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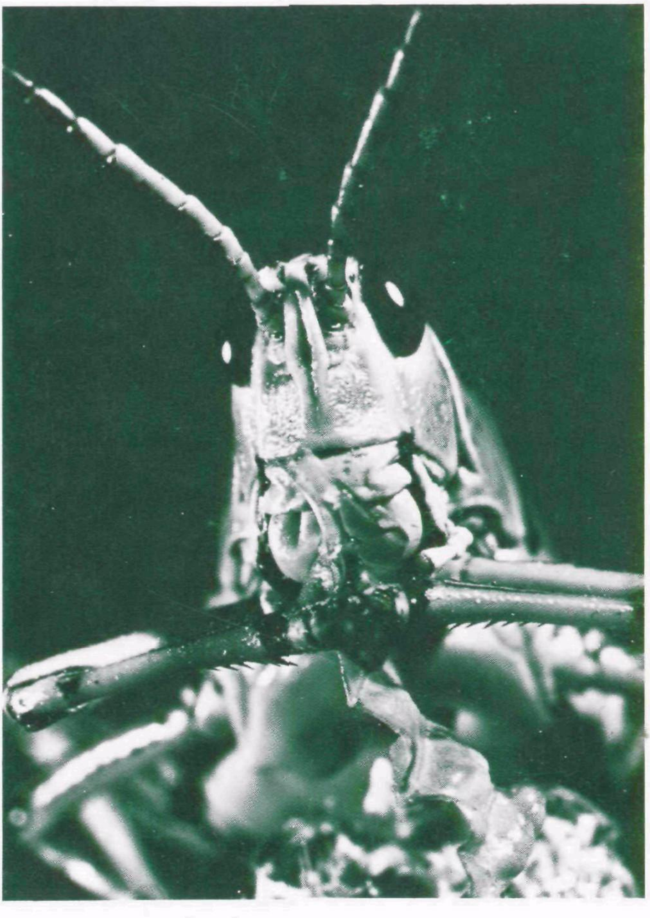
Research Summary

Integrated Pest Management



The tremendous increase in the worldwide use of pesticides over the past three decades has resulted in many unforeseen environmental problems. One of the most serious and best documented of these is pest resistance. More than 300 species of insects, mites, and ticks throughout the world possess genetic strains which are resistant to one or more pesticides. This presents serious problems, especially to U.S. farmers and ranchers who rely heavily on pesticides. In California, for example, 75 percent of the state's most serious crop insect and mite pests have developed genetic resistance to one or more insecticides. This Research Summary describes an alternative approach towards pest management—an approach that takes into account both the necessity and the danger of pesticides. Integrated pest management involves the carefully managed use of multiple pest control tactics. It is a highly effective alternative that minimizes the use of chemical controls and maximizes the use of natural processes; thereby avoiding many of the problems associated with pesticides use.

Stephen J. Gage

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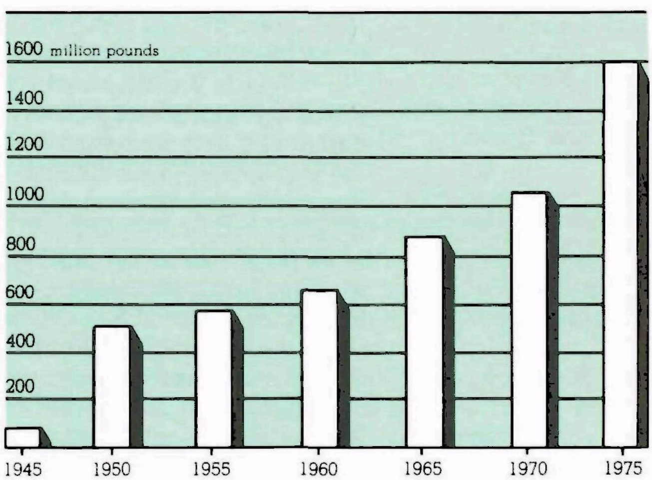
integrated pest management

use of pesticides

Agricultural crops and forests in the United States are the target of several thousand pests, including insects, weeds, and disease-causing micro-organisms. Prior to the Second World War, relatively small amounts of chemicals were used for pest control. Production of pesticides in 1945 was less than 200 million pounds. The development of synthetic chemicals during the war resulted in a dramatic increase in the production and use of pesticides. During the next 30 years, pest management became increasingly dependent upon chemicals, with 1.6 billion pounds of pesticides being produced in 1975.

The rapid rise in the popularity of pesticides was due primarily to their increased effectiveness, low cost, and availability. Because pesticides were initially so successful, farmers came to rely much less on traditional pest control measures such as tillage, crop rotation, and use of the pests' natural

estimated pesticides produced in the U.S.



The Pesticide Review, USDA, Agricultural Stabilization and Conservation Service enemies. Regular application of pesticides became standard practice.

Unfortunately, such widespread use of pesticides has been accompanied by unforeseen problems. The impact of these problems is far reaching and concerns not only the agricultural community but the general population as well.

pesticide problems

In order to meet the demands of a rapidly increasing world population, more food, feed and fiber crops are required each year. As demand increases, prevention or reduction of crop loss becomes even more critical. Today, despite the tremendous amounts of pesticides being used, approximately one-third of the crops planted in the U.S. fail to reach harvest due to pest damage. To a great extent, these losses are due to the development of pest resistance and to other pest problems. Ironically, these problems are caused by the very chemicals formulated to control pests.

pest resistance

Pesticide application seldom results in the total eradication of a pest population. A few individuals, due to their genetic makeup, will be resistant to the pesticide. These survivors mate and produce offspring, some of which will inherit this resistance. The next time the pesticide is applied, a larger percentage of insects will survive and reproduce, increasing the number of resistant insects. Eventually, a highly resistant population will be produced which cannot be controlled by the pesticide developed for its management.

secondary pest damage

Pesticides kill not only target pests, but also insects which help control other pests. The loss of these beneficial insects following pesticide treatment may result in an increase in the population of a previously controlled pest. This "new" pest population may cause more damage to the crop than the initial pest. Such damage is referred to as secondary pest damage.

environmental and health hazards

Perhaps the most significant problem associated with the widespread use of pesticides is the threat to human health and the environment. Some pesticides may be highly persistent; that is, slow to break down via natural environmental processes. Pesticides can filter into the soil or water where they are taken in by microorganisms. Since these microorganisms, in turn, are consumed by other organisms, pesticides may enter the food chain and be concentrated. Pesticide residues are therefore detected not only in treated crops but also in fish, waterfowl, livestock, and humans.

