Insect Control: Alternatives to the Use of Conventional Pesticides

Recent administrative actions by the United States Department of Agriculture and several states as well as legislative action in Wisconsin have affected the licensing, sale, and use of DDT and a few other conventional pesticides. Although the actions will not drastically reduce the use of these chemicals in the near future, some observers believe they are the harbinger of the widespread curtailment of the use of chemical pesticides. Those who have pushed for this curtailment have argued that there are a number of pest control techniques that can be used in place of conventional chemical pesticides.

The alternative methods of pest control are in many stages of development, and several of them require more basic research before their potential can be evaluated; however, in most cases the greatest needs are for large programs to field test new techniques or for changes in existing relations among government, industry, and farmers that will make it possible to implement methods that have already been proved effective. One method with the potential of competing economically with conventional insecticides—the use of an insect hormone or a chemically related substance—is one of the most recent developments and is only now ready for field tests.

Nonpersistent Chemicals

The persistence of many conventional insecticides in soil or water and their tendency to become incorporated into biological systems were key factors in the recent insecticide actions. If these were the only disadvantages of pesticides, pest control problems could be solved with existing chemicals.

A number of new pesticides—principally a few dozen phosphates and a few carbamates—have been developed to minimize these characteristics. If the use of these and several of the more suitable chlorinated hydrocarbon insecticides is tailored to specific crops and crop situations, the problems of persistence and biological residues could be controlled. However, even the careful use of new chemicals would not solve most of the problems associated with pesticides. Insects would still be able to develop resistance to the chemicals, the new pesticides would continue to kill other animals and harmless or beneficial insects, and it would still be difficult to achieve a permanent solution of the insect problem.

Resistant Plants

Several USDA officials have referred to the use of crops that are resistant or partially resistant to insect attack as the most successful and least heralded of the natural methods of insect control, and they have cited the control of the Hessian fly with resistant varieties of wheat as the outstanding example. The first variety of resistant wheat was introduced in 1942, and since that time the wheat in some regions has lost its effectiveness against the Hessian fly, but the problem does not seem to be as serious as the development of resistance to chemicals. When areas populated by resistant flies are discovered, another of the 22 varieties of resistant wheat is planted, and the change is generally effective for about 10 years. In California the Hessian fly population has been reduced to such low levels by the use of resistant strains of wheat that they are no longer a problem.

Other resistant crops now being used or developed include alfalfa for the spotted alfalfa aphid, pea aphid, leafhopper, and alfalfa weevil and barley for the greenbug. Corn inbreds have been released which are resistant to European corn borer, corn earworm, rice weevil, and corn rootworm. Several wheat strains are highly resistant to the cereal leaf beetle but have not yet been released for farmer's use. A number of trees and vegetables are also being screened for resistance to their insect pests.

Because of these current successes, agriculture researchers are optimistic about the practicality of widespread use of additional resistant crops in the near future. They point out, however, that it generally takes 10 to 15 years to develop even partially resistant varieties of most crops, and that in some key areas—cotton, for example—progress has been slow. The reform-minded attribute this to poor research priorities, while others say that development of resistant plants is difficult and that progress has been as rapid as can be expected.

Insect Enemies

The use of natural enemies as the sole means of controlling pests of a seasonal field crop will seldom succeed because the natural lag between the time that the insect population reaches a maximum and the time that the enemy becomes numerous enough to reduce the insect population is such that crop damage occurs before control. This is generally the case with both insect predators and parasites and with pathogenic bacteria and viruses.

In addition, the insect enemies generally do not eliminate the insect population but establish an equilibrium relation in which the insect population is often too high for the crop. Thus, these agents must be used with other control methods—such as resistant plants—or artificially applied at the appropriate time during each growing season to effect a satisfactory reduction in the population. Natural enemies can be used to provide good control over tree and shrub insects when the loss of some foliage before the enemy becomes established is acceptable.

One of the major problems now and in the foreseeable future is getting natural enemies established. Of almost 700 insect enemies that have been introduced, less than one-fourth have become established. Decreasing the use of chemical pesticides will undoubtedly help, but much work must be done on developing methods of dispersing insect enemies at acceptable cost and with equipment and personnel that can be made available.

Predators and Parasites

The first successful control program using an artificially introduced insect involved the importation of the predator, *Rodolia cardinalis*, for control of the cottony-cushion scale of citrus plants. This and several other ladybugs could become increased in sufficient numbers to play an important role in insect control if the heavy use of broad spectrum pesticides is curtailed. In addition, several programs to artificially introduce predators in large numbers are in progress. One of the most promising is the mass rearing of the lacewing larvae for control of the cotton bollworm.

Parasites, however, seem to have more potential for successful control programs; in fact, several parasites are now keeping the numbers of a few important insect pests reduced.

Reece Sailer, Branch Chief of Insect Identification and Parasite Introduction of the Agricultural Research Service, told *Science* that he believes that there will be no recurrence of the widespread destruction of elms that we have witnessed during recent years because a parasite of the vector of Dutch elm disease is becoming established. Sailer also said that several European parasites—one of which is established—show promise in effecting control of the cereal leaf beetle—a European insect first discovered in Michigan less than 10 years ago that has caused great damage to oats and wheat.

