# The role of synthetic pheromone, endosulfan and other techniques for the prevention of carry-over in the integrated management of pink bollworm *Pectinophora gossypiella* (Saunders), (Lepidoptera: Gelechiidae) in South India

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## ABSTRACT

*Investigations carried out over several years developed an integrated management system involving traditional and modern methods of the suppression of field populations and carry over of the pink bollworm* Pectinophora gossypiella *(Saunders). Application of its pheromone, gossyplure, at different doses ranging from 2 to 10 g a.i./ha effected varying degrees of mating disruption of the pink bollworm adults in the field. 10 g a.i./ha of the microencapsulated, twist-tie, rain fast rubber ring (Selibate), and sprayable formulations, of synthetic pheromone was found to cause mating disruption ranging from 59 to 91 percent under various situations. Doses less than 10 g/ha were found to increase the adult activity in the treated field and resulted in considerable damage to the bolls. Gossyplure alone and in alternation with a 'soft' insecticide, endosulfan resulted in yields of 1,355 kg and 2,088 kg seed cotton/ha respectively, with 85% reduction in the activity of adults. This compares with 1,069 kg to 2017 kg of seed cotton/ha in other treatments. The pheromone materials, along with the other integrated management measures, increased the seed cotton yield by 56 to 75 percent with a three to four fold increase in the population of the natural enemies of the cotton insects and decreased use of insecticides by 24 to 30 percent over the fields not treated with gossyplure. The late season population of pink bollworm was reduced by74 percent by suppressing the genesis of unproductive floral and terminal vegetative buds of the cotton crop with a single application of the chemical crop terminator, chloroflurenol at 120 g/ha, at 130 days after germination, without affecting the quality of fibers or the oil content of seeds. The carry-over population of the pink bollworm from the crop residues was also reduced by 61 to 84 percent by the indigenous method of grazing the crop with the flocks of sheep after the final harvest. The reduction was less in the fields with tall hybrid and bushy varieties than in the semi dwarf and non-bushy plant types.*


## Introduction

The production and productivity of cotton in India is limited by an array of insect pests. Among the key insect pests of the cotton the pink bollworm *P. gossypiella* is significant and responsible for the annual loss of 40 to 50 percent of cotton (Sundaramurthy and Basu, 1985). Increased environmental awareness has created much interest in organic cotton in recent years (Sundaramurthy, 1996a). Pheromones can be used to manage pink bollworm population with reduced use for insecticides (Chamberlain *et al*., 1993) especially with insecticide resistant population. Investigations were made for several years to develop an integrated management system involving traditional and modern methods for managing the field and carry-over populations of *P. gossypiella*.

## Experimental procedure

### Suppression of field population

Experiments were conducted from 1984 to 1996 during the winter cropping season starting from August-September (standard weeks 33 to 35) with different formulations of the pink bollworm pheromone, gossyplure, a 1:1 mixture of (Z,Z) and (Z,E)-7,11-hexadecadienal acetate (Critchley *et al*., 1985). A micro- encapsulated formulation of the pheromone materials (ICI London) was evaluated at different doses ranging from 4 to 10 g a.i./ha in replicated experiments with two replications located in different places within a 1.5 km radius. Each plot was 0.1 ha in size. The different doses were applied every 20 days from the pin square stage to 125 days from germination with the aid of a manually operated backpack sprayer. A total of five applications were made and no insecticide was used. Untreated check plots of similar size were maintained in the same locality. Traps baited with the pheromone were deployed in the center of each plot for monitoring the activity of the adult moths. Observations were recorded on the daily catch of the moths in the traps and the population of the pink bollworm larvae from a sample of the randomly collected 50 bolls at each sampling occasion. Affected flowers and shed reproductive parts were examined from the entire area of the plots along with yield; damaged boll number and seed cotton damage levels.

Pheromone materials were further tested at what proved to be an effective dose of 10 g a.i./ha in fields of 0.4 ha with two replications. This experiment was conducted as detailed above. The population of the pink bollworm larvae was assessed from 1000 buds, flowers and bolls collected at random on each sampling date. The yield of the seed cotton, damaged boll number and seed cotton were again recorded. In these tests the pheromone materials were evaluated in combination with the relatively 'soft' insecticide endosulfan, and in alternation with insecticide in village farms planted with the variety MCU 5 VT. In the three treatments 10 g of the active material of (Z,Z)-7,11-Hexadecadien-l-ol-acetate and (Z,E)-7-11-Hexadecadien-l-ol-acetate/ha (supplied by Pest Control India Pty. Ltd.) was applied alone, or in combination with endosulfan at 875 g a.i./ha or alternated with endosulfan. Treatments were applied from the pin square stage of the crop until 125 days after germina-

tion as done in the earlier experiments. Plots with the insecticide application alone and an untreated isolated farm of the same size served as controls. Two replicates were maintained for each treatment. Observations were made as in the previous experiments.

The utility of the pheromone materials for managing pink bollworm was also assed under the pest management system in village farms of 2.5 to 5.0 ha in size in size, planted either with the variety MCU 5 or the hybrid DCH 32. Two replicates were maintained. 10 g active materials of (Z,Z)-7,11-hexadecadien-ol-acetate and (Z,E)-7,11-hexadecadien-l-ol-acetate (Consep, USA) were applied at a threshold level of 10 percent incidence of *P. gossypiella* in bolls with the aid of a power-operated sprayer. The population of other insects was kept under check by applying both soft and hard insecticides along with other management measures at the threshold level as detailed elsewhere (Sundaramurthy, 2002).