DDT is an example of a highly persistent pesticide. Due to its widespread use in the years following World War II, tremendous amounts of DDT were introduced into the environment, entered the food chain, and accumulated in the fatty tissue of living organisms. In December 1972, following the discovery that DDT causes some birds to produce abnormally thin-shelled eggs and causes cancer in laboratory mice and rats, EPA placed a near-total ban on its domestic use. Despite this ban, DDT persists in the environment. Mussels and fish collected four years after the ban were still found to contain residues of DDT.

Of even greater concern are reports which link specific adverse human health effects with pesticides. An estimated 40,000 people were treated for pesticide poisoning in 1978. The actual number of poisonings may be even larger since many cases are not reported or are misdiagnosed. This is because the symptoms of pesticide poisoning often mimic those of common illnesses. Among agricultural workers, pesticide poisonings are particularly difficult to recognize due to the variety of chemical agents to which they are exposed and to the circumstances surrounding their use. The association between pesticides and adverse human health effects can be more clearly demonstrated among industrial workers who are exposed to pesticides during their manufacture and formulation. In 1977, dibromochloropropane (DBCP) was found to cause sterility in male workers exposed to the pesticide during its formulation. Several years earlier, workers at a chemical processing plant in Hopewell, Virginia, developed complex neurological disorders as a result of chemical exposure during the production of the pesticide kepone.

integrated pest management

Recognition of the problems associated with widespread pesticide application has encouraged the development and utilization of alternative pest control techniques. Rather than employing a single control tactic, attention is being directed to the coordinated use of multiple tactics, an approach known as integrated pest management. Integrated Pest Management (IPM) is an interdisciplinary approach incorporating the judicious application of the most efficient methods of maintaining pest populations at tolerable levels.

IPM is by no means a new concept; some forms of integrated pest control have been practiced for centuries. The significance of today's IPM concept is that it is based on a scientific approach employing sophisticated control techniques. Development and implementation of an IPM system requires an understanding of the crop-pest ecosystem and available control tactics.

crop-pest ecosystem

Understanding an entire crop-pest ecosystem is not a simple task. It requires not only simple identification of the crop and the pest to be managed, but also close examination of complex crop-pest interrelationships. Detailed study of a crop's botanical characteristics is essential to allow the IPM strategist to take full advantage of natural processes. The IPM approach recognizes that almost every cropland, as compared to a meadowland, represents an unusual ecological setting composed of a single plant type. In such single plant communities, natural ecological balances are altered, leaving crops highly susceptible to pests.

Under IPM, the pest targeted for control is also studied in detail. Attention is given to the pest's life cycle and to precisely how it adversely affects the plant. An important consideration is the dynamic nature of pest populations; most pests reproduce frequently and produce numerous offspring, enabling them to adapt quickly to changing environments. Relationships between the pest and other organisms are also studied, with particular attention being given to the pest's natural enemies

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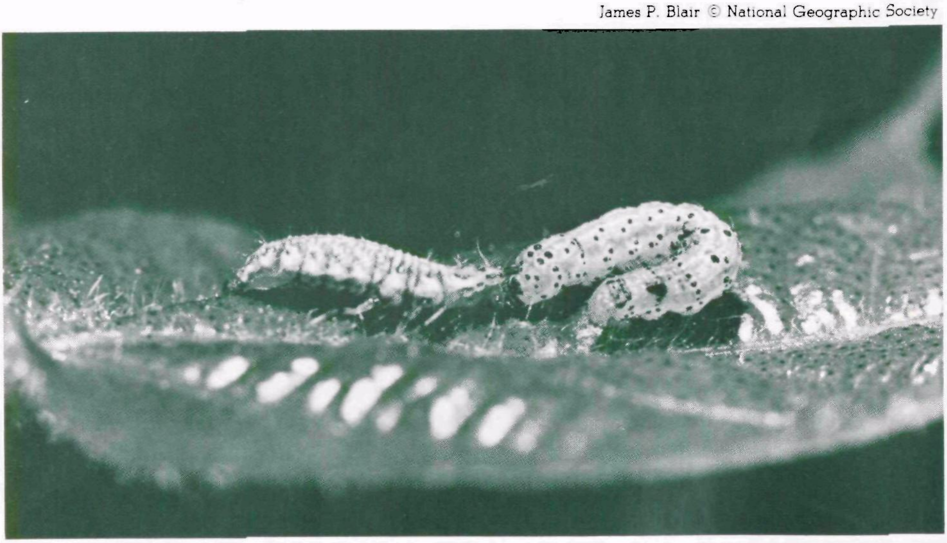


and to its role in controlling other pests.

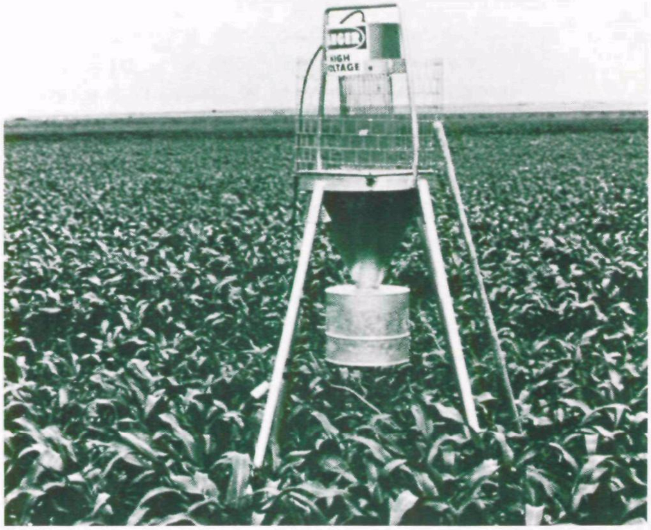
With an understanding of the characteristics of both the crop and the pest, the most desirable control tactic or combination of tactics can be selected. Pest control tactics can be divided into three areas: biological, cultural, and chemical.

biological controls

A fundamental form of biological control involves the use of natural enemies. Although control of pests by predators and parasites does not work as quickly as chemical control, it reduces pesticide pollution and is often less expensive. There are several hundred naturally occurring species of insects and mites that prey on the pests of major agricultural crops. Pest populations may be effectively kept below damaging levels if these parasites and predators are maintained in crop areas. Preservation of natural enemies can be achieved by applying selective pesticides only when necessary based on careful monitoring of pest populations and the damage they cause. The individual pictured below is scouting a crop to assess pest infestation. Another strategy for ensuring the continued presence of the natural enemies of crop pests involves preserving appropriate habitats for these enemies in crops and surrounding vegetation. Predators and parasites may also be introduced from other countries. There are currently 95 species of imported parasites established in the U.S. which are being used for pest control.

