Insect Control (I): Use of Pheromones

Reports of famine in Africa and India, depleted grain reserves in the United States, and the current soaring food prices have all emphasized the necessity of controlling the insect pests that are man's major competitors for food and fiber. The problem is how to do this effectively and economically but with a minimum of the environmental disruption frequently attributed to the broad spectrum insecticides that have dominated pest control for the past three decades. Many entomologists think they can achieve this goal by exploiting the chemical messengers—the hormones and pheromones—by which an insect regulates its growth, development, and behavior.

Pheromones are chemicals secreted by one insect that affect the behavior of other individuals of the same species. Although pheromones can evoke many types of behavioral responses—alarm or aggregation, for example—the sex attractant pheromones are the ones most frequently considered for insect control programs. Since pheromones are natural substances that regulate behavior essential for survival of the species, insects are less likely to become resistant to them than to more conventional insecticides. Nevertheless, entomologists caution that insects are remarkably adaptable—and a change in their pheromones is possible.

Three approaches to the use of pheromones in pest management programs are now being explored. One of these—the monitoring of insect populations by using traps baited with attractant—has already proved valuable. For example, such traps are now deployed throughout the eastern United States to detect gypsy moth infiltrations.

The gypsy moth is a most destructive insect that has been defoliating forests in the Northeast (Fig. 1). Like many of this country's worst pests, it is an import that has been freed from the restricting activities of its natural enemies in the original habitat. Introduced into Massachusetts in 1869 by a scientist who wanted to use it to breed a hardier silk moth, the gypsy moth is now spreading westward and southward. Its spread is greatly aided by the movement of recreational vehicles that inadvertently transport larvae and egg masses, and by the banning of the insecticide DDT, which previously prevented the spread of the moth.

The gypsy moth female, burdened with eggs, flies poorly if at all; in order to attract a male, she releases minute quantities of a potent sex pheromone. Morton Beroza and Barbara A. Bierl at the Agricultural Environmental Quality Institute, U.S. Agricultural Research Service (ARS), Beltsville, Maryland, were able to identify and synthesize the pheromone, which they named disparlure. Traps containing microgram quantities of disparlure, together with an agent to regulate its volatilization, retain their trapping effectiveness throughout the summer.

Monitoring Is Useful

Accurate monitoring and early detection of infiltration by a pest should reduce the use of broad spectrum insecticides, which can be applied only where and when the pest is found. One of the disadvantages of many insecticides is their lack of specificity. They kill beneficial as well as harmful insects (only about 1 percent of the 1 million insect species identified are harmful to man; the rest are either beneficial or innocuous), and may also be toxic to birds and mammals. Thus, it would be both economically and ecologically advantageous to use them only against known infestations rather than apply them prophylactically.

The other two strategies for pheromone use in pest management are the mass trapping and "male confusion" techniques; both rely on preventing reproduction by the target insects. In the mass trapping technique, traps are usually baited with sex pheromone that lures all or practically all of the males to the traps rather than to the females. "Male confusion" (also called male disruption or communication disruption) is achieved by permeating the air with female sex pheromone. The male, surrounded with the attractant, becomes confused and thus frustrated in his attempts to locate the female.

The practicality of both these methods remains to be demonstrated, especially on a large scale; however, investigators in several laboratories are conducting field trials to test their effectiveness. The results indicate that the techniques can control light pest infestations. Insecticides will still be required for immediate reduction of heavy infestations.

David Wood of the University of California, Berkeley, and William D. Bedard of the Pacific Southwest Forest and Range Experiment Station of the U.S. Department of Agriculture, Berkeley, are attempting to devise ways to control the western pine beetle with pheromone-baited traps. They are using a mixture of pheromones that elicits a synchronized invasion of the target tree by thousands of insects; if the beetles fail to aggregate in this manner they can neither feed nor reproduce.

In an experiment conducted in 1969, Wood and Bedard found that the traps captured over 70 percent of the western pine beetle population in a test area of 20 square miles. Moreover, the number of infested trees was reduced from 250 at the start of the season to only 6 at the end. The results of a more ambitious study begun in 1972 were less encouraging. Although they trapped more than 2.5 million beetles during the first season, the number of infested trees increased from 1900 to 2100. During the second season of the trial, tree mortality increased by another 200 trees even though 4.5 million insects were trapped. Thus both the beetle population and the number of killed trees increased in spite of the large numbers of beetles trapped.

The caterpillar larvae of several moth species are extremely destructive pests. Wendell Roelofs and his colleagues at the New York State Agricultural Experiment Station, Geneva, have identified a large number of moth pheromones.

Roelofs is particularly interested in applying pheromones to the control of the redbanded leafroller and other pests of eastern apple orchards. In one experiment that lasted 4 years, he and his colleagues achieved 99 percent control of the redbanded leafroller population in a lightly infested area by using traps baited with sex pheromone. Apple damage was negligible. In a heavily infested area, however, mass trapping did not produce satisfactory control; 32 percent of the

apple crop was damaged. The results illustrate the difficulty of using pheromones to control severe pest infestations. When the insect population is low, a high ratio of traps to females is possible and sufficient males are trapped to reduce mating adequately.