Sprayable micro-encapsulated and rain-fast formulations of gossyplure (Selibate), containing (Z,Z) and (Z,E)-7, 11-hexadecadienyl acetate (PWD, Agrisense-BCS Ltd. UK) were used in the village farms of 5 ha in size. The sprayable micro-encapsulated formulation was applied as and when the threshold level of 10% damage by the pink bollworm was reached while the rain-fast gossyplure-impregnated rubber rings were inserted around the terminals of the plants when the crop was 45 days old and left in the field throughout the crop season. Insecticide was also used as and when required to keep other insect pests in check. Fields that received all normal pest management strategies within the village, and the farms that received only insecticides, served as controls. Observations on the use of insecticides, the daily trap catches of moths, yield of seed cotton, stained cotton and the populations of natural enemies were recorded as described in the earlier study (Sundaramurthy 2002). In all these experiments the mating disruption (MD) was worked out by using the formula:

### *Suppression of late season carry over population*

**Grazing by sheep** Eighty to 100 sheep and goats were let into fields of 2 to 4 ha in size located in two different places. These were allowed to graze on the residues of the standing crop after the harvest, for a period of six hours daily over seven days. Observations on the height of plants and of unproductive bolls carrying the larvae of *P. gossypiella* were recorded by collecting 200 leftover bolls at random in each field before and after grazing by the sheep. The reduction of the larva population could thus be calculated.

**Crop terminator** The effect of a crop terminator for the suppression of late season population of *P. gossypiella* were investigated in a randomized experimental design with four replications for two seasons. The chemical, chloroflurenol [(Methyl-2-Chloro-9-Hydroxyfluren-9-carboxylate, (Gela Merck, Gmbh, Germany), was applied at 60, 120 or 140 g a.i./ha with a knapsack sprayer once on the crop at 130, 140 and 150 days after germination. At the time of removal of stalks from the fields the buds, small flowers and unopened bolls were removed from the plots and the number of larvae present in these parts was recorded, as was the final yield of seed cotton and the level of damaged cotton.

## *Results and Discussion*

### *Management of field populations*

In cotton varieties pink bollworm enters into the crop when it is 45-50 days old with the appearance of pin squares. Infestation reaches a peak at peak flowering and declines with the advancement of boll maturation. In hybrids the abundance of pink bollworm remains greater all through the late phases of crop growth.

The microencapsulated formulation of gossyplure at different doses greatly reduced moth catches and caused 48 to 92 percent mating disruption. (Figure1a). The population of *P. gossypiella* larvae in the bolls was higher at the dose of 4 to 8 g a.i./ha decreased at 6-8 g and was lowest over the whole period at a dose of 10 g a.i./ha, at which a maximum of 92 percent mating disruption occurred. The number of shed squares due to the damage caused by the larvae was greater at of 6 and 8 g a.i./ha as compared to other doses used (Figure 1b). The number of rosetted flowers with pink bollworm larvae was highest at the dose of 4 g a.i./ha and declined subsequently with increase in dose (Figure 1b). The stained seed cotton was also increased by 14, 23 and 27 percent at doses of 4, 6 and 8 g a.i./ha respectively while it was only 10 percent at a dose of 10 ga.i./ha (Figure 1c). The yield of the seed cotton was 1,359 kg, 914 kg and 1,081 kg/ha at 4, 6 and 8 g a.i./ha respectively as against 1,725 kg/ha at 10 g a.i./ha and 1,405 kg/ha in the check plot (Figure 1d). These results suggest that a high degree of population suppression took place only at the highest dose of 10 g a.i./ha, giving advantages over the insecticide control in the check blocks.

A dose 10 g a.i./ha of gossyplure was used in the 0.4 ha plots and the results revealed that the application of gossyplure reduced moth catches in the field greatly (Figure 2a). The population of *P. gossypiella* larvae (Figure 2b) and damage caused to the bolls and seeds were also significantly less as compared to the field that was not treated with the gossyplure. The gossyplure caused 69 to 78 percent trap catch suppression and resulted in the realization of 1,554 kg/ha, as against 721 kg/ha of seed cotton per hectare in the field not treated with any pheromones (Figure 2c).

Similar effects were reported earlier with a gossyplure application (El-Adl *et al.*, 1988). The results of these investigations suggest that the synthetic pheromone material, gossyplure, may be ideal for use in production of organic cotton, as it does not leave any hazardous residue on the plants and fibers.

However the frequent use of the pheromone materials alone may lead to the phenomenon of development of resistance in the population of *P. gossypiella* as with insecticides, and therefore the prospects for using the pheromone materials along with insecticides, which are "soft" on beneficial organisms, were explored. These experiments show that moth catches in pheromone plots were fewer than in untreated ones during the early flowering phase but almost same during the late phase of the crop growth. The reduction in trap catch was greater in treatments with pheromone alternated with insecticide than in others (Figure 3a). Trap catch was higher following the treatment with application of pheromone mixed with endosulfan (Figure 3a). The population of *P. gossypiella* larvae was reduced in all the treatments as compared to that of untreated plots (Figure 3b). However, the larval population was tended to increase progressively with advancing crop growth despite the application of either the pheromone materials alone, or in combination with insecticide. But the population of pink bollworm larvae was significantly lower when the pheromone material was either mixed with the insecticide or alternated with insecticide as compared to pheromone alone (Figure 3b). The boll damage was 38 percent and seed damage was 41 percent respectively in the treatments with the pheromone alternated with insecticide while they were 50 and 48 percent in the plots treated with pheromone materials alone (Figure 3a). The untreated plots and the plots that either received insecticide alone or mixture of both pheromone and insecticide recorded higher values. The seed cotton yield was 2,088 kg/ha in the treatment with the pheromone materials alternated with insecticide, which was 4.3 percent greater than the yield of the plot treated with the pheromone materials alone and 85.0 percent more over the check plot but little different from the insecticide only treatment. The yield realized in other treatments ranged from 1,080 to 2,017 kg/ha (Figure 3c). The approach of alternate applications of the pheromone materials and a soft insecticide, endosulfan, which spares honey bees and some species of natural enemies of the cotton insect pests in the cotton system, has the advantages of delaying or minimize the development of resistance in the insect population to either the pheromone or insecticides.