One of the best known pest predators is the ladybug, which controls aphid and scale insect populations. In one year in California, some 7.5 billion ladybugs fed on a 3.75 trillion aphid population in alfalfa fields. Another useful predator

Dr. Ray Frisbie



Dr. Ray Frisbie

is the green lacewing, which kills leaf-hoppers, aphids, mealybugs, and other pests. The *Trichogramma* wasp is a parasitic insect which may also be valuable in pest control. This wasp can help control moths which damage cotton, tobacco, corn, and tomatoes, by destroying the moths' eggs.

Disease-causing organisms such as viruses, protozoa, fungi, and bacteria are also effective biological control agents. These microorganisms usually affect only one type of pest. For example, a virus controls the alfalfa caterpillar; a protozoan, *Nosema locustae,* controls grasshoppers; and the bacterium *Bacillus thurigiensis* controls the gypsy moth, bollworm, tobacco budworm, cabbage looper, and several other pests.

Another form of biological control involves the use of pheromones. Pheromones are chemicals secreted by an insect to elicit some form of response from other members of its species. Many pheromones are secreted to attract mates, and may be effective over distances of several miles. They are known to be effective at very low concentrations. In monitoring studies, pheromones are used to lure insects into a trap where they are captured on a sticky material. The traps can then be examined to determine the insects' stages of development and to approximate the magnitude of the local infestation. This information can then be used to time pesticide applications or other control tactics. Mass trapping of insects using pheromone traps is also being investigated. Pheromones can also be used directly to disrupt normal mating behavior. The spraying of a large area with synthetic pheromones masks the attractants secreted by individual females. Male insects cannot locate the females and consequently are unable to mate.

Reproduction may also be prevented by release of insects sterilized by radiation. If the number of sterilized males exceeds the number of normal males, the pest population can be sharply reduced. Release of sterilized males is most successful when an insect population is isolated, so that untreated insects cannot mix with the treated population. It is also useful for controlling small populations which survive pesticide treatment.

Although most biological controls focus on the pest, one of the most successful biological tactics is the use of pest-resistant plants. Resistant varieties possess genetic defenses such as protective physiological or physical characteristics which reduce their susceptibility to pests. In corn, for example, varieties with thicker husks are better protected from the corn earworm and varieties with root system regenerative capabilities withstand corn rootworm attack. New varieties of pest-resistant plants are continually being developed in order to keep pace with constantly changing pests.

cultural controls

Cultural methods of pest control involve agricultural practices such as crop rotation and removal of crop residues which shelter pests after harvest. For example, if a corn growing area is infested with

USDA photo

corn rootworms, rotating with soybeans or some other crop which these insects do not damage will control the pest. The proper timing of crop planting and harvesting can also reduce pests. Crop planting can be delayed so that the pest matures when there is no crop to feed on. If a particular pest has a relatively long lifecycle, control is achieved by switching to a crop with a shorter growing season.

Another cultural control tactic involves the planting of "trap crops"—expendable crops which are more attractive to pests than the crop being protected. In cotton fields, alfalfa planted in strips between the cotton serves as a lure of pests.

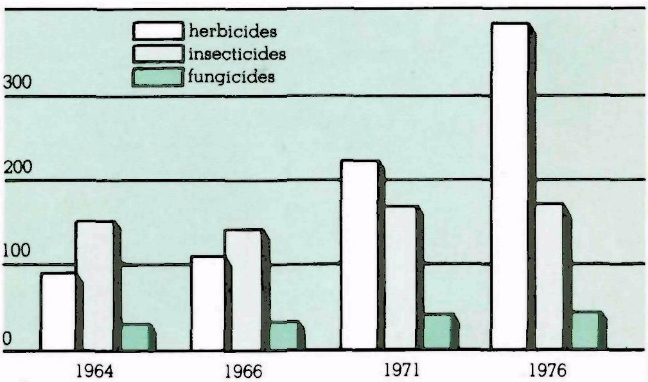
chemical controls

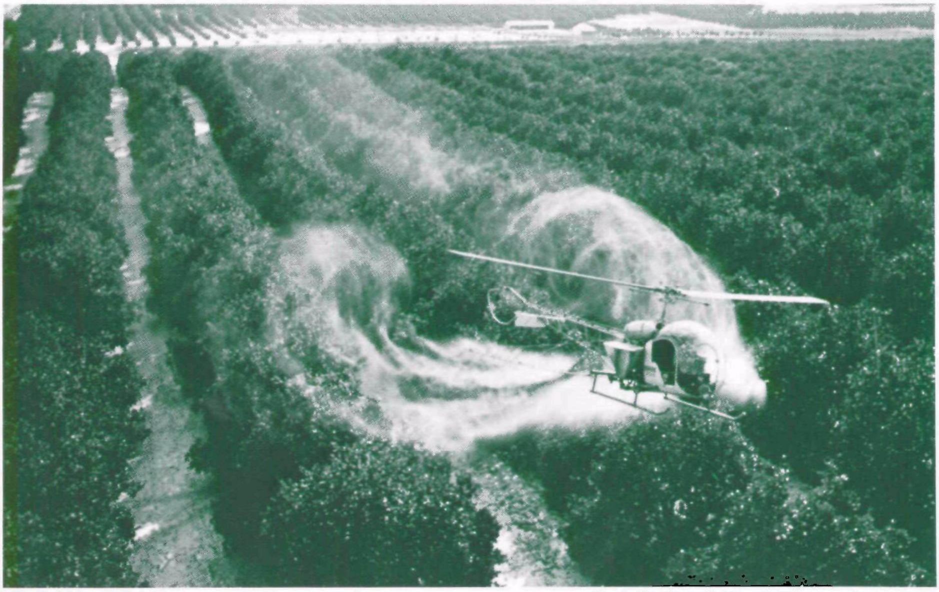
Despite their potential hazards, chemical controls are an essential component of pest management programs. Chemicals usually act quickly and are effective against large pest populations. In certain crop ecosystems, the application of pesticides may be the most effective and feasible control tactic.

