Controlling the Pink Bollworm by Disrupting Sex Pheromone Communication Between Adult Moths

Abstract. *The synthetic sex pheromone (gossyplure) of the pink bollworm was evaporated into the atmosphere of three cotton fields during an entire growing season. The resulting disruption of premating pheromone communication between male and female moths led to a reduction in the population of larvae infesting cotton bolls. This larval control was comparable, in terms of both effectiveness and expense of materials used, to the control achieved in ten comparison fields by growers using conventional insecticide applications.*

The use of pheromones as a direct means of insect control has been proposed by many authors (*1*). Such a method is based on the fact that the males and females of many insect species rely on sex pheromone communication in order to come together and to perform various essential courtship behaviors before mating. Disrupting this vital communication link between the sexes by permeating the insects' environment with synthetic sex pheromone should cause the females not to mate and, thus, not to lay viable eggs.

During the last several years, we have been exploring the biological and chemical nature of premating sex-pheromone communication of the pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), one of the most serious pests of cotton in the world (*2, 3*). After mating, the female moths of this species lay their eggs on cotton fruiting bodies; both cotton yield and quality may be greatly reduced by the feeding activities of the larvae. Several overlapping generations of this pest occur within a given cotton field during a single growing season.

In a number of preliminary experiments (*4*), we explored strategies for distributing adequate quantities of the synthetic sex pheromone, known as gossyplure (*5*), of pink bollworm moths in the environment. We have now released economically practical amounts of the pheromone into the air within three cotton fields throughout an entire growing season and have suppressed the population of pink bollworm larvae infesting the cotton bolls of those fields to an extent comparable to that achieved in ten comparison fields treated with conventional insecticide applications.

Pheromone was evaporated from hollow, 104 mm long, thermoplastic fibers (*6*) fashioned into hoops of 1.5 revolutions (22 mm in diameter) (*7*). The hoops were attached by hand at 3-week intervals to upper petioles or stems of cotton plants on a 1 by 1 m grid throughout the 23 ha (individual fields of 5, 6, and 12 ha) that constituted the three experimental fields. Thus, 230,000 hoops were distributed on each of five application dates, from the middle of May through early September 1976, a period that overlaps most of the breeding cycle of the pink bollworm (*8*).

The three experimental fields, as well as ten comparison cotton fields (totaling 200 ha) that were located in the same general area but did not receive pheromone treatments (grower practice fields), were monitored at weekly intervals during the growing season for the success of adult moth sex pheromone communication and for larval damage. Success of adult communication was measured by means of four gossyplure-baited traps (*9*) maintained in each field. During the season, an average of seven male moths were captured in the traps in each gossyplure-treated field, as opposed to an average of 356 males in each comparison field. This 98 percent decrease in the numbers of trapped males in the treated fields probably indicates a nightly disruption in moth communication ability coupled with a resultant suppression in resident moth populations as the season progressed.

Of more practical significance is the low density of pink bollworm larvae found in cotton bolls in the treated fields (*10*) (Fig. 1). Only during the first sampling period was the larval density on the treated fields different from that on the comparison fields, and this high initial density was entirely attributable to one field, which developed earlier than any other field in the area and which may have received immigration flights of mated females from surrounding areas (*11*). Significantly, the generation of adults that resulted from the larvae from this one field appeared, on the basis of lower subsequent larval infestation, to have been inhibited from mating and laying viable eggs. Similarly, the late-season larval density in all of the pheromone-treated fields may result in part from immigration of mated females from the nearby infested fields.

The growers who managed the experimental and comparison fields were instructed to use conventional insecticide applications as needed for control of the pink bollworm. The mean number of insecticide applications per hectare during the growing season was 0.3 (range 0 to 1) in the pheromone-treated fields and 2.6 (range 0 to 8) in the comparison fields, an average ninefold reduction in insecticide usage in the treated fields (Fig. 2).

The calculated amount of pheromone evaporated per season in the treated fields was 33 g/ha (*12*). At a present cost of approximately $0.80/g for relatively small batches of gossyplure, this amounts to $26 per hectare per season, which is equivalent to the expense of the insecticide used in two applications. Large-scale use of gossyplure would probably reduce the cost of the pheromone per gram. The costs of formulating and applying the pheromone are not included in this calculation because suitable mechanical application technology is currently being developed.