The usefulness of the pheromone materials in integrated pest management systems under varieties and hybrids was assessed in the village farms using the sprayable liquid formulation of the pheromone at a dose of 10 g a.i./ ha. The gossyplure was applied with the aid of manually operated knapsack sprayer from the pin square stage as described earlier. The other pest management measures were also systematically followed as detailed earlier (Sundramurthy and Basu, 1985). The results reveal that the abundance of the adult moths of *P. gossypiella* was greater in the farms cropped with an interspecific hybrid DCH 32 than in the farms grown with a hirsute variety, MCU 5. The farms cropped with the variety MCU 5 showed a reduced activity of the adult moths throughout the cropping season and recorded less than 5 moths/trap/week (Figure 4a) and resulting in 83 percent trap catch suppression, reducing the population of the pink bollworm larvae and the degree of damage to the seed cotton and recording 1,345 kg/ha of seed cotton as against 734 kg/ha in the field that received only various standard management measures (Figure 4b). Inclusion of the pheromone materials in the pest management strategies has also resulted in the reduction of insecticide use by 31 percent.

In the hybrid DCH 32 system the abundance of the adult moths steadily increased from the pin square stage by to reach a peak level during the flowering, boll maturation and boll opening stages but decreased subsequently (Figure 5a). The greater level of abundance of the moths in the hybrid system during the early and mid reproductive phases of the crop growth is attributed to heavy proliferation of the reproductive parts as compared to varietal cotton. The pheromone reduced trap catch by 59 percent up to 137 days of the crop growth. Thereafter the activity of the adults increased by two and half fold and was comparable with that on the farms, which were not treated with pheromone (Figure 5a). The differential effects might either be due to improper coverage of the pheromone materials later in the season in the canopy of the tall hybrid DCH 32, which reaches to a height of 2 m or due to a high density of the moth population, a natural phenomenon that is known to prevail in the hybrid cotton system during the terminal growth phase of the crop due to its long growing period. Mating disruption in the population of *P. gossypiella* in the hybrid system decreased the damaged seed cotton by 80 percent with insecticides use reduced by 80 percent. The yield realized under this situation was 2,570 kg/ha as against 1,798 kg/ha under the normal pest management system (Figure 5b).

It is also evident from the present investigations that the moth catches in pheromone traps at farms treated with the sprayable and rain fast formulation (Selibate) of gossyplure was kept at a low level of less than 10 moths/week up to 156 days and caused 54 and 59 percent of mating disruption respectively in these farms. Beyond 156 days the moth activity increased significantly indicating that both formulations were least effective during the terminal phase of the crop growth. Moth activity was greater in the farms employing integrated measures and in chemically managed farms, as against the pheromone permeated fields (Figure 6a).

The prevailing high temperature of more than 30 °C during the terminal phase of crop growth might

have speeded up the processes of volatilization and subsequent disintegration of the gossyplure molecules and thereby reduced its biological effect, resulting in higher damage to the bolls. The quantity of insecticides used was almost same in the farms treated with the pheromone materials and in the farms managed by adopting the integrated management measures, which consumed 26 to 35 percent insecticides than was used in farms following the chemical method of pest control which consumed 5.24 kg a.i./ha. Seed cotton damage by pink bollworm was considerably less in the farms treated with the sprayable formulation of gossyplure than in other farms. The average yield of the seed cotton was 2,995 kg/ha and in the farms that received application of the rain fast formulation and 2,738 kg/ha for farms using the sprayable formulations of gossyplure (Figure 6b). Seed cotton yield in the farms that received the chemical methods of pest control was 2,791 kg/ha and that of the farms that received all pest management measures was 3,118 kg/ha. A similar cotton yield increase due to application of the gossyplure was reported earlier from Egypt, Pakistan, USA, and Mediterranean countries (Critchley *et al.,* 1985; Campion *et al.,* 1989; Critchley *et al.,* 1991; Chamberlain *et al.*, 1993; Staten *et al.*, 1987; El Adl *et al.*, 1988) and was shown to have reduced pesticide usage.

The mean number of the natural enemies of the cotton pests was almost same in the integrated measures farms and chemically managed farms. But the pheromone material treated farms had 3 to 4 fold increased population of natural enemies (Figure 6b). Although the rain fast formulation of gossyplure reduced the cost of application in the fields, it may aid the adults to pick up resistance to the pheromone materials as they are constantly exposed to the pheromone through out the crop season. It may be relevant that there was seven percent more damaged seed cotton in the farms treated with the rain-fast formulation of the gossyplure than in the other treatments (Figure 6b).

### *Management of late season carry-over populations*

Fields planted with the different varieties and hybrids were grazed by sheep after the final harvest of the seed cotton (Table 1). The carry-over population of the pink bollworm from the residue of the crop was reduced by 11 to 84 percent by grazing depending on the stature of the crop. The reduction of the carry-over population of *P. gossypiella* was 11 percent in the fields grown with a hybrid DCH 32 while it was 61 to 84 percent respectively in varieties LRA 5166 and MCU 5VT cultivated fields.

The fields that were grown with the short-stature strains of 70E and 70G showed a reduction of 80 percent of the carry over population of the pink bollworm indicating that the reduction significantly related to the height of the plants. The taller the plants, the less the reduction of the carry-over population after grazing by sheep. This phenomenon was due to the fact that the animal could not reach the terminal and laterals of tall plants like the hybrid DCH 32 (Table 1). These results suggest that the carryover pest load could be kept to minimum through cultivating varieties of cotton that do not grow very tall plants by increasing the population of the plants around 30 to 40 percent over the existing varieties and hybrids. The current efforts towards the stabilization of the production of cotton through cultivation of tall growing hybrids and varieties is useful in India, particularly under irrigated situations in the changed condition as it always goes against the health of the environment (Sundaramurthy, 1996b). This hypothesis receives support from the results of investigations carried out with the hybrids and varieties with different growth habits in the village farms (Table 2; Sundaramuthy and Gahukar, 1998).