The primary agricultural pesticides are herbicides, insecticides, and fungicides. Since 1964, the volume of herbicides used on agricultural crops has increased fivefold. During the same period, insecticide and fungicide usage has remained relatively stable, as the figure below illustrates.

Most insecticides can be classified chemically as chlorinated hydrocarbons, organophosphates, carbamates, inorganics, and more recently synthetic pyrethroids. Over the past 10 years, there has been a shift away from the use of the persistent

volume of pesticides used on U.S. farms





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chlorinated hydrocarbon pesticides. Since 1970, EPA has banned most uses of DDT, mirex, kepone, chlordane, and heptachlor. New pesticide formulations are being developed to meet the need for safe and effective chemical controls. Particular attention is being given to development of biodegradable pesticides. Since such chemicals do not persist in the environment, their use could reduce the potential hazards to harmless insect populations and other forms of life, including humans. Research is also underway to develop alternative formulations for specific pests. When a series of different pesticides is applied to control a pest, the probability that resistant members of the pest species will become prevalent is reduced. The use of alternative formulations also reduces the chances of any one chemical accumulating in the soil and entering the food chain in dangerous quantities.

The hazards of chemical control are also being reduced by the development of more selective application practices. In the past, crops were often blanketed with pesticides as a preventive measure. Under the IPM approach, pest population levels are monitored and pesticides are applied only when populations approach levels which may result in economic losses.

Chemical control may also involve disruption of the pest's normal development or behavior. Juvenile hormones are growth regulators normally produced by an insect during the early stages of its development. Once an insect reaches a certain stage of maturity, juvenile hormones are no longer produced and development continues to the adult stage. If juvenile hormones are applied to the insect after this stage, development is disrupted, resulting in a malformed insect which dies without maturing and without reproducing. Use of this method of control is particularly effective against pests which are most destructive in adult stages. Both natural and synthetic juvenile hormones, as well as chemically similar compounds, offer control potential. These substances are highly specific to target pests, effective in small doses, and of low toxicity to higher organisms.

federal responsibilities

Recognition of the serious environmental and health problems caused by the excessive use of pesticides resulted in the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and its amendments in 1972, 1975, and 1978. This Act requires EPA to register all pesticides currently on the market, and to classify them into general or restricted use categories.

EPA's Office of Pesticide Programs is responsible for the registration of pesticides. This office is required to evaluate data submitted by pesticide manufacturers concerning the risks associated with the use of their products. Based on the conclusions of this evaluation, EPA may refuse to register a new product or may cancel or suspend registration of a product already on the market.

EPA is also required to conduct research on Integrated Pest Management. The President's Second Environmental Message to Congress in August of 1979 directed federal agencies to support the work of IPM. In response to this message, an Interagency IPM Coordinating Committee was established. This Committee includes representatives from each of the Federal agencies involved in IPM. The EPA, the U.S. Department of Agriculture (USDA), the National Science Foundation (NSF), the Council on Environmental Quality (CEQ), and the Department of the Interior, Housing and Urban Development, and Defense are the principle agencies represented on the committee.

USDA plays a major role in agricultural IPM research and education. The Department cooperates with land-grant universities and state agriculture experiment stations to develop IPM programs.

The National Science Foundation was the lead agency in the Huffaker Project, the first extensive

Federally supported project in integrated pest management. NSF has also developed undergraduate courses and initiated trial pest management studies at Michigan State University, Cornell University, Kansas State University, the University of California, and Alabama A&M to be used as models for programs at other institutions.

The Council on Environmental Quality is responsible for coordinating the Federal IPM program, and chairs the Interagency IPM Coordinating Committee. In response to the President's Environmental Message of 1972, CEQ issued an Integrated Pest Management Report promoting the integrated approach as an environmentally sound method for crop protection. CEQ recently completed a second IPM report which reviews integrated pest management in the United States, and recommends future Federal actions to advance IPM concepts and techniques.

The Environmental Protection Agency's Integrated Pest Management research program is the responsibility of the Office of Research and Development (ORD). Because an IPM approach requires knowledge of both the crop system and insect activity, it is necessary to involve a broad-based multidisciplinary group of researchers. ORD's program is being conducted through grants, contracts, and cooperative agreements with universities and other institutions. ORD works closely with the EPA Office of Pesticide Programs in providing technical expertise for the evaluation of pesticides for registration and in providing assistance in the development of regulations under the FIFRA.

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IPM research

EPA is developing pest management strategies combining non-chemical and chemical controls which are ecologically and economically acceptable. A fundamental research goal is to develop an understanding of individual crop ecosystems and their unique pest control problems. Most crops selected for study are of great economic significance and currently require extensive pesticide application.

Huffaker project

The Huffaker Project, a $13 million research project initiated in 1972, was the first national study undertaken to implement the principles and strategies involved in Integrated Pest Management. In this intensive 7-year study, cosponsored by NSF, EPA, and USDA, scientists at 19 universities investigated pest control for six major crops: cotton, soybeans, alfalfa, citrus fruits, pome fruits (such as apples and pears), and stone fruits. As a result of this research, a great deal of basic scientific information concerning the six crops and their pests was acquired. With this background, alternative control methods not using chemicals were developed. In some cases, pilot studies were also undertaken.

During the course of this project, improved methods for data collection, handling, and interpretation were developed. This included the use of computers to analyze the data which allowed the consideration of multiple factors that affect plant growth or pest populations. The results of the analysis were used to derive a mathematical model to represent relationships among the significant components of crop-pest ecosystem. These models were then used to predict the effects of different control techniques on crop growth.

Significant accomplishments were made in each of the six crops studied. The most extensive research was done on cotton and alfalfa. The alfalfa research expanded the understanding of both the plant and its insect pests, specifically three types of alfalfa


USDA photo

weevil. Researchers found that alfalfa cutting practices have a catastrophic effect on natural predators and parasites of the weevil. Based on this finding, alternative cutting practices, such as strip cutting and border harvesting, were suggested as possible cultural control tactics.

