THE USE OF PHEROMONES TO CONTROL THREE SPECIES OF BOLLWORM IN PAKISTAN

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Introduction

The pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is a major world-wide pest of cotton. Once the eggs have hatched and the larvae have entered into the bolls it is difficult to control using conventional insecticides.

The spiny bollworm, *Earias insulana* (Boisduval) (Lepidoptera: Noctuidae), is largely confined to the near and middle Eastern areas of the world, including the Mediterranean; the spotted bollworm, *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) is found further East, particularly in the Indian sub-Continent and is a more sporadic and localised pest. However, in some years it is capable of causing serious reductions in cotton yield. Unlike the pink bollworm, which as its name implies primarily attacks the cotton bolls, the spiny and spotted bollworms damage all stages of the crop, the pin-squares, flowers and bolls, and can also act as a stem borer in young cotton plants.

P. gossypiella and the two *Earias* spp. are the major bollworm pests on cotton in Pakistan. The American bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), is also present but attack by this insect is sporadic and at the present time it is considered a minor pest although its importance is increasing.

During the past few years, a number of commercially available formulations containing the synthetic female sex pheromone of *P. gossypiella*, Gossyplure (Hummel *et al*., 1973; Bierl *et al*., 1974) have been used widely in the developed world to control the pink bollworm (Shorey *et al*., 1974; Staten *et al*., 1987), and also in countries in the developing world, such as Egypt (Critchley *et al*., 1983, 1985; El Adl *et al*., 1987; Moawad *et al*., 1991) and Pakistan (Qureshi *et al*., 1988; Critchley *et al*., 1991). However, in countries, where the pink, spiny and spotted bollworms occur simultaneously (i.e., the cotton growing areas of the Indian sub-Continent) and where pheromones have been used as a prophylactic to control pink bollworm by a mating disruption technique, control of *Earias* species has been carried out using conventional insecticides (Critchley *et al*., 1991). This has disadvantages in economic terms and in order to optimise the use of, and benefits from, using pheromones to control pink bollworm, it would be useful to control spiny and spotted bollworms also using pheromones.

Following the identification and synthesis of the female sex pheromone of *E. insulana* (Hall *et al*., 1980) and *E. vittella* (Cork *et al*., 1988), it was found that both species contained (*E,E*)-10,12-hexadecadienal as the major component. Subsequently, scientists at the Natural Resources Institute (NRI), U.K., Agrisense-BCS, Ltd, U.K. (Cork *et al*., 1989) and the Shin-Etsu Chemical Co., Japan, developed combined slow release pheromone formulations capable of controlling all three bollworm species with a single pheromone formulation.

Methods and Results

Initial mating disruption trials were conducted in Pakistan during 1985, by a team from NRI in collaboration with scientists from the Central Cotton Research Institute (CCRI), Multan, Pakistan. The project was funded by the Overseas Development Administration (ODA), UK. The trials were conducted between 1986 and 1988 using the Shin-Etsu "twist-tie" formulation. This consisted of a wire stiffened, polyethylene tube sealed at both ends, containing 38 mg of gossyplure, plus 40 mg of the major component (*E,E*)-10,12-hexadecadienal and 4 mg of *Z*11-hexadecenal, a minor component, of the *Earias* pheromone. The formulation was applied at 1000 twist-ties/ha and attached directly to the cotton plant, just below the terminal shoot and was applied early in the cotton season when the first

fruiting bodies had appeared. It was demonstrated that up to eight weeks mating disruption, as measured by trap catch shut-down, could be achieved for all three bollworm species (Critchley *et al*., 1987). This offered the prospect of season-long control of three major pests of cotton, pink, spotted and spiny bollworms, by mating disruption, using a single application of their pheromones combined in the same formulation.