A pheromone-based pest control program would offer a number of potential advantages if used against a key agriculture pest such as the pink bollworm. The need for insecticide applications would be reduced. Also, pheromones are selective, having little adverse effect on any

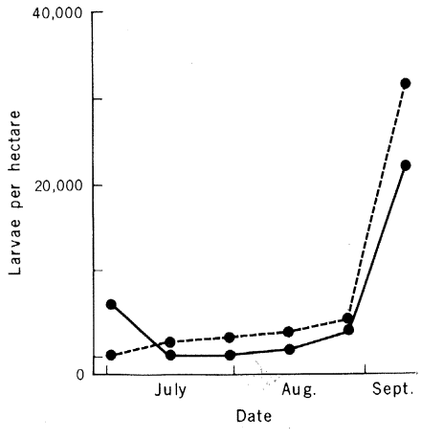

Fig. 1. The mean number of pink bollworm larvae per hectare in three pheromone-treated fields (solid line) and ten grower practice fields (dashed line).

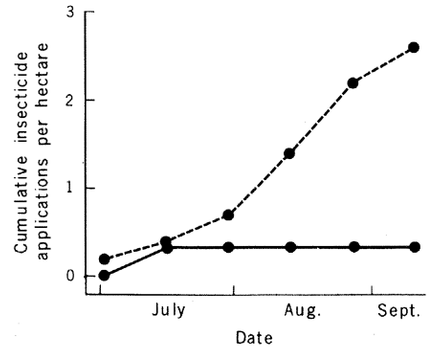

Fig. 2. The cumulative mean number of insecticide applications per hectare for three pheromone-treated fields (solid line) and ten grower practice fields (dashed line).

organisms other than the target species. The results of our experiment, together with results of similar promising ones (*13*), demonstrate that disruption of pest-insect pheromone communication may soon become a useful component of the pest management systems used on a variety of crops.

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5. Gossyplure is a 1:1 mixture of *cis*-7, *cis*-11, and *cis*-7, *trans*-11 synthetic isomers of hexadecadienyl acetates (*3*).
6. Hollow fibers made from Celcon, a biodegradable polyoxymethylene polymer 0.22 mm inside diameter by 0.45 mm outside diameter, were produced by Conrel, an Albany International Corp. subsidiary, Norwood, Mass. The rate of evaporation of pheromone from a hollow fiber sealed at one end is controlled by diffusion from the open end. The rate of pheromone evaporation from a point source, which probably should be greater than the female rate of evaporation, can be specified by the number of fibers located together constituting a release site; the amount of pheromone evaporated per unit area can be specified by the number of release sites per hectare; the longevity of a fiber can be specified by the length of fiber filled with pheromone [E. Ashare, T. W. Brooks, D. W. Swenson, in *Proceedings of the 1975 International Controlled Release Symposium*, F. W. Harris, Ed. (Wright State University, Dayton, Ohio, 1975), p. 42].
7. One end was sealed and one was open. Each hoop was filled with gossyplure containing 1 percent of the antioxidant *N*-2-octyl-*N'*-phenyl-*p*-phenylenediamine (Union Oil Products No. UOP-688) by immersing the hoops in gossyplure, reducing the pressure to 6 mm, and then releasing the vacuum.
8. We applied the hoops by hand to ensure a precise 1 by 1 m grid. This degree of precision could not be accomplished with the available commercial equipment used by Conrel for ground and aerial application of 20-mm-long gossyplure-filled fibers on a semicommercial experimental basis on 1600 ha of cotton in California and Arizona during 1976. Also, hand application permitted locating the hoops at the most effective location on the foliage, the top of the plant. Hoops were chosen as the method of attachment because they ensured retention on the plant until it was defoliated (*4*).
9. Traps [described by J. R. McLaughlin, H. H. Shorey, L. K. Gaston, R. S. Kaae, F. D. Stewart, *Environ. Entomol.* 1, 645 (1972)] were baited with a 20-mm-long No. 22 Teflon tube containing a 3-mm length of gossyplure. Two traps were placed at the top of the cotton canopy and two at the base of the cotton plants. Traps were examined twice weekly starting 15 May for pink bollworm moths.
10. The experiment was evaluated by weekly examination in the laboratory of 100 randomly selected susceptible bolls from each treated and control field for first- through third-instar larvae. Density of susceptible bolls was determined weekly by counting the number of bolls in four 1-meter segments of row per field. Evaluation was started 1 July and continued until 15 September according to the method of R. A. Van Steenwyk, G. R. Ballmer, and H. T. Reynolds [*J. Econ. Entomol.* **69**, 579 (1976)].
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12. A rate of evaporation from each fiber of 10 μg/day was determined in a wind tunnel (0.4 m/sec) with the temperature programmed for a typical hot growing day, 21° to 43°C. This corresponds to about a 2-mm length of gossyplure evaporated per week.
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14. We thank T. W. Brooks and R. Kitterman for bringing to our attention the potential of using hollow fibers as pheromone dispensers, and W. E. Yates for determining the rate evaporation of glossyplure for those fibers. Supported by the California State Cotton Pest Advisory Board of the California State Department of Food and Agriculture, Cotton, Inc., and The Rockefeller Foundation.

