Applied Ecology: Showing the Way to Better Insect Control

As the condition of the environment goes downhill—and the cost of applying and developing insecticides goes up—many members of the agricultural community are recognizing that total reliance on chemical insecticides is both environmentally and economically unsound. As a result, the trend during the past few years has been toward "integrated pest management," in which synthetic chemicals are only one part of the arsenal for controlling insect pests. Also included in that arsenal are the pests' natural enemies, insect hormones and pheromones that disrupt their development and mating, insect-resistant plant strains, and alterations in crop management procedures.

Integrated pest management requires that insecticides be applied only when needed and in the lowest amounts that will do the job. By cautious use of insecticides scientists hope to avoid the selection of resistant pests and the disruption of natural controls that have so frequently occurred in the past. Tailoring insecticide practices to fit specific situations is obviously more difficult than simply spraying insecticides at fixed intervals, still the most common practice for many crops. In order to work effectively, integrated strategies require accurate, up-to-date information about a crop ecosystem, including its pests, their parasites and predators, the weather, and how all of these influence one another.

Providing this kind of information and developing alternate strategies to wean farmers away from indiscriminate use of chemical insecticides are among the major goals of the Huffaker project, named after its coordinator, Carl Huffaker of the University of California at Berkeley. The project, which can be described as an exercise in applied ecology, illustrates many of the current trends in pest management research; but more than that, it aims to develop new ways of doing agricultural research in general, according to Huffaker.

The application of computer technology and systems analysis to build models of crop ecosystems that can provide farmers with reliable information on controlling insect pests and other aspects of crop management is a new development in agricultural research and is heavily emphasized in the Huffaker project. Equally noteworthy is its multidisciplinary approach. The project involves agronomists, ecologists, economists, entomologists, plant pathologists, and systems analysts at 18 universities. A high degree of central coordination helps to ensure that the right problems are tackled with minimal duplication of effort and that the results of the investigators are integrated.

The research phase of the Huffaker project began in March 1972 and will run for one more year. The total cost during this time will be about $14 million, with the National Science Foundation and the Environmental Protection Agency (EPA) each contributing about $6 million. The United States Department of Agriculture (USDA) put up the remaining $2 million. The potential annual savings that may result from the research are great; in 1974, almost $645 million was spent on insecticides used in agriculture, according to the USDA.

Five major crops and pine forests are the targets of the six subprojects* into which the Huffaker project is divided. The crops are alfalfa, citrus fruits, cotton, pome (fleshy fruits containing a core and seeds) and stone fruits, and soybeans. The goals of the subprojects depend on the crops. For example, cotton and fruit orchards are noted for their heavy insecticide applications and the need is to reduce the amount of chemicals used without adversely affecting yields. In contrast, the use of insecticides on alfalfa and soybeans is comparatively low and the goal is to keep it that way.

Despite these differences, development of models that describe the particular ecosystem is at the core of all of the subprojects. Andrew Guttierrez of the University of California at Berkeley, who has contributed to the development of the cotton and alfalfa models, says that they are essentially libraries of all the things known about a crop and its pests. The weather is the major factor regulating plant and insect development and is thus a major component of the models.

*The directors of the subprojects are Perry Adkisson of Texas A & M University (cotton), Edward J. Armbrust of the Illinois Natural History Survey (alfalfa), Brian Croft and William H. Whitcomb of Michigan State University (pome and stone fruits), L. Dale Newsom of Louisiana State University (soybeans), Louis Riehl of the University of California at Riverside (citrus fruits), and W. E. Waters of the University of California at Berkeley (pine bark beetles).

Not all the models are complete but the ultimate goal is to use them in conjunction with current data from field and weather monitoring to predict when—or if—an insect population will exceed the economic threshold, that is, the population density that will cause enough crop damage to make spraying with insecticide worthwhile. Only then need insecticide be applied in quantities just high enough to control that outbreak. This is in contrast with traditional practices in which some crops are sprayed at approximately the same time in every growing season regardless of need.