Agriculture entomologists often have cited the establishment of several parasites of the spotted alfalfa aphid as one of the most successful cases of natural insect control. The success of this program is due partially to the earlier development of resistant species of alfalfa, and it now appears that the combination of the two pest control techniques may result in a permanent solution to the alfalfa aphid problem.

At one time an established parasite and resistant varieties of corn were controlling the European corn borer, but this pest has now reappeared without its parasite. The reason for this is unknown although Sailer thinks that the use of resistant corn may have reduced the borer population below that necessary to support the parasite. Whatever the reason, the failure illustrates the difficulties of parasite control and helps explain why many parasites that are available are not yet being used widely.

For example, Trichogramma—a large group of wasplike insects that are egg parasites on many species of insects—have been considered a potentially useful means of pest control for many years. Many laboratory and field tests have been run on these insects, and some of the species are even available commercially. Sailer, however, says that a vast amount of information is needed "before we can reliably utilize Trichogramma." He notes, for example, that "for each crop situation and each insect one needs to know the genetic composition of the Trichogramma," but that within this group entomologists "are not really sure of what constitutes a species."

Sailer's explanation of the apparent successes with commercial Trichogramma that have been reported by farmers is testimony for those who have argued that much of the current use of chemical insecticides is not only unnecessary but harmful. He says that "because the grower has released the Trichogramma he has confidence that they are going to take care of his problem—which might not have developed anyway. Alternatively, having released the Trichogramma he does not complicate his pest problem by the use of pesticides which would reduce the normal complement of predators and parasites that would be present in his field."

Bacteria and Viruses

There are a few pathogenic bacteria now in use, but for large-scale crop applications the use of bacterial toxins seems to be more promising. *Bacillus thuringiensis* was identified as an insect pathogen in 1927. In the early 1950's its toxin was isolated, and eleven serological types from all over the world have now been isolated.

The toxins have complex chemical structures and it is not likely that they can be synthesized economically, but two companies have been producing a commercial toxin prepared from cultures. At Abbott Laboratories attempts are being made to produce a commercial product from an especially pathogenic strain isolated 2 years ago by Howard Dulmage of the USDA station in Brownsville, Texas, and there are reports that several other pharmaceutical companies are working on highly pathogenic strains of their own.

Bacillus thuringiensis toxins are not specific, although different insects show large variations in susceptibility, so in some cases they would be used like a broad spectrum insecticide. However, they have little effect on higher animals, and Arthur Heimpel, Director of the Insect Pathology Pioneering Research Laboratory of the ARS, says that insects will probably not be able to develop resistance to the toxins as easily as they do to conventional insecticides.

For specificity, insect viruses seem to be more promising than insect bacteria. Heimpel says that 254 viruses have been isolated that are pathogenic to insects and that about ten of these are "feasible" for near-term use. Of these ten, a virus that is effective against *Heliothis zea* (called the cotton bollworm or corn earworm depending on what it is eating) is in the most advanced stages of development. For the past 5 years two companies have had petitions with the USDA and the Food and Drug Administration to produce the virus. Although over 2000 tests on animals—including man—have shown no response to the virus, there is no precedent for registering viruses and the FDA is proceeding with caution.

Even if fast registration procedures are instituted, several hurdles must be cleared before viruses can be used widely. Methods must be developed to grow them economically on artificial media, and techniques for dispersing them under field conditions are needed. For example, many viruses are damaged by ultraviolet radiation, so methods must be developed to get them onto crops while protecting them from sunlight.

Chemicals

In addition to toxins that are obtained from insect pathogens, there are two other categories of chemicals that are potentially useful for insect control. One group can be loosely gathered under the heading attractants; the other group consists of a number of chemicals that are associated with a set of insect development hormones.

Agricultural scientists generally refer to three types of attractants—food, sex, and ovipositional. Several of the latter are known, but they appear to have little potential for insect control. There are many uses for food attractants, and several are quite successful. For example, methylbutanol attracts and kills male oriental fruit flies and is widely used in control programs. The most active research area, however, is in the use of sex attractants.

The first sex attractant (these substances are also called pheromones) was isolated from the female gypsy moth in 1960, and since then some 200 have been discovered. Martin Jacobson of the Agricultural Research Service said in an interview that about two dozen that may be useful for pest control have been identified. Attractants for the male pink bollworm, the cabbage looper, and the fall armyworm are commercially available. These were originally extracted from the female insects, but synthetic compounds are now available.

The use of pheromones for some control schemes seems likely. For example, field tests of a synthetic attractant for the female boll weevil have been encouraging. However, their use in inexpensive spray programs may be limited because their effect on insect behavior is both subtle and complex. It has been shown, for example, that changes in the time of day that the pheromone is applied and small variations in the concentration can determine whether an insect is attracted or repelled and in a few cases may even determine which species is affected.