Natural factors regulating some seven to eight important cotton pests were also examined, and research on resistant cotton plants and short-lived cottons was initiated. As a result of this research, cotton varieties resistant to a wide range of pests were developed. Significant progress was also made in sampling techniques and in computer modeling. Mathematical models of cotton crop production and cotton pest systems were developed and used to assess control techniques. Pilot tests of certain combined management programs were then conducted.

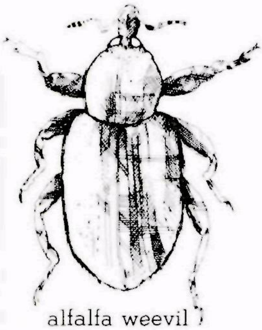
The Huffaker Project was a major step forward in the development of IPM strategies. Perhaps the most significant contribution of the project was the foundation it established for future IPM research.

the consortium for integrated pest management

In September 1979 EPA awarded a consortium of 15 universities a total of $3 million yearly for five years to advance the IPM concepts developed in the Huffaker Project. Beginning with fiscal year 1981, EPA and USDA will jointly fund this project. The Texas A&M Research Foundation in College Station, Texas, is responsible for coordinating the project.

The involvement of 15 universities allows for a regional approach to each crop system. The crops involved—alfalfa, apple, cotton, and soybean—are among the most important grown in the U.S. and each presents unique pest management problems.

alfalfa

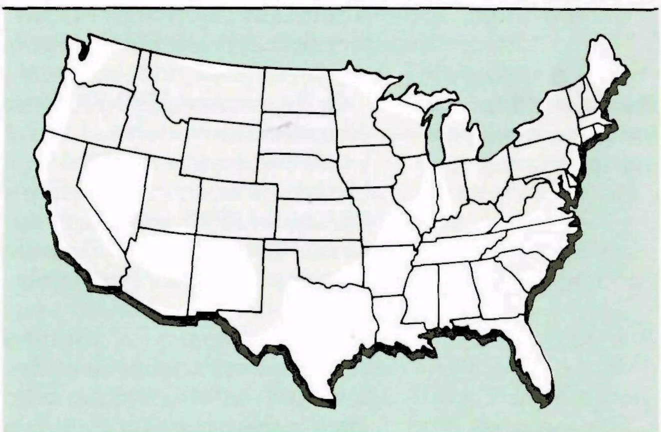

alfalfa weevil

Alfalfa is the world's most valuable livestock feed crop. In the United States, alfalfa is exceeded in acreage only by corn, wheat, and soybeans. Alfalfa is a perennial legume which increases nitrogen levels in the soil. As a perennial, alfalfa comes up year after year, an uncommon characteristic of field crops. The longevity of an alfalfa field is usually three to five years; however, plant pathogens, worms, insects, and weeds can significantly reduce both productivity and longevity.

Alfalfa is especially suited to integrated pest management since it can sustain a limited level of pest damage without significant loss of yield or quality. Five universities are currently involved in the development of IPM strategies for alfalfa: the University of California, Cornell University, University of Illinois, University of Kentucky, and the University of Wisconsin.

Previous research resulted in descriptive models for some components of the alfalfa ecosystem. Researchers are modifying and improving these existing plant models, and are developing new models for various pest species. The pests under investigation include insects, such as the alfalfa weevil, alfalfa leafminer and leafhopper; diseases of both the leaves and roots; and weeds. Studies are underway to determine losses attributable to pests, interactions among these pests, and combined effects of pests on alfalfa longevity and productivity. Researchers at each of the five universities are developing new strategies to maintain pests below

states with significant alfalfa harvests – 1974



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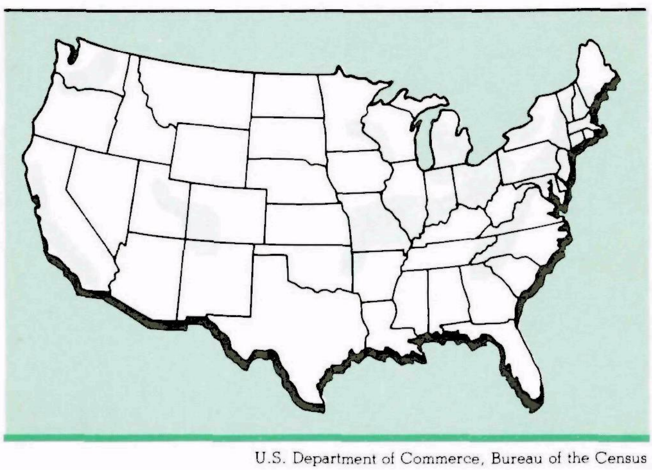
economic injury levels. Once a management system is available, mechanisms for its implementation will be developed.

apples

Apples are grown in almost every state in the U.S. Apple orchards are highly diversified and complex ecosystems having more in common with natural ecosystems than most other crop settings. They often consist of mixed plant varieties with a highly varied ground cover surrounded by numerous types of wild plants. Apples are attacked by a variety of pests including codling moths, aphids, scale insects, mites, and leafhoppers. Plant diseases such as apple scab and powdery mildew are also enemies. Apples rate sixth nationally among individual crops in the total volume of pesticide used. Of the 11,600,000 pounds of pesticides used on apples in the United States (excluding California) in 1978, approximately 7 million pounds were fungicides, 3 million pounds were insecticides, and seven hundred thousand pounds were herbicides.

Because of the traditionally widespread use of pesticides on apples, alternative control tactics have been investigated for 10 to 15 years. Six universities are involved in apple pest research under the Consortium for Integrated Pest Management (CIPM). Researchers at Cornell University, North Carolina State University, Washington State University, Pennsylvania State University, Michigan State University, and the University of California

states with significant apple harvests—1974



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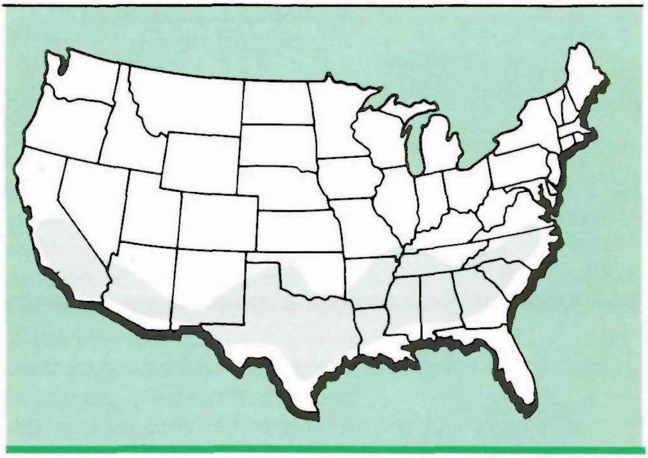
are testing previously developed computer models and control methods and, where necessary, modifying them. New management systems are being developed, including methods for implementing the more advanced models.