Amongst the cultivated crops, cotton receives the greatest amount of pesticide. Allowing sheep to feed on the residue of the crop, which are likely to be contaminated with the residues and metabolites of pesticides, may result in transmission to the upper levels of the food chain. Therefore the chemical, chloroflurenol, that selectively aborts further development of the meristem of the vegetative and reproductive buds of the cotton crop, was assessed for suppression of the late-season carry-over population of the pink bollworm. Application of chloroflurenol at different doses at different growth phases of the crop during late season reduced the population of the pink bollworm by aborting further genesis of floral buds. The foliage of the terminated crop became brownish in color thick, succulent or brittle and harbored late season sap-feeding aphids, *Aphis gossypii*. Earlier applications were more effective than later ones. 6.0 g a.i./ha reduced the number of larvae per sample by 52 to 72 percent. The higher doses (120 and 140 g a.i./ha produced larval reduction of 83 to 94 percent (Figure 7a). The processes of suppression of the vegetative and reproductive growth of the crop with different doses of chloroflurenol used, affected the productivity of the crop. The yield of the seed cotton in different treatments ranged from 736 to 1,762 kg/ha. Termination at 130 days produced yields not greatly different of those of the check fields. Later termination showed some benefits at the higher doses but effects were inconsistent and more work is required. (see earlier reports Bariola *et al.*, 1976; Thomas, 1979). From these studies it is concluded that these measures help to keep the population of the pink bollworm and other bollworms well under the economic threshold level with minimum damage to the environment.

## *Conclusion*

The present studies indicate that the field population of *P. gossypiella* effectively be checked by using the gossyplure either alone or in alteration with insecti-

cides or along with other management measures in village farms and these measures will increase the production of seed cotton. Both the late season and carry over populations of pink bollworm can be reduced either by grazing with sheep or by using a single application of chemical crop terminator.

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***Table 1.*** *Effect of grazing the crop by sheep on the population reduction of pink bollworm larvae.*

| | | | Population of the pink bollworm larvae No./sample of 200 bolls | | |
|---|---|---|---|---|---|
| | | Height (cm) | Before grazing | After grazing | % Reduction |
| Hybrid | DCH 32 | 138.8 | 172.0 | 152.0 | 11.00 |
| | LRA5166 | 119.0 | 114.0 | 17.14 | 84.64 |
| Varieties | MCU 5VT | 93.0 | 130.0 | 50.30 | 61.30 |
| | 70 E | 64.1 | 166.0 | 39.00 | 80.00 |
| CD | | | NS | 37.8* | 6.00* |

(* = Significant, NS=Not significant. Regression co-efficient for height of plant and reduction of the population was significant at P= 0.05 level with a value for r=-0.66 and slope a=130.0).

***Table 2.*** *Productivity of short and tall stature interspecific hybrids with different growth habits.*

| Hybrids | Habit | Height (cm) | Yield (kg/ha)* |
|---|---|---|---|
| Sruthi | Short | 88.0 | 1410 |
| CDHB 2 | Short | 95.7 | 1790 |
| HB-224 | Tall | 161.4 | 1481 |
| DCH-32 | Tall | 170.4 | 1230 |
| TCHB-213 | Tall | 187.9 | 1490 |

* Regression co-efficient for height of plant and yield was not significant with a value for r = -0.46 and slope –2.06)

