Agricultural Pest Control and the Environment

The need to control pests and to protect the environment from pollution creates conflicting problems.

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The quality of the environment stands high among the problems demanding attention today. As we cope with the needs and complexities of a faster moving, more populous world, we must at the same time prevent pollution of the air, the land, and the water beyond a level that man can and will endure. One of the greatest needs is production of food for billions of people. At present such production requires the use of pesticides, but in turn this use carries with it the possibility of environmental pollution.

Because the Agricultural Research Service (ARS) is responsible for an important share of the nation's research on pests and pesticides, for federal registration of all pesticides, and for administration of a large number of federal programs for pest control in cooperation with the states, it is in a unique position to observe and participate in the scientific and legal controversies that now abound on the subject of pesticides. Accordingly, it may be useful to present the ARS rationale: why we try to control agricultural pests at all; the circumstances that dictate our doing it as we do; and the reasonable alternatives and outlook for doing it differently.

Why Control Agricultural Pests?

Man controls pests because they compete with him for the means of survival. This is a deliberate choice; when pests threaten man with plague or starvation, he fights them as best he can. Some people of the world are being threatened in these respects right now. Fortunately, the United States is a nation of relatively healthy and well-fed people. We can afford to be–and should be–circumspect about the ways in which we control pests, and the effects of these controls on other elements of our environment. However, we do not hold such an edge over malaria mosquitoes and boll weevils that we can seriously contemplate attaining a natural balance between man and his pest enemies. The balance of nature is not an achievable ideal, if it is an ideal at all.

From the time he gave up his nomadic existence, man has increasingly upset the balance of nature, until today it is hardly a meaningful term. Man has constantly tried to tip the balance in his favor. His decisions have not always been wisely made. History is replete with instances where short-range objectives or more often, ignorance, has led to missteps.

Whether or not man has relied excessively on chemical control of pests is now being debated. That there are both benefits and problems accruing from the use of chemicals is quite clear. However, the pertinent fact is that, at this time, pesticides are essential to the abundance, quality, and variety of agricultural production which our nation has come to expect.

American agriculture has evolved a monoculture system. It is an efficient system wherein food and fiber crops and livestock are produced in regions of the country best suited in climate and soils for the optimum in quality and quantity. However, the large acreages of wheat, corn, or citrus orchards provide inviting environments for pests and diseases of the crops and big broiler flocks and cattle-feeding operations increase greatly the opportunity for animal diseases and pests to survive and spread. Thus, the balance of nature would be heavily weighted on the side of the pests were it not for pesticides. The synthetic organic pesticides, which can be applied over large areas in a matter of hours, fit our efficient agriculture. Along with fertilizers, irrigation systems, and complex machinery, they have made it possible for only 5 percent of the American work force to meet the nation's food and fiber needs. Pesticides have helped to make possible production of the cheapest food in the world, in terms of percentage of take-home pay, and to free the manpower that now provides the other goods and services our high standard of living demands.

Contributions of pesticides have been worldwide. The National Academy of Sciences–National Research Council Committee on Persistent Pesticides states (*1*):

> During the past quarter of a century, nations in all parts of the world have benefited from increasing use of the synthetic organic pesticidal chemicals. Through use of these chemicals, spectacular control of diseases caused by insect-borne pathogens has been achieved, and agricultural productivity has been increased to an unprecedented level. No adequate alternative for the use of pesticides for either of these purposes is expected in the foreseeable future . . . . Modern agricultural productivity depends on coordinated increase in the use of pesticides, fertilizers, machinery, and better crop varieties.

This does not mean that use of pesticides is the only available method for combating pests and diseases. Nor does it mean that current pesticides must continue to be used in present quantities. It does mean that chemicals are now the most effective weapons for pest control the farmer has and that in the future chemicals will continue to be an essential part of the integrated program for pest control. The use of some pesticides will decrease, and some will cease to be used altogether; but the total amount of chemicals used for pest control in agriculture can be expected to increase as the need for agricultural production increases.

Quarantine, Eradication, and Controls

The first step in avoiding pest problems is quarantine—keeping pests out of the country. To that purpose, ARS maintains quarantine and inspection at U.S. ports of entry in order to intercept pests and diseased materials that might be brought here from other countries. This is an operation of some magnitude. Last year inspectors examined the cargo of thousands of trains, ships, and air-

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planes; millions of passenger automobiles; nearly 76 million pieces of baggage; and over a million imported animals. Without this first step of control, the pest problem in this country would quickly be staggering. Just one illustration from among the many exotic insects and diseases that might be taking their toll from our agriculture—the Mediterranean fruit fly, or Medfly—makes this point.

