.5 and 80.7% of farmers gained knowledge about sowing of cotton between 15 April to 15 May, recommended varieties/hybrids, no spray upto first week of July, economic threshold levels, identification of insect-pests and natural enemies in cotton and use of recommended insecticides at recommended dose for the proper management of insect-pests of cotton, respectively.

On the basis of the impact of IRM strategy on the economics of plant protection and production in cotton (Table 6), in Mansa, Ferozepur and Bathinda districts under IRM, the number of insecticidal sprays was 3.1, 4.4 and 2.7 during 2005-06 crop season and 2.7, 3.9 and 2.5 during 2006-07 crop season, respectively, representing 41.5, 37.1 and 15.6% and 44.9, 42.6 and 30.5% reduction in number of sprays during 2005-06 and 2006-07 crop season, respectively. The mean total number of sprays in non-IRM villages of Mansa, Ferozepur and Bathinda districts was 5.3, 7.0 and 3.2 ; and 4.9, 6.8 and 3.6 during 2005-06 and

2006-07 crop season, respectively. The cost of spray in Mansa, Ferozepur and Bathinda districts under IRM during 2005-06 and 2006-07 was Rs 1,669, 2,378 and 1,333 ; and Rs 2,053, 2,170 and 1,844 per hectare, respectively, with 29.7, 43.9 and 17.0 ; and 43.2 48.9 and 30.4% reduction in cost over non-IRM with cost of Rs 2,375, 4,243 and 1,607 ; and Rs 3,617, 4,244 and 2,666 per hectare, respectively for the two crop seasons. The cost of cultivation in IRM in Mansa, Ferozepur and Bathinda districts during 2005-06 and 2006-07 crop seasons, was Rs 13,993, 14,338 and 13,841 ; and Rs 16,735, 16,941 and 17,029 per hectare, respectively, representing 8.81, 15.4 and 5.0 ; and 11.44, 9.57 and 5.89% reduction over non-IRM villages with total cost of cultivation of Rs 15,346, 16,952 and 14,577 ; and Rs 18,997, 18,735 and 18,095 per hectare, respectively. The average seed cotton yield in IRM villages in these districts during 2005-06 and 2006-07 crop seasons was 2,395, 2,421, 2,540 ; and 2,526, 2,355 and 2,692 kg/ha with 9.2, 9.4 and 10.2 ; and 4.3, 6.6 and 10.6% increase over non-IRM villages in same districts with seed cotton yield of 2,194, 2,212 and 2,304 ; and 2,421, 2,208 and 2,434 kg/ha, respectively. By adopting IRM strategies, the farmers got net-profit of Rs 31,158, 31,228 and 33,254 ; and Rs 36,309, 32,507 and 39,503 per hectare during 2005-06 and 2006-07 crop seasons in Mansa, Ferozepur and Bathinda districts of Punjab, with 20.9, 27.6 and 15.2 ; and 14.1, 18.1 and 20.1% increase over non-IRM villages in these districts, respectively. The additional profit of Rs 5,377, 6,735 and 4,398 ; and 4,491, 4,998 and 6,601 per hectare was achieved due to the adoption of IRM strategies during 2005-06 and 2006-07 crop seasons in Mansa, Ferozepur and Bathinda districts, respectively.

On the basis of over all mean of three districts during 2005-06 and 2006-07 crop seasons (Table 6), the number of sprays in Punjab in IRM was 3.4 and 3.0, respectively, representing 34.6 and 41.2% reduction over non-IRM with 5.2 and 5.1 number of sprays. The cost of spray and cultivation during these crop seasons in IRM in Punjab was Rs 1,793.33 and 2,022.44 per hectare ; and Rs 2,741.66 and Rs 3,509 per hectare, respectively, representing 34.6 and 42.4% reduction over non-IRM, respectively. The average seed-cotton yield in Punjab was 2,452 and 2,524 kg/ha, representing 9.6 and 7.2% increase over non-

IRM with 2,236.66 and 2,354.33 kg/ha seed-cotton yield during 2005-06 and 2006-07 crop seasons, respectively. The net profit in IRM in Punjab was Rs 31,880 and Rs 36,106.33 per hectare, which was 20.9 and 17.4% increase over non-IRM with Rs 26,370.66 and 30,745 per hectare net profit in non-IRM villages in Punjab during 2005-06 and 2006-07 crop seasons, respectively.

Thus, adoption of IRM strategies resulted in reduction of cost of spray up to Rs 1,217.5/ha, cost of cultivation up to Rs 1,620.88/ha, with increase in seed-cotton yield of 192.67 kg/ha with an average of two years. There was over all additional profit of Rs 5,435 per hectare in IRM than non-IRM in Punjab.

In one study, the number of sprays for the control of sucking pests and bollworm complex varied from 2 to 20 in North India, and there was 90% reduction in IRM-selected villages, the square and boll damage reduction was 15 to 52%, seed cotton yield increased in some cases up to 59% and plant protection cost was reduction by 2.5—60% (12). Suruli Velu et al. (13) also reported 63.0% reduction in number of sprays at Coimbatore and Theni districts, with mean of 2.7 in project village as compared to 7.3 in control villages. Dhawan et al. (14) also reported reduction in plant protection cost, number of sprays, bollworm damage to pickable bolls and loculi, and increased cotton-seed yield was 25.6, 24.4, 32.6 and 37.5, and 19.2; and 25.8, 42.0, 45.7 and 34.8, and 15.5% respectively during 2002 and 2003 in Punjab. The cost : benefit ratio was also increased up to 63.2 and 71.9% during 2002 and 2003, respectively. Properly timed sprays along with number of cultural and mechanical practices resulted in 38.5% reduction in bollworm incidence in the operational research project (ORP) area as compared to the adjoining non-ORP areas. In spite of reduced plant protection expenditure, the ORP farmers obtained 23.2% higher yield and 31.7% net income (15). Similar results were reported by Rajak et al. (16) with 30 to 50% reduction in pesticide consumption in IRM-adopted fields and 21—27% increase in seed-cotton yield. In our results, the over all increase in yield and net-income was 8.39 and 19.03%, respectively with over all additional profit of Rs 5,435 per hectare in IRM than non-IRM in Punjab.

### Conclusion

It is thus concluded that with the adoption of IRM strategy, there was less damage by the bollworms, less incidence of sucking pest population, higher number of natural enemies, less number of insecticidal sprays, lowest cost of production and increase in net income. Due to less number of sprays, the population of natural enemies during early season remained high in cotton crop and thus helped in reducing the pest population and ultimately the damage done by these pests.

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