Researchers at each of the institutions involved are working on a variety of projects. Investigators are refining an apple tree growth model, APPLETREE, originally developed by researchers at Michigan State University and Cornell University. Researchers are developing a computer model representing the apple orchard ecosystem, and investigating different subcomponents which will be incorporated into the model. Their activities include both laboratory and field evaluations. One particular area of attention is determination of the role that ground cover plays in the orchard ecosystem. Scientists are also conducting studies to verify and improve strategies to control apple diseases.

Economic cost/benefit comparisons between newly developed IPM tactics and older or established methods are being conducted. An economic-crop production model which incorporates features of pest damage and control, weather, tree production, and crop pricing conditions will also be developed.

USDA photo

states with significant cotton harvests — 1974



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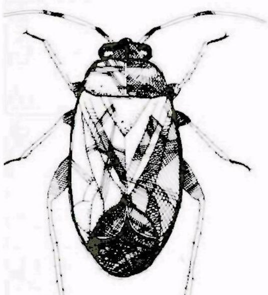
cotton

Cotton, the world's most important fiber crop, is grown on more than 74 million acres in some 80 countries. More insecticides are used on cotton in the U.S. than on any other crop. The Consortium for IPM includes research institutions in the four largest cotton producing states: Arkansas, California, Mississippi, and Texas.

Researchers at the University of Arkansas, the University of California, Mississippi State University, and Texas A&M University are conducting studies ranging from basic research on pest population and community ecology to testing of specific control tactics. Much of the research is an expansion of the accomplishments of the Huffaker Project. Development of pest-resistant cotton varieties is being continued, and researchers are seeking to identify farming practices which minimize pest damage. Researchers are developing sampling systems for cotton pests which account for environmental conditions and cultural situations. In addition, the population dynamics, physiology, and behavior of specific pests are being investigated.

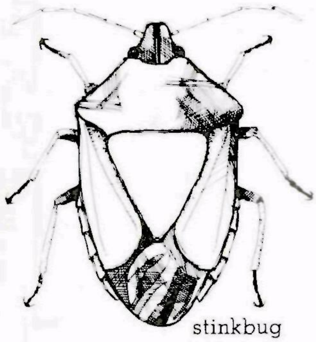


lygus bug

Researchers at Mississippi State and Texas A&M are giving particular attention to the examination of biological control of the boll weevil and lygus bug by predators and parasites. This involves a cooperative agreement with the USDA for the importation, quarantine, mass rearing, release, and evaluation of lygus bug parasites.

In the area of computer analysis and modeling, work is continuing on the development of a cotton ecosystem population model. Components of this model will be validated by field studies, and economic comparisons of alternative control systems will be performed.

soybeans

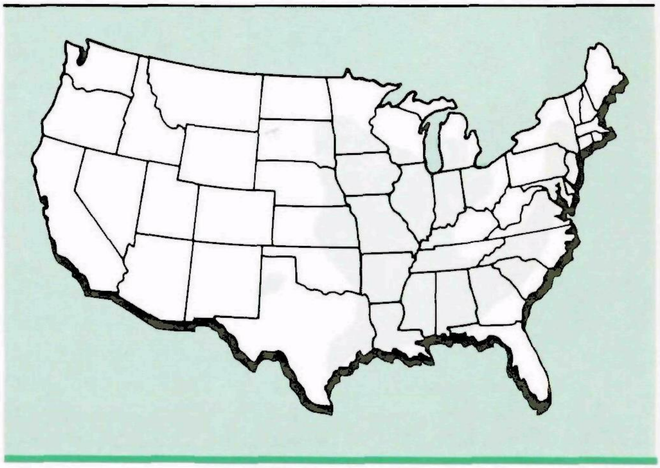


stinkbug

Soybeans rank third behind corn and wheat in total acreage planted in the U.S. Although soybeans are plagued by a wide variety of weeds, worms, and disease-causing microorganisms, extensive use of chemicals has not been required. Since this crop does not have a history of widespread chemical pest management, it is of special interest to IPM researchers. As with the three other major crops being studied, researchers are involved in gaining a better understanding of the soybean plant and its major pests. These studies are being conducted at Clemson University, Louisiana State University, North Carolina State University, the University of Arkansas, the University of Florida, and the University of Illinois.

Soybean varieties planted from late April to mid July differ widely in their maturity time, growth characteristics, susceptibility, and attractiveness to pests. These variations are being studied in relation to their effects on pest development and damage. This information is useful in the development of pest-resistant varieties of soybeans. Scientists are also evaluating indigenous and imported natural pest enemies. The latter research involves studying predator-prey interactions in selected natural

states with significant soybean harvests — 1974



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habitats, labeling of prey, and direct observation of predation and parasitism.

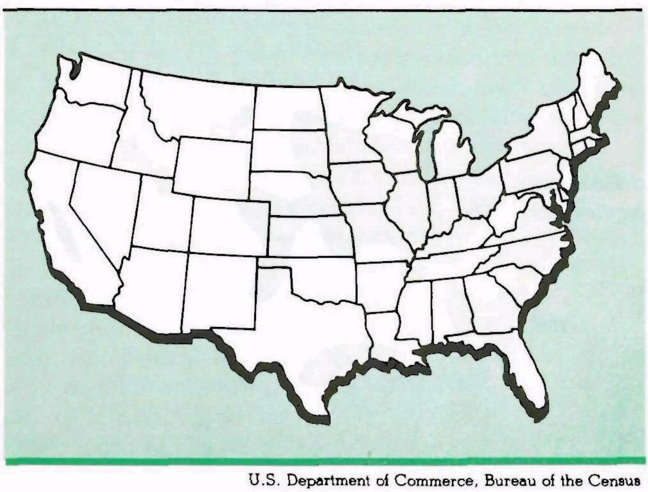
Researchers are also studying the effects of pesticides on natural enemies. This work includes a determination of the effects of pesticides on population resurgence and secondary pest development.

pest management strategies for soil insects on corn

A consortium of six universities is studying soil pests which affect the corn crop: cutworms, rootworms, and wireworms. Scientists at the University of Missouri, the University of Nebraska, Purdue University, the Illinois Natural History Survey, Iowa State University, and the Ohio Agricultural Research and Development Center are conducting field and laboratory studies.