One way the models can be applied is illustrated by the "dial-a-bug" service for orchard owners in Michigan. The service, which is a product of the pome and stone fruit subproject, provides the owners with information about how to manage their crops and protect them from pests such as the coddling moth and spider mite, which cause major damage to apples. According to Brian Croft, daily information about the weather, insect populations, and the like is collected in each of 27 regions throughout Michigan and fed into computer terminals for analysis by the central computer. The computer uses the model to derive information about crop management needs, including whether or not to spray for certain pests. The information is then passed on to the agricultural extension agents who record the appropriate telephone message for each region.

The Michigan investigators have compared pesticide use and crop yields in 200 orchards whose owners use the message system with those in control orchards and have concluded that the system permitted a reduction in insecticide applications of about 30 percent. Croft says that the savings on insecticide expenditures more than make up for the cost of monitoring the orchards and running the computer system. In addition, the environment benefits from reduced pesticide use. These advantages are not restricted to Michigan. Croft points out that similar programs in California, New York, Pennsylvania, and Washington are achieving reductions in insecticide applications.

Orchards lead in the number of pounds of insecticide applied per acre but cotton is the greatest user in terms of total quantities of pesticide. The latter crop accounts for approximately 45 percent of all the insecticide applied to agricultural crops. The cost of the chemicals is about $150 million per year. Even so, losses of cotton to insect pests exceed $500 million annually.

Part of this loss is undoubtedly due to the selection of resistant pests and disruption of natural controls brought about by overuse of insecticides. In some areas, growers apply the chemicals 10 or even 20 times in one growing season. This situation has been recognized for some time and a downward trend in the application of insecticides to cotton began several years ago. But the problem of resistant insect pests has not yet been solved. Recently, the USDA endorsed requests from 11 cotton-producing states to the EPA to permit use of four experimental insecticides for control of the tobacco budworm, which also attacks cotton. The pesticides are not yet registered, which means that they cannot be legally sold without a special exemption from the EPA, and registration procedures will not be completed before the start of the upcoming growing season. Since the budworm is highly resistant to insecticides that are now available, state agricultural authorities fear that budworm infestations may be a problem for cotton farmers this year.

Perry Adkisson thinks that the research being carried out under the aegis of the cotton subproject can help to accelerate the trend away from total reliance on chemical insecticides, reduce the problems with resistant insects, and save money for the cotton farmer. One approach that has already been proved in the field involves the planting of a strain of cotton that matures quickly and can be harvested approximately 1 month earlier than standard strains. Most of the cotton bolls of this strain mature before the boll weevil population becomes large enough to do a lot of damage. Moreover, early harvest deprives the boll weevil of food and breeding grounds, with the result that there will be fewer insects to go into the dormant state for winter. Thus, the population for the following year can be reduced even without insecticide applications.

If it is necessary to spray for boll weevil control, the timing, dosage, and kind of insecticide are chosen to minimize destruction of insect enemies, especially those that control the budworm and certain other insect pests. Some of these have become economically important only because heavy insecticide use has relieved them of the natural constraints that used to control their populations. According to Adkisson, it is not necessary to spray for budworms on the short-season cotton even though their populations may exceed what had previously been considered to be the economic threshold. He says that the biological controls work better than the currently registered insecticides and that the populations subside within a few days without seriously affecting cotton yields.

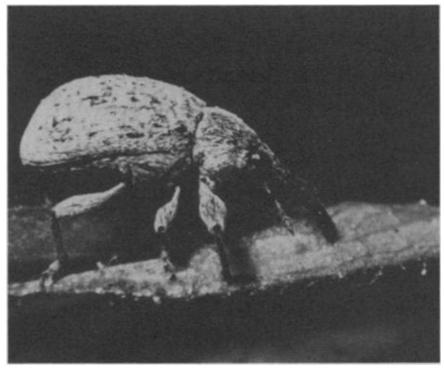

Fig. 1. The boll weevil, seen here on a cotton plant, is one pest that can be controlled through the techniques of integrated pest management. [Photo courtesy of the United States Department of Agriculture]

By planting the short-season cotton at double the usual density, the farmer can not only save money on insecticide but he can also reduce costs for irrigation and nitrogen fertilizer. This is especially important in view of the current shortage of natural gas (a starting material for nitrogen fertilizer synthesis) and the drought in some parts of the country, including California and the Southwest. Cotton grown in the short-season system requires only about one-fourth of the insecticide, one-fourth or less of the nitrogen fertilizer, and one-half of the irrigation required by conventionally grown cotton. And the system pays off for the farmer. Field studies have shown that the average profit per acre for the short-season cotton system was almost $150 more than that for conventionally grown cotton.