During the following three years (1986 to 1988) large scale trials were conducted using the Shin-Etsu *Pectinophora/Earia*s (PBW/SBW) "twist-tie" or rope formulation (Chamberlain *et al.,* 1992). In 1986 and 1987, the % mating disruption as measured by pheromone trap catch shut-down, as described by Critchley *et al*. (1991), against pink bollworm and spotted bollworm was high (99.5%, 98.7% and 97.7% for pink bollworm), (99.5%, 99.1% and 92.5% for spotted bollworm) (Table 1). However, overall populations of spiny bollworm during this period were lower than average and as a result there were no significant differences in the numbers of adults trapped in the pheromone+insecticide and insecticide-only treated plots (Table 1). In 1986, a reduction of four insecticide applications in the pheromone-only treated plots was achieved in areas treated with the Shin-Etsu PBW/SBW pheromone formulation when compared with the insecticide-only treated plots. Yields of seed cotton in the pheromone-only treated plots were not significantly different from the insecticide-only treated areas. (Table 2). During the 1987 season, there was an average saving of three insecticide applications and an increase in yield of 16% in the pheromone-only and pheromone+insecticide treated plots when compared with the insecticide-only treated areas (Table 2). In 1988 plots treated with the Shin-Etsu PBW/SBW pheromone formulation showed levels of mating disruption 93.7% and 77.3% for pink bollworm, 92.6% and 98.3% for spotted bollworm and 58.9% and 45.7% for spiny bollworm, as measured by the reduction in trap catch (Table 3). There was a saving, on average, of 2.5 insecticide applications and an increase in yield of 38% when compared with the insecticide-only treated areas (Table 4). The increased yield of seed cotton, particularly during the 1988 season, was due mainly to the increased number of bolls/plant and lower levels of boll infestation in the pheromone treated plot (Table 4). A high infestation by the two *Earias* spp., during September, caused severe shedding of fruiting parts in the insecticide treated plots. Subsequently, these were not able to compensate and contained fewer mature bolls at the end of the season (Table 4).

The PVC resin formulation, known as (Selibate PBW/SBW), marketed by Agrisense-BCS Ltd, was first evaluated during 1988. The formulation was supplied as strips, 100 mm long x 10 mm wide x 1 mm thick, each weighing about 1.0 g and incorporating 35 mg of gossyplure and 9 mg of *Earias* pheromone, similar to that in the Shin-Etsu twist-tie formulation. This formulation was also hand applied early in the season at a rate of 1,000 strips/ha by stapling the PVC around the stem of the cotton plant just below the terminal shoot. The formulation is now supplied as a complete ring or band which can be dropped easily over the terminal shoots of the plants. Plots treated with the Agrisense PBW/SBW pheromone formulation gave levels of mating disruption of 77.3%, 89.2% and 82.8% for pink bollworm; spotted bollworm and spiny bollworm respectively (Table 3). This treatment resulted in a reduction of two insecticide applications to the cotton during the season and an increase in yield of 26% in the pheromone+insecticide treated plots when compared to the insecticide-only treated areas. This was again attributed to the fact that cotton plants in the insecticide treated plot had fewer bolls/plant, due to an attack by *Earias* spp. and higher levels of boll infestation than those in plots treated with the combined pheromone formulation only (Table 4).

Build up of secondary pests such as the American bollworm, *H. armigera* and whitefly, *Bemisa tabaci* (Gennadius) (Homoptera: Aleyrodidae) in all the pheromone treated areas was suppressed by the abundance of beneficial organisms within the crop. These had not been destroyed by early season applications of pesticides. During the entire three year trial period neither of these pests exceeded economic threshold levels in the pheromone treated plots and insecticides applications were not necessary.

Conclusions

There are now two pheromone formulations available with which it is possible to control the three major bollworm pests of cotton in Pakistan. Trials have demonstrated

clearly that larval infestations by these three species can be reduced and yields of seed cotton increased by a single early season application of either of the formulations containing both pheromones. Numbers of insecticide applications to control secondary pests can also be reduced. An important consequence of the reduction in the levels of pesticide applied is the increased numbers of beneficial insects present in the pheromone treated areas which contributes to reduced levels of attack by potentially serious pests such as *H. armigera* and *B. tabaci*.

Although the materials and techniques are now available, pheromonal control of the *Earias* spp. is not an economically viable option at the present time due to the current cost of *Earias* pheromone. It is hoped that new and cheaper synthetic routes will be developed, as has happened with other pheromones, which will reduce their cost and lead to their eventual commercial use in cotton pest management. However, acceptance by farmers and decision makers in Pakistan of the benefits of using pheromones to control of *P. gossypiella* is expanding and current commercial evaluation of *P. gossypiella* pheromone formulations is expected to lead to wider availability and increased use.

The use of slow-release pheromone formulations to control cotton bollworm pests will also provide the opportunity to reduce current levels of pesticide applied to control the cotton pest complex in Pakistan. If their use is integrated into the cotton pest management recommendations, they will form an important element of a future Insecticide Resistance Management (IRM) strategy. This could be of considerable benefit in a region where pesticide resistance in cotton pests is an increasing threat to sustainable cotton production.

Although both the pheromone formulations tested can only be applied by hand, this makes them particularly suitable for use in Pakistan and other developing countries, where agriculture in general and cotton cultivation in particular is labour intensive and a work-force is available with which to apply the formulations.