Data collected from monitoring studies are providing valuable insight into the behavior of corn pests. Successful monitoring tests have been conducted on black cutworms using synthetic pheromone traps for males and black light traps for females. Corn rootworm movement is also being monitored using sticky pheromone traps. The tufted apple bud moth (TABM) pheromone is being used to monitor wireworms. Scientists will use the information gathered from these studies to determine, for each of the three pests, population levels which may result in significant economic losses.

states with significant corn harvests—1974



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USDA photo

The monitoring of Missouri corn fields revealed eight wireworm species, making it possible to develop an identification key with descriptive illustrations of the larvae of each wireworm species. This information is also being used to prepare a field guide on wireworms for use by pest management personnel.

A computer model of corn root growth is being developed which includes factors such as air temperature, daily precipitation, and corn variety. Additional models are being developed to predict when soil insect populations might develop. These models are being validated by pest management scouts and will improve efficiency of scouting programs.

onion crop agroecosystem

Onions, like many other food crops, were traditionally grown on small farms in gardens along with other vegetables. These gardens were often surrounded by fields used for cattle grazing. Pests in these gardens were controlled by a variety of natural controls, including predation. Onion pests, for example, were controlled by maggots which lived in the cow manure in surrounding fields.

As the cultivation of onions was taken over by large commercial industries, control of onion pests was accomplished more by chemical pesticides than by natural controls. The reduction of pest populations by pesticides results in the decline of natural predators or competing species. It may take years for these natural controls to be reestablished following cessation of treatment. Our current dependence on chemicals to protect onion crops was demonstrated in a study conducted by researchers at the University of Michigan. In this study, one half of an onion field was treated chemically for onion pests, while the other half received no pesticides. Onions survived only in the area treated; 100% of the crop was lost to pests in the untreated section. The study was continued to see how long it would take for natural controls to offer protection. Researchers found that it took five years for natural controls to be established.

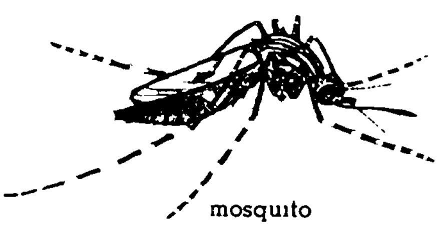
Michigan researchers have also been studying the onion pest control problem from an energy-related perspective. The onion tops and culls which remain in fields after harvest provide a food source and habitat for insect pests. One means of controlling these pests is to remove this crop refuse. Investigators at the University of Michigan have found that these onion remains can be fermented to produce 6% alcohol. Although this means of producing alcohol is currently very expensive, researchers are exploring ways to reduce costs. For example, it may be possible to use municipal wastes and potato production wastes from nearby areas as a heat source for the distillation of the alcohol.

musk and plumeless thistle

Researchers at Virginia Polytechnic Institute are currently evaluating the impact of three biological control agents used simultaneously for the control of musk thistle and plumeless thistle in pastures. Both thistles are serious weed problems in many parts of North America. Current control procedures depend mainly on the use of herbicides which are expensive and provide only a temporary solution. The biological control agents under study are three insects, each of which attacks a different part of the thistle: the thistle-head weevil, the rosette weevil, and the leaf beetle. To date, researchers have found the weevils to be useful in controlling the thistles. The effectiveness of the leaf beetle has been reduced greatly since it is parasitized by other insects. Researchers are now determining the optimal weevil population for controlling thistles and the most favorable time for release of the insects. Information gained from this study may assist in the control of other pastureland weeds.

The musk thistle is also being investigated by researchers at the University of Kansas. Specific attention is being given to the biology of the thistle and to procedures for monitoring and detecting it using remote sensing. Remote sensing involves aerial photography using various types of film, including film sensitive to infrared radiation. In aerial photographs of this kind each plant species appears as a distinct color. Examination of these photographs reveals the distribution and density of thistle populations. By comparing photographs taken over a period of time, scientists can determine trends in rates of infestation.

mosquito management



mosquito

The freshwater wetlands created by the irrigation of rice fields and other crops provide an excellent breeding habitat for mosquitoes. More than six million acres of U.S. land are devoted to growing rice, and this figure is expected to increase in coming years. As more and more land is used for rice production, mosquito populations will grow. Controlling these insects is important because, in addition to being a nuisance, mosquitoes can carry diseases to humans and domestic animals.

Cropland mosquitoes are adapted to habitats controlled by humans and are therefore somewhat dependent upon them for their existence. Since changes in farming practices can affect these mosquito populations, IPM strategists are particularly interested in investigating methods for controlling mosquitoes by changing crop management practices.

ORD is providing funds to support researchers in six universities who are investigating the use of chemical and non-chemical techniques to control mosquitoes in ricelands. The institutions involved are the University of Arkansas, University of California—Berkeley, the University of California—Davis, Louisiana State University, Mississippi State University and Texas A&M University. An understanding of mosquito behavior is essential to the development of control methods. Researchers at Texas A&M University are studying the migration patterns of mosquitoes which inhabit Texas ricefields. To determine the time, direction, and distances of mosquito migrations, researchers release populations of dye-marked mosquitoes and recapture them in traps placed at various distances from the point of release. Several types of traps are used to recapture the marked mosquitoes. Researchers prefer to use traps which are not baited because baited traps could alter migration patterns. Data collected from this study will be used to develop forecasting models which can be used by mosquito control personnel to better predict mosquito movement and enable them to apply control strategies more effectively.