High population density may have also contributed to the failure of an experiment recently completed by U. Eugene Brady at the University of Georgia, Athens. He attempted to prevent the mating of two insects that infest stored food products, the Indian meal moth and the almond moth, by the male confusion technique. Exposure of the moths in peanut storage bins to a high concentration of a sex pheromone produced by females of both species did not reduce mating; as a matter of fact, mating may have increased slightly. When populations are high, especially in a limited area, vision may be as important as pheromones for locating a mate.

Conversion of minor pests to major pests is another problem experienced by Roelofs. He found that when the redbanded leafroller population decreased, those of two formerly minor pests, the oblique and three-banded leafrollers, increased. Nevertheless, he still believes that some form of pheromone control is feasible. The leafrollers studied by Roelofs are closely related; the females of the different species secrete the same attractant. They do not mate with males of the wrong species because, in addition to the attractant, they also secrete one or more chemicals that increase the attractiveness of the pheromone to males of the same species and decrease its attractiveness to males of different species. Secretion of such "synergists" or "maskers" is common, but it can complicate the identification of pheromone formulations that are effective in the field. Roelofs hypothesizes that it may be possible to control all of the leafroller species by employing the common attractant in the male confusion technique.

The prospect of increased selectivity in insect control methods has been a major stimulus to research on pheromones. Eliminating the pest without destroying beneficial insects and the pest's predators is an obviously desirable goal. On the other hand, specificity for a single species is a disadvantage if separate methods are needed to control all of the members of a pest complex. Not all pheromones are completely species-specific. The

Fig. 1. Defoliation by the gypsy moth. This forest area on Cape Cod, Massachusetts, was photographed in July 1970. [Source: M. Beroza, U.S. Agricultural Research Service]

leafrollers share a common attractant, as do the Indian meal and almond moths. Brady also found that traps baited with females of one species attracted males of other species. According to Harry H. Shorey and his colleagues at the University of California, Riverside, looplure, a sex pheromone of the cabbage looper, disrupts communications between the males and females of several other species.

In addition to his studies of the cabbage looper, Shorey has been investigating methods of controlling the pink bollworm, the major pest of cotton in California. Hexalure, a synthetic compound that is not the natural sex pheromone of this moth, does attract the males and can be used to disrupt the communication between males and females. At least, treatment of cotton fields with the chemical decreased the capture of male moths by survey traps baited with females. In this type of experiment, a decrease in the number of captured males implies that confusion was achieved—the males could not find the traps. The males did find other females, however. Most females mated at least once, and cotton bolls taken from treated fields contained as many larvae as did those from untreated fields. The results of another experiment were more encouraging; treatment with hexalure did decrease the number of larvae per boll from 7 to 0.6.

Shorey has now identified a natural sex pheromone of the pink bollworm. He anticipates that it will prove more effective than hexalure in field trials.

The gypsy moth pheromone, disparlure, also shows promise in field trials of the male confusion technique. Beroza and his colleagues distributed the sex pheromone, on filter paper squares, over 40-acre forest plots; the number of gypsy moth males (laboratory-raised moths released in the field) captured in traps baited with disparlure or females declined by 93 percent. They are now investigating more efficient methods of distributing the pheromone. In a current experiment, they sprayed 22 square miles of naturally infested Massachusetts forest with microcapsules of disparlure. The microcapsules (diameters of 100 to 200 micrometers) release the pheromone gradually so that it is expected to be effective for 6 to 8 weeks, a period that Beroza thinks is adequate for mating prevention.

Although not all entomologists agree, Beroza and Edward Knipling, now science adviser at the ARS in Beltsville, believe that it is theoretically possible to eradicate, not just control, insect pests in lightly infested areas (either the sites of incipient infestations or of formerly heavy infestations that were controlled by previous insecticide applications) with mass trapping or male confusion techniques. If the methods prevent mating and cause a population decrease, they should become proportionately more effective with each successive generation, and the chance of a fertile mating should ultimately approach zero. In any event, pheromones, used both for monitoring and maintaining low insect populations, should play an important role in pest management programs that combine a variety of control techniques.

Most investigators stressed that insect control with pheromones is still chemical control. Pheromones and other attractants are chemicals, even though their use is based on inherent behavioral and physiological mechanisms. This may also be said of the application of insect hormones to pest control. Methods employing hormones, together with a method that is truly biological—the use of viruses for insect control—will be discussed in a second article.—JEAN L. MARX

Additional Readings

1. M. Beroza and E. F. Knipling, *Science* **177**, 19 (1972).
2. W. L. Roelofs and A. Comeau, "Chemical releasers in insects," *Pesticide Chemistry: Proceedings, International IUPAC Congress 2nd*, A. S. Tahori, Ed. (Gordon & Breach, New York, 1971), vol. 3, pp. 91–114.
3. H. H. Shorey, *Proc. North Cent. Branch Entomol. Soc. Amer.* **27**, 30 (1972).