Development hormones or related compounds seem to show more promise for inexpensive, widespread use than do the pheromones. Many insect physiologists think that insect development is controlled by a brain hormone that regulates the juvenile hormone and ecdysone—the hormones responsible for larval and pupal development, respectively. Both substances are potentially useful for insect control because when present at certain stages of development they cause the formation of abnormal insects that cannot develop or reproduce.

In 1964, Carroll Williams and Karel Sláma working at Harvard University found that a substance produced by balsam fir affected linden bugs, which Sláma had brought from Czechoslovakia, in much the same way as juvenile hormone did. Analysis showed that its structure was similar to that of the juvenile hormone, but that it was specific for the linden bug and closely related insects.

Since 1964 several laboratories have been in on the search for plant extracts containing juvenile hormone, ecdysone, and related compounds; and other researchers have synthesized the juvenile hormone and a host of similar substances. Ecdysone, although valuable for insect physiology studies, has a complex chemical structure that would be difficult to synthesize commercially, and it acts on insects only after being ingested; thus it is not a good candidate for an insect control agent.

On the other hand, the juvenile hormone and hundreds of related compounds have been synthesized, many of them act on contact, and they appear to be harmless to higher animals—although after the DDT fiasco no one makes the latter claim lightly. Williams told *Science* that some of the substances could be "used as a substitute for DDT right now" if they were available. However, until recently scientists have been working with milligram quantities of the substances; so large-scale field tests and animal studies have not been conducted.

There is no facility within the government or farm industry to develop new pesticides, and private industry is often unwilling to develop compounds that are within the public domain, which includes all compounds that have been developed in government laboratories or in research programs that utilize any government money. However, the use of hormone-like compounds for insect control now looks promising enough for several companies to have started programs of their own.

Perhaps the largest effort in the United States is being conducted by Zoecon Corporation of Palo Alto, California, a company that formed from Syntex a little more than a year ago for the sole purpose of developing hormone-like insect control methods. Vice President Daniel Lazare told *Science* that the company has several hundred compounds with varying degrees of development potential, and that several have been field tested. He said the company was formed with the idea of producing a marketable product in about 5 years after spending close to $10 million—about the same amount of time and twice as much money as required to develop a conventional pesticide.

The Sterile Male Technique

For many years Edward Knipling, Director of Entomology Research of the Agricultural Research Service, has advocated the programmed release of sterile male insects as a means of eliminating pest populations. Although difficult to carry out in practice, the basic technique is simple. Male insects are sterilized in such a way that their normal mating habits are not altered. Female mates of the sterilized males lay infertile eggs so their offspring do not develop. When a high ratio of sterile to normal males is maintained the population will decrease.

Knipling directed a research program that led to the elimination of the screwworm fly first in Florida and then in the Southwest, and the USDA now keeps this insect suppressed in the United States by releasing an average of 125 million sterile males each week in areas where the flies reappear and along a 300-mile buffer zone along the Mexican border. The USDA and the Mexican government are considering pushing the zone to the Isthmus of Panama in order to eliminate the screwworm fly from all of North America.

The sterile male technique is used successfully along the border between California and Mexico to control the Mexican fruit fly, and last month the USDA in cooperation with California and Arizona officials began releasing sterile pink bollworms in an effort to eliminate this important cotton pest from the San Joaquin and Coachella valleys. Knipling thinks that the method could be used to control the cabbage looper in the eastern and southeastern states and the codling moth in the northwestern states.

Sterilization is now being considered as one part of an integrated control scheme that might someday eliminate the boll weevil. As a first step in this project, a committee of federal, state, and industrial representatives headed by Knipling has outlined a plan for a 2-year pilot program on a 10,000-acre test plot in southern Mississippi. If funds are provided, the use of insecticides, crop management measures, and sex attractants will be integrated to find out whether the boll weevil population can be eliminated.

Knipling said that some control programs might have succeeded by now if they had been started 10 years ago. Recent advances should make the chances for success even better now. These include improvements in mass rearing techniques, the development of chemical and hormonal sterilization methods, and a few successful field tests where sterility or some other "favorable" trait was passed on genetically.

How Do You Get There from Here?

Some basic research remains to be done, many field tests must be conducted, and tactics for using different pest control methods must be developed. But even when this is done, the problem of administering the programs remains. The returns of pest control are quite high (especially if the insect population is permanently reduced or eliminated), so the problem is not one of overall economics but one of rechanneling money. For example, the annual cost of the screwworm program is one-fifteenth of the estimated annual losses due to control costs and livestock damage before the insect was eliminated. Knipling's price tag on the cabbage looper program is $2.5 million a year, less than the cost of developing a new insecticide, and he says that control of the boll weevil alone would pay for all other pest control programs combined. We have, therefore, knowledge of pest control methods that will solve many of the problems associated with the use of conventional pesticides and that could pay for themselves in the long run, but the structures that evolved among the government, industry, and farmers to implement the use of conventional pesticides appear to be unsuitable for the initiation of new control measures.

—Robert W. Holcomb