Successful mosquito control currently relies heavily upon the use of chemical insecticides. In order to reduce dependence on chemical controls, researchers are developing and assessing biological and cultural control methods. One promising biological control agent is the mosquitofish, a freshwater fish which eats mosquito larvae. Researchers at the University of Arkansas are studying better methods for culturing, harvesting, storing, and transporting these fish to target sites within the U.S. where this approach is not currently being used. A parasitic worm, *Romanomermis culicivorax,* is effective in controlling some species of riceland mosquitoes. Large scale field trials will be conducted by investigators at the University of California—Davis and Louisiana State University to further assess the usefulness of this parasite. Other biological agents such as bacteria, fungi, and flatworms are also being studied.

Water management is considered the most effective means of controlling mosquito populations. Research is being conducted at the University of California—Berkeley and Louisiana State University to determine which water management techniques are most effective against mosquitoes and which are suitable for use in rice producing areas in the U.S.

Although the emphasis of the EPA program is to develop alternative control methods, insecticides are expected to remain an important control weapon because chemicals work more quickly than other control agents. Chemicals are currently the best means for controlling outbreaks of many mosquito-borne diseases. Researchers at the University of California—Davis, the University of California—Berkeley, and Mississippi State University are therefore studying and developing new insecticides which will be effective in emergency situations and which will be compatible with other non-chemical approaches to mosquito control in our nation's irrigated croplands.

urban IPM

Although most IPM research concerns the agricultural environment, pest management is also important in urban areas. Urban pest management problems are being investigated by researchers at the John Muir Institute for Environmental Studies in Berkeley, California. Shade trees in Modesto, California, were recently the subject of a study in which trees were monitored and the key pests identified. Following identification, the pests' life-cycles, habitat preferences, population dynamics, and natural enemies were studied. Using this information, a new schedule of pesticide application was determined. Researchers discovered that much of the prior pesticide application was unnecessary. Over a three-year period, pesticide treatments were reduced 99% in a 5,000-tree area.

The information gathered on urban shade tree pests and their natural enemies was entered into a computer. Current plans call for expansion and evaluation of this computer data base, as well as creation of a similar data base for urban residential pests. In addition, an indexing system for identifying urban IPM information and research needs will be developed.

In a related project funded by EPA's Office of Pesticide Programs, the John Muir Institute is developing a pilot technical assistance center for providing urban IPM information. The Institute is developing information packages and determining audiences for potential distribution.

Chip Clark, Smithsonian Institution

individual research projects

Selected research projects funded by ORD and EPA's Office of Pesticide Programs are listed below:

- Development of Comprehensive, Unified, Economically and Environmentally Sound Systems of Integrated Pest Management for Major Crops *(Texas A&M Research Foundation)*

- Development of Pest Management Strategies for Soil Insects on Corn *(University of Missouri)*

- Design and Management of a Multi-Pest Agroecosystem *(Michigan State University)*

- Biological Control of Musk and Plumeless Thistle in Pastures *(Virginia Polytechnic Institute and State University)*

- Pesticide Use Reduction through Integrated Control Procedures on Musk Thistle *(Carduus nutans)* *(University of Kansas—Center for Research, Inc.)*

- Development of Strategies Optimizing Non-Chemical Approaches to Managing Mosquito Populations in Freshwater Irrigated Cropping Systems Using the Riceland Agroecosystem as a Model *(Texas A&M Research Foundation)*

- Development of a Model Program for the Large-Scale Statewide Implementation of Integrated Pest Management by Farmer Financed Associations *(Texas Pest Management Association)*

- Integrated Pest Management on Selected Greenhouse Vegetable and Floricultural Crops* *(Ohio Agricultural Research and Development Center)*

- Urban and Suburban Residential Pest Management Data Systems
  (John Muir Institute for Environmental Studies, Inc.)

- Urban IPM: Design of a Model System and Design and Development of a Technical Assistance Center*
  (John Muir Institute for Environmental Studies, Inc.)

*Funded by EPA's Office of Pesticide Programs

for further information

publications

- EPA Research Outlook. February 1980.
  EPA-600/9-80-006. 224 pages.
  A concise description of EPA's plans for future environmental research.

- EPA Research Highlights. January 1980.
  EPA-600/9-80-005. 100 pages.
  Highlights of the EPA research and development program of 1979.

- EPA/ORD Program Guide. October 1979.
  EPA-600/9-79-038. 85 pages.

  A guide to the Office of Research and Development—its organizational structure, program managers, and funds available for contracts, grants, and cooperative agreements.

other research summaries

- EPA Research Summary: Controlling Sulfur Oxides. August 1980. EPA-600/8-80-029. 28 pages.

- EPA Research Summary: Industrial Wastewater. June 1980. EPA-600/8-80-026. 32 pages.

- EPA Research Summary: Controlling Hazardous Wastes. June 1980. EPA-600/8-80-017. 24 pages.

- EPA Research Summary: Chesapeake Bay. May 1980. EPA-600/8-80-019. 32 pages.

- EPA Research Summary: Controlling Nitrogen Oxides. February 1980. EPA-600/8-80-004. 24 pages.

- EPA Research Summary: Acid Rain. October 1979. EPA-600/8-79-028. 24 pages.

- EPA Research Summary: Oil Spills. February 1979. EPA-600/8-79-007. 16 pages.

Information on the availability of these publications may be obtained by writing to:

Publications
Center for Environmental Research Information
US EPA
Cincinnati, OH 45268

technical reports

- Alternatives for Reducing Insecticides on Cotton and Corn: Economic and Environmental Impact. August 1979. EPA-600/5-79-007a. 145 pages. (PB-80-145071).
- Environmental Implications of Trends in Agriculture and Silviculture. Volume II. Environmental Effects of Trends. December 1978. EPA-600/3-78-102. 227 pages. (PB-290674).
- Environmental Implications of Trends in Agriculture and Silviculture. Volume III. Regional Crop Production Trends. April 1979. EPA-600/3-79-047. 180 pages. (PB-299311)

Technical reports or manuals may be obtained by writing to:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
or by calling: (703) 557-4650

questions or comments

The Office of Research and Development invites you to address any questions or comments regarding the EPA integrated pest management research program to:

Darwin Wright
Director, IPM Research Programs
Office of Research
& Development, RD-682
US EPA
Washington, D.C. 20460

EPA's IPM research program is administered by Dr. Allan Hirsch, Deputy Assistant Administrator for Environmental Processes and Effects Research.

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