Breeding insect-resistant plant strains is another major aspect of the cotton, soybean, and alfalfa subprojects. The Texas A & M investigators have already field-tested in Mexico a cotton strain resistant to the budworm and related species. The resistant strain, developed by Maurice J. Lukefahr of the USDA, produced more than 1700 kilograms of seed cotton per hectare whereas a commercial strain produced less than 400. No insecticides were applied to the fields, which were heavily infested with budworms and bollworms. The traits that make cotton less attractive to the budworm are smooth leaves that hinder egg laying, absence of nectar, and a high content of gossypol, a bitter chemical found in cotton.

Another line of investigation that is being vigorously pursued for controlling pests is the use of pest parasites or predators, some of which have to be imported because the target species are not native to this country. Such biological control for pests of citrus crops has been developing for many years. Louis Riehl says that with the aid of a small wasp (*Aphytis melinus*) that is a parasite of the California red scale, an important citrus pest, integrated pest management works very well in the citrus orchards of Southern California. However, the wasp fails to thrive in the San Joaquin Valley because of unfavorable climatic conditions. One aim of the citrus subproject is the adaptation of the wasp to the San Joaquin Valley. Meanwhile, program participants have introduced a related wasp into Florida citrus orchards to control the snow scale. According to Robert Brooks of the University of Florida, this biological control is already saving as much as $10 million per year in reduced insecticide costs.

It is difficult to assess the economic impact of the subprojects that aim to prevent rather than reduce the application of large quantities of insecticides. According to L. Dale Newsom, participants in the soybean subproject wanted to demonstrate the feasibility of insecticide alternatives very early in the game because insecticide manufacturers were beginning to pressure soybean farmers to use their products. Several of the integrated pest management strategies developed for controlling pests have since been adopted as recommendations of the Agricultural Extension Service for general farmer use.

Although the insecticide practices of soybean farmers have not led to the development of resistance in the pests, the practices of other farmers may. Newsom says that farmers in northern Florida, Georgia, and South Carolina have recently noted that they required more insecticide than previously to control the soybean looper. Laboratory tests confirmed that the insects have indeed become more resistant. The current thinking is that the application of large quantities of the insecticide on certain vegetable crops and chrysanthemums in southern Florida, the site of origin for soybean loopers that migrate northward, caused the increased resistance. Thus, the success of one group in achieving integrated pest management can still be undermined by other groups who have not yet adopted the techniques.

Few people in this day and age question the environmental wisdom of diminished reliance on chemical insecticides. In addition, most insecticides are petrochemicals, and in the winter of 1977 no one needs to be reminded about what is happening to the cost of oil products. Research such as that in the Huffaker project is demonstrating that integrated pest management is also economically attractive. If the costs of insecticides continue to escalate, it should become even more so.—JEAN L. MARX

Unconventional Energy Sources: Brazil Looks for Applications

Campinas. The existence at the university here of a large and, for Brazil, novel research group devoted to solar energy would seem to contradict the oft-repeated saying about everything taking longer in a developing country. During the time that a solar energy institute has been under study in the United States, the Campinas solar energy group was conceived of, assembled, and funded, and it has been in operation for nearly 2 years. The project is part of a larger national research program on unconventional energy sources to which the Brazilian government has committed about $15 million, a substantial sum here, in its first 2 years. The emphasis of the research is decidedly practical—"low-profile science" one of the principal investigators proudly calls it—but the results are already attracting industrial interest for such applications as drying crops with solar heaters to prevent spoilage. In addition, investigations are getting under way here and at other research centers to explore a hydrogen economy, conversion of biomass to fuels, conservation, and even ways to use coal, which in Brazil is an unconventional energy source.