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Table 1. Mean season long trap catch (moths/trap/night) and % mating disruption for the three bollworm species in areas treated with Shin-Etsu "twist tie" PBW/SBW pheromone formulation, Multan, Pakistan, 1986 and 1987.

Insect species and treatments	Bokhari Farm 1986	Bokhari Farm 1987	Salahuddin Farm 1987
Pectinophora gossypiella			
Pheromone+insecticide	0.04	0.25	0.61
Insecticide-only	8.52	19.21	26.99
% Mating disruption	**99.50**	**98.70**	**97.70**
Earias vittella			
Pheromone+insecticide	0.42	0.56	0.38
Insecticide-only	78.50	60.50	5.01
% Mating disruption	**99.50**	**99.10**	**92.50**
Earias insulana			
Pheromone+insecticide	0.44	0.18	0.06
Insecticide-only	4.01	0.48	0.41
% Mating disruption	**89.10**	**62.40**	**84.90**

Taken from Chamberlain *et al.*, 1992.

Table 3. Mean season long trap catch (moths/trap/night) and % mating disruption for the three bollworm species in areas treated with Agrisense Selibate and Shin-Etsu twist tie" PBW/SBW pheromone formulations, Multan, Pakistan, 1988.

Insect species and treatments	Agrisense Selibate[1]	Shin-Etsu "twist-tie"[2]	
		Trial 1	Trial 2
Pectinophora gossypiella			
Pheromone+insecticide	2.82	0.36	5.70
Insecticide-only	12.44	5.72	25.05
% Mating disruption	**77.30**	**93.70**	**77.30**
Earias vittella			
Pheromone+insecticide	3.89	1.40	1.52
Insecticide-only	36.06	18.94	88.07
% Mating disruption	**89.20**	**92.61**	**98.27**
Earias insulana			
Pheromone+insecticide	1.90	3.37	10.38
Insecticide-only	11.03	8.19	19.10
% Mating disruption	**82.80**	**58.90**	**45.70**

[1]D.J. Chamberlain, unpublished data.
[2]Taken from Chamberlain *et al*., 1992.

Table 2. Weight of seed cotton, number of bolls/plant and yields from pheromone-only and insecticide-only treated plots of cotton in 1986 and pheromone-only, insecticide-only and pheromone+insecticide treated plots of cotton in 1987 in Multan, Pakistan.

Year	Treatments	Insecticide Applications*	Mean wt. of seed cotton (g) per boll	Mean No. of bolls/plant	Mean % boll infestation	Yield (kg/ha)
1986[1]	Pheromone only	0	3.36a	23.8a	7.4a	2598a
1986[1]	Insecticide only	4	3.31a	19.7b	4.6a	2524a
1987[1]	Pheromone only	0	3.05a	25.3a	0.9a	2790a
1987[1]	Insecticide only	2	2.99a	17.4b	0.7a	2350b
1987[2]	Pheromone + insecticide	1	3.45a	24.7a	1.2a	2810a
1987[2]	Insecticide only	5	3.13a	21.7a	1.4a	2360 b

* Insecticide applications specifically against bollworms

[1] Bokhari farm
[2] Salahuddin farm

Means followed by the same letter vertically are not significant at the 5% level (Duncan's Multiple Range Test) on
untransformed data.

Table 4. Weight of seed cotton, number of bolls/plant and yields from pheromone+insecticide and insecticide-only treated plots of cotton, Multan, Pakistan, 1988.

Year	Treatments	Insecticide Applications*	Mean wt. of seed cotton (g) per boll	Mean No. of bolls/plant	Mean % boll infestation	Yield (kg/ha)
Shin-Etsu pheromone formulation[1]						
1988	Pheromone+ insecticide	1	3.73a	20.5a	3.7a	1826a
1988	Insecticide only	4	3.64a	16.7b	9.4b	1162b
1988	Pheromone+ insecticide	1	3.76a	22.3a	3.8a	2363a
1988	Insecticide only	3	3.87a	12.8b	12.1b	1415b
Agrisense Selibate formulation[2]						
1988	Pheromone+ insecticide	2	4.10b	16.7b	2.1a	2861a
1988	Insecticide only	4	3.91a	13.9b	5.2b	2101b

* Insecticide applications specifically against bollworms

1 Taken from Chamberlain *et al*., 1992.
2 D.J. Chamberlain, unpublished data.

Column means followed by the same letter are not significant at the 5% level (Duncan's Multiple Range Test) on untransformed data.