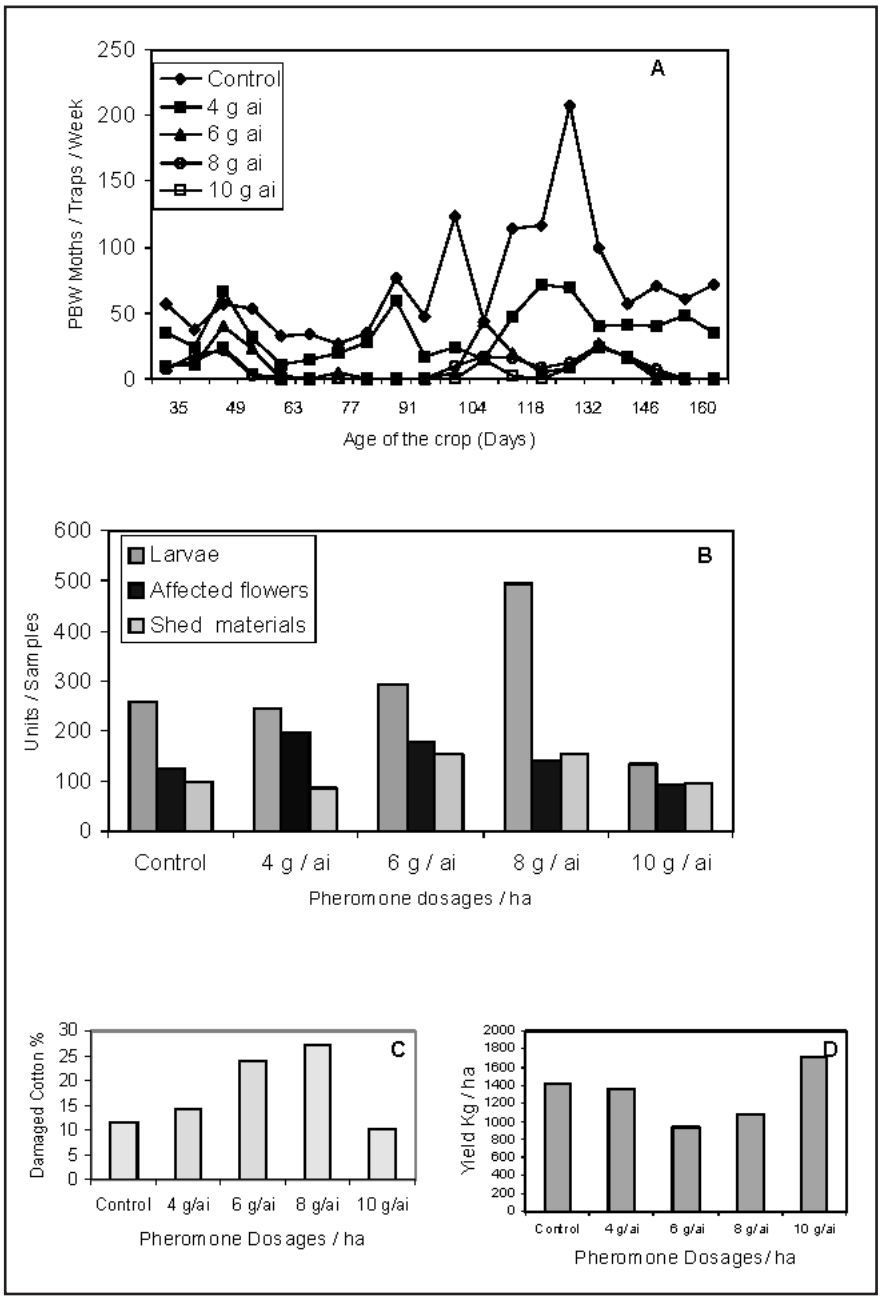


***Figure 1.***
*Effects of microencapsulated gossyplure at different doses on (A) pheromone trap catch, (B) population of the pink bollworm larvae and affected flowers and buds, (C) seed cotton damage and (D) yield of seed cotton under a no-insecticide regime.*

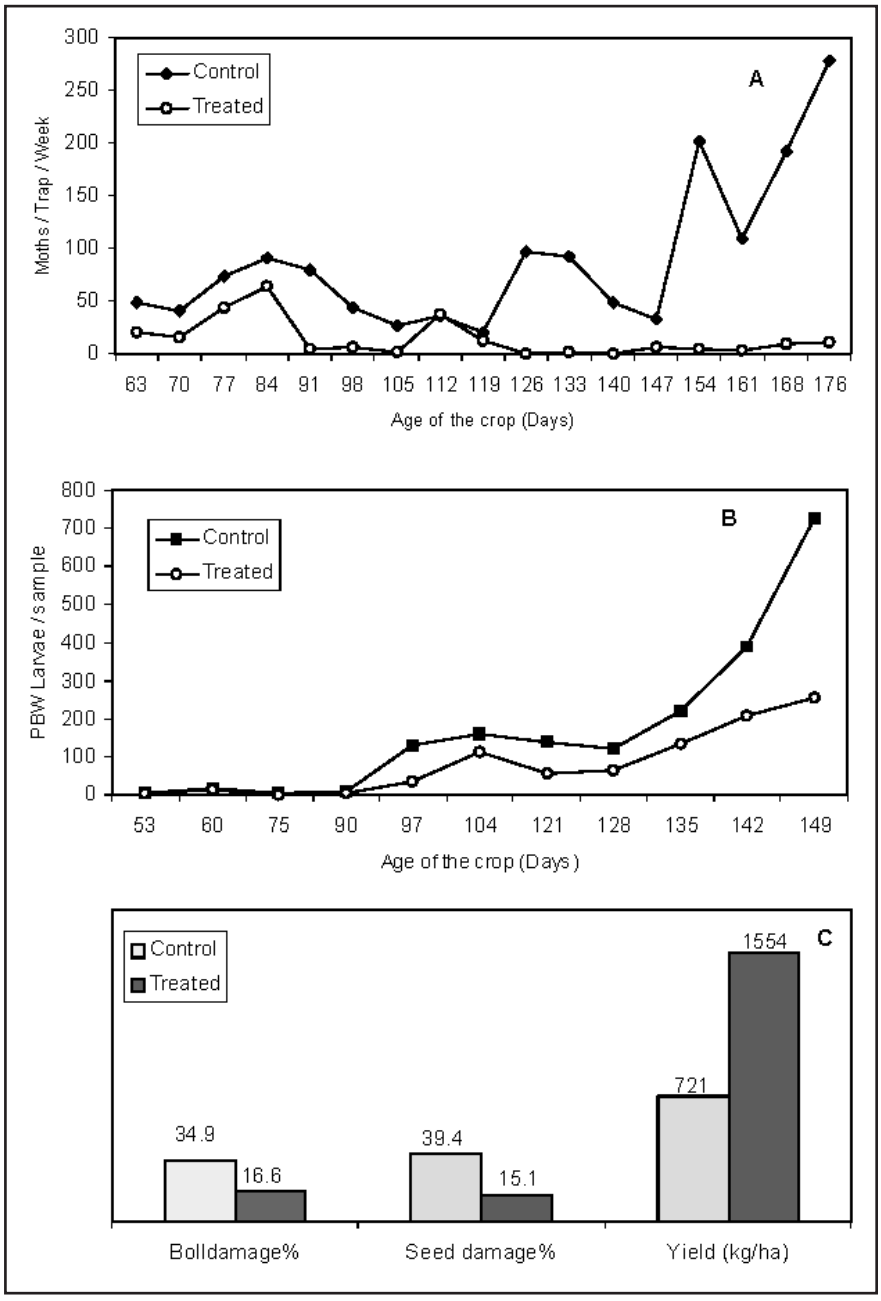


***Figure 2.***
*Effects of microencapsulated gossyplure at 10 g a.i./ha on (A) pheromone trap catch, (B) population of the pink bollworm larvae, (C) boll, seed damage and yield of seed cotton under no-insecticide regime.*