15 November 1976; revised 17 December 1976

Lesch-Nyhan Syndrome: Low Dopamine-β-Hydroxylase Activity and Diminished Sympathetic Response to Stress and Posture

Abstract. *Patients with Lesch-Nyhan syndrome with virtually no hypoxanthine phosphoribosyltransferase activity demonstrate significantly low plasma activity of dopamine-β-hydroxylase but normal basal levels of norepinephrine. Under conditions of emotional or postural stress the plasma concentrations of norepinephrine in Lesch-Nyhan patients increased less than in a normal population.*

Lesch-Nyhan syndrome, described in 1964 (*1*), is an X-linked disorder of purine metabolism and is characterized clinically by automutilation and aggressive and compulsive self-destructive behavior, choreoathetoid cerebral palsy, marked hypertonicity, athetoid dysarthria and dysphagia (*2*). There is a marked deficit in hypoxanthine phosphoribosyltransferase (HPRT, E.C. 2.4.2.8), hyperuricemia, and excessive uric acid production (*3*). Increased activity of dopamine-β-hydroxylase (DBH, E.C. 1.14.17.1) with an absence of the pressor response to cold stimulation has been noted (*4*).

The hypertonicity and involuntary dyskinetic movements in Lesch-Nyhan patients have been likened to symptoms in dystonia (*2*), and we have found both increased DBH activity and increased concentrations of norepinephrine (NE) in the autosomal dominant form of torsion dystonia (*5*). Accordingly, we undertook the evaluation of sympathetic function in Lesch-Nyhan syndrome by measuring NE concentrations and DBH activity under various environmental circumstances.

Although plasma activity of DBH has been related to sympathetic nervous system activity (*6*), measurement of basal levels of NE and its increment with postural stress appear to provide a more direct and sensitive measure of both the basal state and responsivity of the sympathetic nervous system in humans (*7*).

Fourteen patients with Lesch-Nyhan syndrome with a mean age of 14 ± 1 (± standard error) years (range, 6 to 22 years), all with evidence of severe self-mutilation and virtual absence of erythrocyte HPRT activity (*8*), were evaluated for possible sympathetic dysfunction after the proper consents had been obtained. A control group consisted of 14 healthy volunteers (mean age of 23 ± 2; range, 12 to 44 years). Although plasma concentrations of NE vary with age but not sex (*9*), there was no significant difference among the basal levels of NE in the present control group, the Lesch-Nyhan patients, and an age-controlled group (15 ± 1 years; basal NE of 221 ± 37 pg/ml) which did not undergo the same postural change after the basal blood sample was taken for NE determination. Since DBH activity may not increase after the second decade (*6*, *10*), 312 adult volunteers (42 ± 1 years) also served as controls for DBH activity. All subjects were placed in a supine position after which the needle of a "heparin lock" was inserted into an antecubital vein. Blood (12 ml) was withdrawn immediately from ten Lesch-Nyhan patients, and a blood sample was taken from all subjects (in the resting supine position) after about 15 minutes, by which time normal subjects reach basal levels (*7*). Pulse rate was measured by radial palpation at the time of blood sampling. Eight patients and all the controls were subsequently allowed to sit upright (two patients were tilted to 60 degrees) and blood was sampled after 10 minutes. In normal subjects these maneuvers (sitting and tilting) increase similarly the plasma concentrations of NE (*7*). Volunteer subjects were asked to discontinue all medications for 1 week before the test. All Lesch-Nyhan patients were receiving allopurinol; eight of them were also taking diazepam; three, thioridazine; three, dantrolene; two, phenobarbital; and one, diphenylhydantoin. Five patients had their medication discontinued 24 hours before the test.

Blood was collected, centrifuged, and stored as described (*7*) until assayed for DBH by the method of Weinshilboum and co-workers (*6*) and for NE by the radioenzymatic method of Henry *et al.* (*11*) modified as described (*7*).