The solar energy research program is motivated by the realization that Brazil's more than 8 million square kilometers lie almost totally between the equator and the Tropic of Capricorn. Except for parts of the Amazon Basin that are often obscured by clouds, intense sunlight is readily available in all parts of the country. Yet except for burning wood, which is still a major source of energy in rural areas, solar energy has never been exploited in Brazil. Even the architecture of most houses reflects the influence of imported designs rather than of the tropical climate.

The goal of the national research program on unconventional energy sources is to remedy this situation and to lay a technical base for tapping what is certainly an enormous long-range potential. The program is the brainchild of the Financiadora de Estudos e Projetos (Finep), a science-oriented funding agency attached to the Ministry of Planning. The program is the agency's first venture into the energy field, but as the guardian of the national fund for science and technology and the major source of support for graduate education in the sciences in Brazil, Finep is no stranger to research.

Most of the research is being done at universities such as the State University of São Paulo at Campinas, a suburb of São Paulo. Finep officials say that the Campinas group has been the national program's pioneering effort and so far its most successful one. One American energy researcher who has visited Campinas, Robert Williams of Princeton, says there is "a great deal of intelligence in the design of the research." He is impressed with how much they have achieved with relatively little money, which he describes as a "refreshing contrast" to solar energy research in the United States. The Campinas research group is headed by João Meyer, a particle physicist who until recently was senior physicist at CERN, the European high-energy research center in Geneva, but who came back to Brazil for that purpose. Meyer also helped plan the national program.

The Campinas energy research program is in many ways not typical of university research in Brazil, which is far more often basic than applied and is usually organized along strict disciplinary or departmental lines. At Campinas, for example, the physics department is dominated by a large, sophisticated solid-state laboratory that thinks of itself as the Bell Labs of Brazil and works on such things as semiconductor lasers. The energy research group, however, has a very different orientation, more applied and directed toward Brazil's immediate problems. Meyer says, "We are consciously doing development science," rather than trying to compete in the international arena. The group now comprises 70 people, including more than a dozen young, U.S.-trained Ph.D.'s, and is interdisciplinary in composition—physicists, chemical and mechanical engineers, architects, and agronomists. The energy research effort is also institutionally independent of the regular university departments, an arrangement for which Meyer credits the flexibility of the university administration and which has helped get things off to a quick start.

A major focus of research has been to see if solar energy can be used to reduce crop spoilage. Brazil produced about 40 million tons of corn, coffee, soybeans, rice, and wheat in 1976. But rainfall and fungus infections damaged as much as an additional 50 percent—the exact amount is not really known and varies greatly from year to year, according to Gonzalo Roa of the Campinas group. Much of this damage arises because crops have traditionally been left to dry either in the field or on open floors. To reduce spoilage, the Brazilian government has begun to help farmers use more mechanized techniques, particularly drying bins through which hot air is forced continuously; the air is usually heated by burning oil, however, which exacerbates the country's energy problems because oil is an expensive and largely imported fuel. Roa believes that a scheme in which solar energy is used to heat the air in the drying bins would be cheaper and more efficient, in addition to saving petroleum.

The Campinas group has developed mathematical models of the drying process, building on U.S. work along similar lines. They have also built drying bins equipped with simple and very inexpensive solar collectors, which were made from galvanized iron sheets in a frame covered with polyethylene. Measurements of incident solar radiation, inlet and outlet air temperatures, humidities, and other variables in experiments with these bins have shown that low-temperature drying is as much as 50 percent efficient, Roa says, and significantly faster than leaving the crop out to dry naturally. Red beans, for example, dry four times as quickly in the solar drier. The experiments and simulations with the mathematical models have now been used to determine the optimum drying conditions for half a dozen different grains.

The lack of prior research on drying in Brazil means that even modest advances can have a major impact. The Campinas results have begun to interest bin manu-