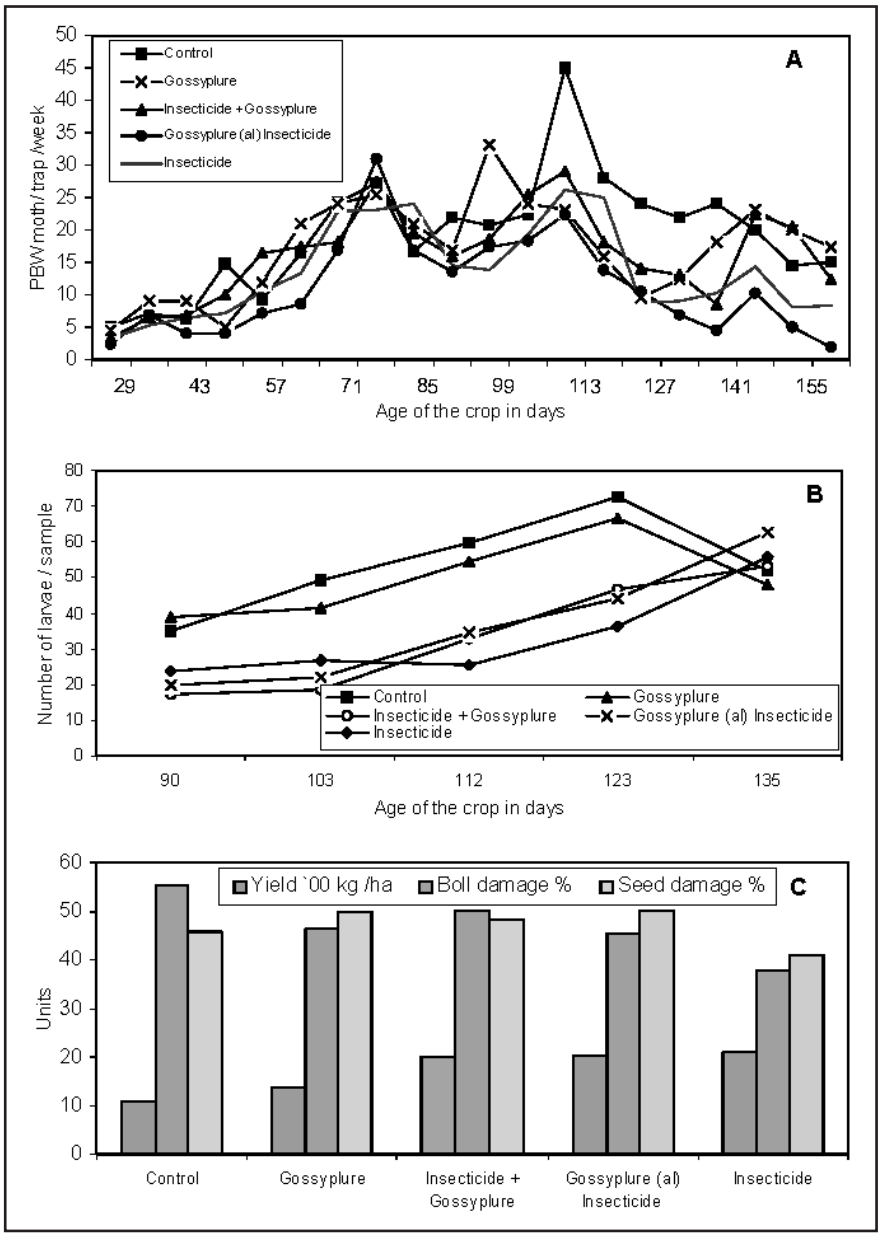


***Figure 3.***
*Effects of microencapsulated gossyplure at 10 g a.i./ha alone, in combination and alternation with endosulfan on (A) pheromone trap catch,(B) population of the pink bollworm larvae and (C) boll damage, seed damage and yield of seed cotton.*

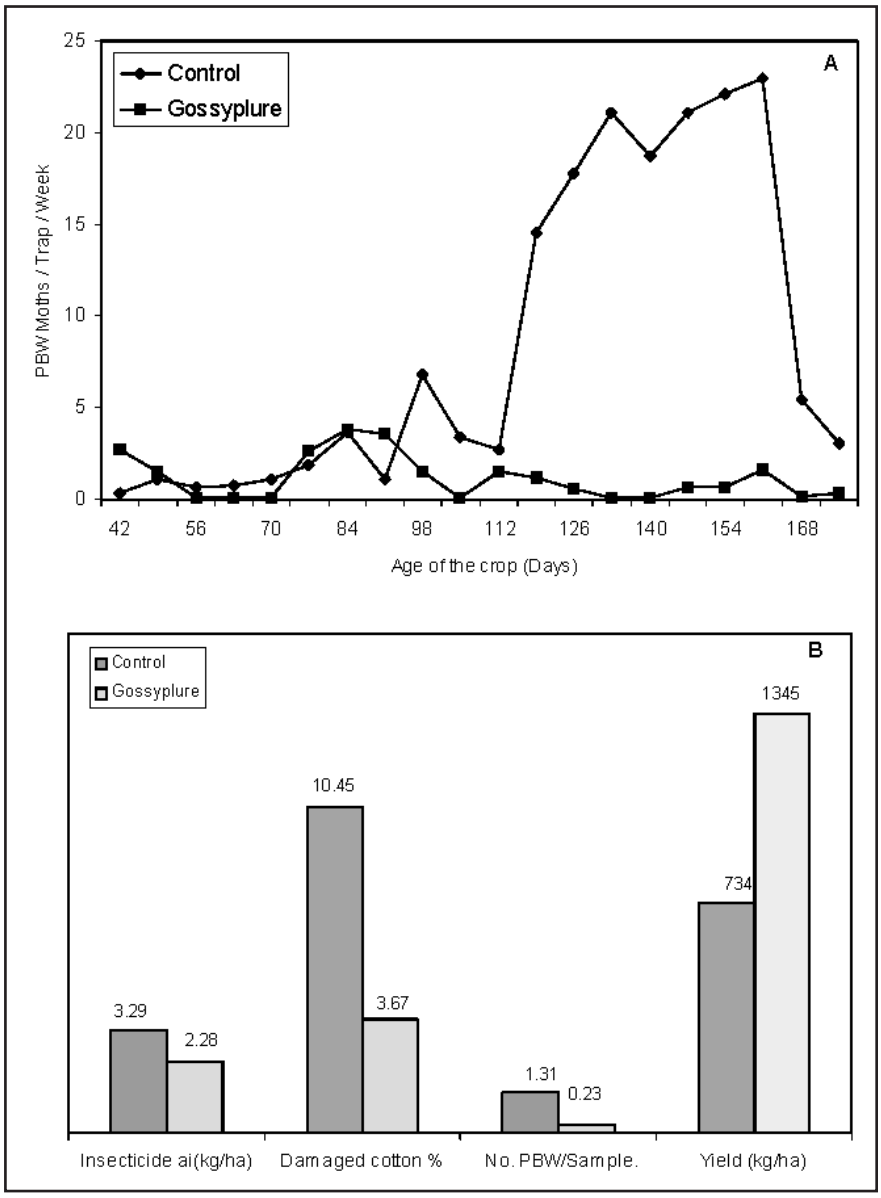


***Figure 4.***
*Effects of microencapsulated gossyplure at 10 g a.i./ha on (A) pheromone trap catch, (B) consumption of insecticide, damaged cotton, population of the pink bollworm larvae and yield of seed cotton in the variety system on village farms.*

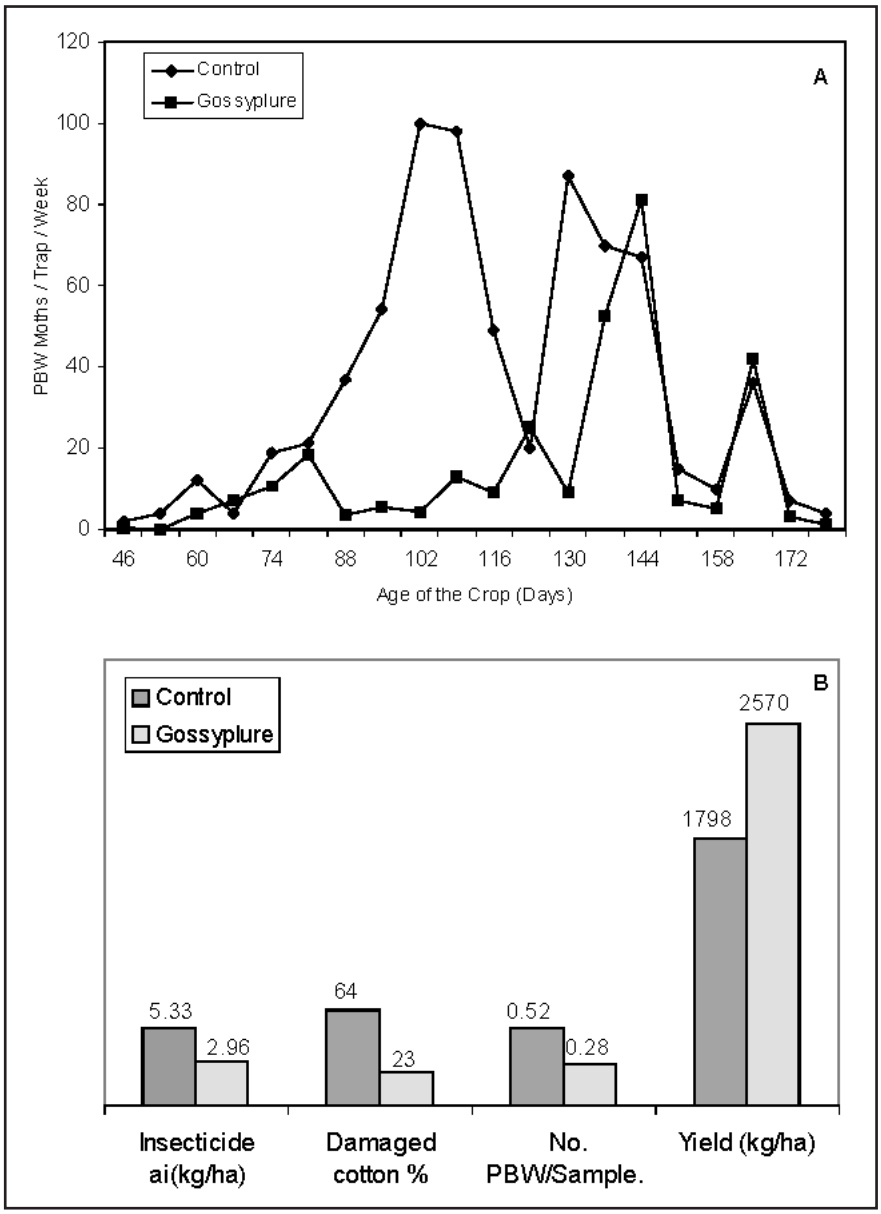


***Figure 5.***
*Effects of microencapsulated gossyplure at 10 g a.i./ha on (A) pheromone trap catch,(B) consumption of insecticides, damaged cotton, population of the pink bollworm larvae and yield of seed cotton in the hybrid system on village farms.*

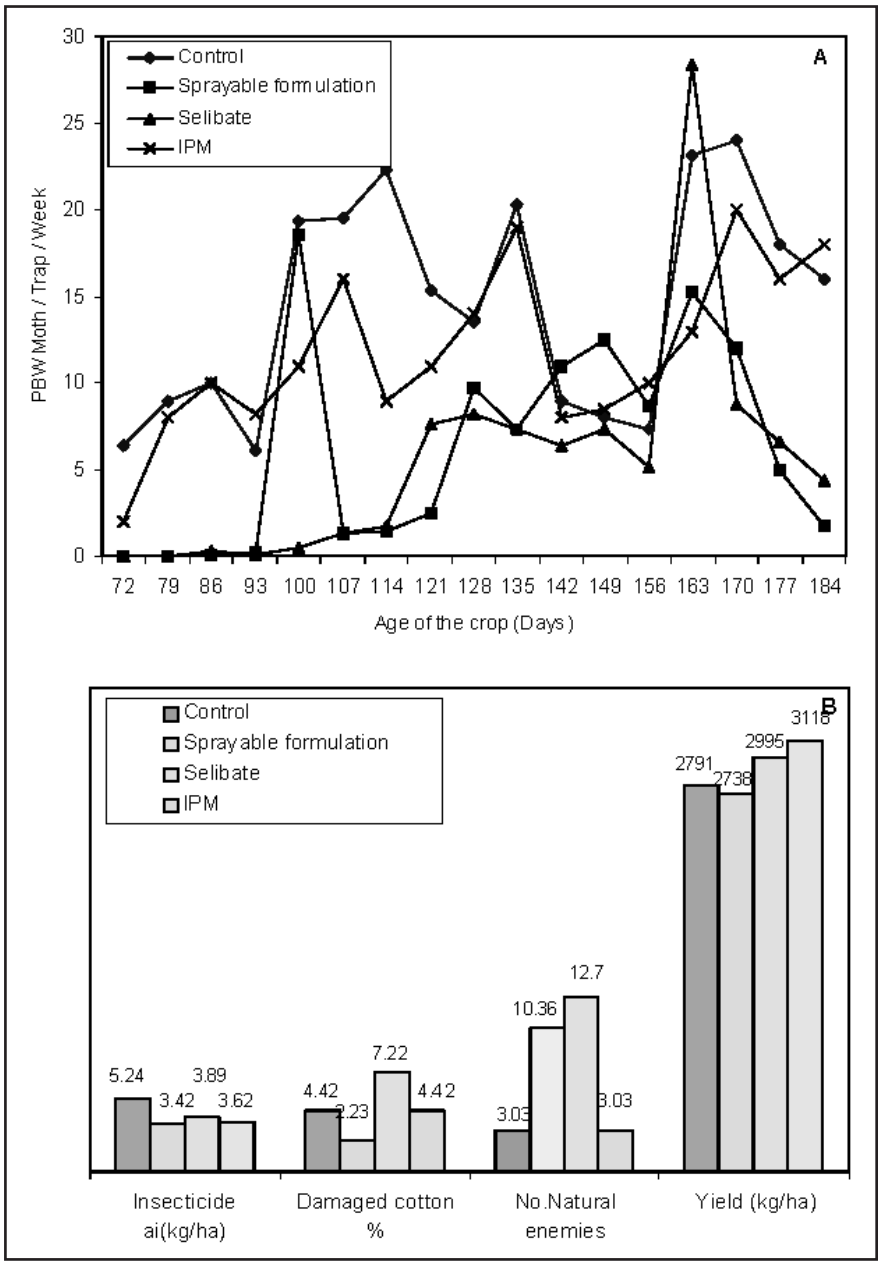


***Figure 6.***
*Effects of different formulations of gossyplure at 10 g a.i./ha on (A) pheromone trap catch, (B) consumption of insecticides, damaged cotton, population of natural enemies of cotton insects and yield of seed cotton on village farms.*

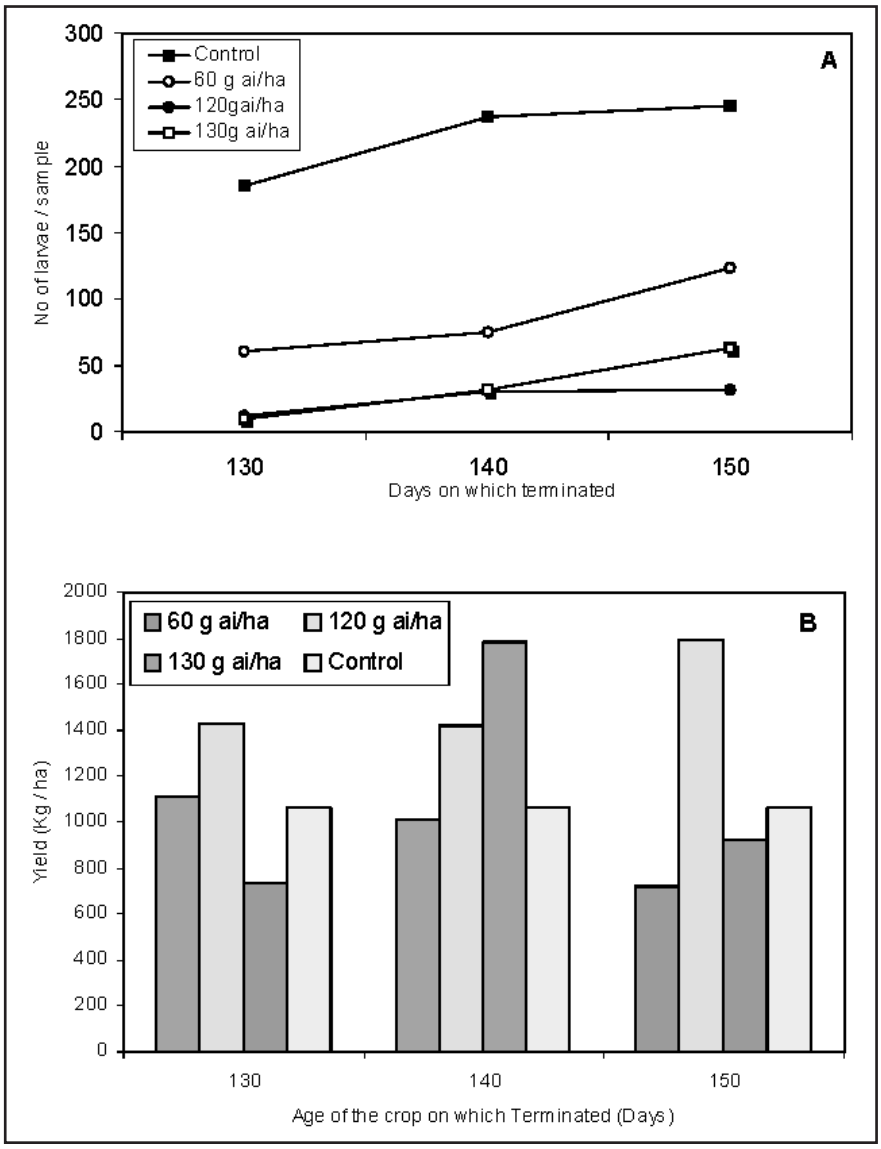


***Figure 7.***
*Effect of the chemical crop terminator at different doses on (A) the population of the pink bollworm larvae and (B) yield of seed cotton.*