Medflies attack citrus fruit and a wide range of other soft fruits and vegetables. Despite vigorous quarantine and inspection, the United States has been invaded by Medflies four times in the past 14 years. One invasion cost $10 million to eradicate; the others were discovered and eradicated more quickly and cheaply.

To have been invaded four times in 14 years is not good, but it is not nearly as bad or as costly as it might be. Plant quarantine inspectors intercept the Medfly in incoming cargo and baggage as many as 148 times a year. Without inspection and quarantine we could have 148 infestations of the Medfly every year. At the very least, we know that we would have many more frequent and expensive battles with this and other exotic pests than we now face.

Quarantine, then, is a necessary and remarkably effective precaution, but it is far from sufficient. Quarantine programs can never be completely effective, and their weaknesses are being increased by several factors. We have for some years now been in an era of rapid and frequent international travel. Ever faster jet planes, and increasing plane capacity for both passengers and freight, tax our inspection system, which must also cope with the understandable impatience of travelers and shippers with any delays occasioned by the inspection process. As a result, the inspection for unwanted pests and disease organisms has already become selective and can only be less effective than complete inspection. This means that we can rely less now than formerly upon quarantines to provide more than a thin, but still essential, front line of defense. Foreign pests and diseases can and will gain entrance into the United States more frequently in the future.

What do we do when this occurs? First, a cooperative network of federal and state personnel, working with all of the legal chemicals and other tools available, tries to stamp out the invasion at the incipient stage, as has been done several times with the Medfly. Sometimes, as is the case with the cereal leaf beetle, the attempt is unsuccessful, and infestation becomes established. Again, the federal-state network tries to contain the infestation, control its spread by intra- and interstate quarantines, and suppress numbers to levels that can be tolerated. This "living with" the insect continues until research develops new tools, and experiments indicate that eradication is feasible. Then the ARS and the states eradicate the U.S. infestation as we did with the screwworm in the southeastern states, as we are trying to do now with the fire ant, and as we believe we might be able to do with the boll weevil. Once eradicated, the insect again becomes a target for our quarantine inspectors who try to prevent its reentry.

As a practical matter, however, "living with" the insects we have long had, as well as with the more recent invaders, is more nearly the normal way of life for agriculture. It is for this reason that much of the research on pest containment and control is focused on development of resistant crop varieties; improvement of cultural practices; the use of insect parasites, predators, and pathogens as biological agents; the development of genetic defects such as sterility; physical devices; and more selective chemicals such as attractants and hormonal insecticides.

Resistant Crop Varieties

In combating pests and diseases we prefer to use a method that is specific to the target organism, that interferes only with its welfare, and that does not introduce new contaminants into the environment. Ideal in this regard is the immune or resistant crop variety. By growing crops that are naturally immune or substantially resistant to pests and diseases, we compound our benefits. We avoid crop losses from insect and disease damage, save the cost of preventive chemicals, and reduce contamination of the environment.

Many plant varieties resistant to disease have been developed and are in use. However, less progress has been made in developing plant resistance to specific insects. Farmers do not yet have the alternative of using resistant plant strains in fighting insects that they do in combating diseases. Accordingly, pesticides have been the principal weapons for controlling plant insect pests.

Breeding plant resistance to diseases or insects is not a simple undertaking, because the relationship between the host and the parasite is intricate and their physiologies are complex. The plant scientist and the cooperating scientists working on the pests must know the elements of heredity of the particular plant involved, the habits of the disease or insect pest, and the factors that control its behavior, before they can find and combine genes to confer the type of resistance desired. Resistance to a specific pathogen or parasite is also a delicate characteristic. A plant resistant to one disease or pest may be quite susceptible to another.

In many cases, there are wide gaps in the existing knowledge about the relationships of hosts and parasites. Until these gaps are closed, the development of resistant plants continues to be tedious and time-consuming. Scientists have searched the world for more than 75 years to find crop-breeding materials that might carry identifiable and usable hereditary factors for resistance. They have made worldwide collections of germ plasm and comprehensive assemblages of varieties and strains of crop plants and their related species. Crop specialists of ARS and other scientists continue to seek the wild forbears of the cultivated plants at the places where the species originated. They are combing the countries where the particular diseases and pests are endemic in search of strains and individual plants which, through operation of natural selection, may have developed factors of resistance. Once found, the selections and strains from the collected germ plasm must be tested under exposure to a wide range of diseases and conditions in many areas at the same time. Such tests are necessary to determine whether or not the plants do have resistance to pests and diseases in this country. If the resistance of the imported plants is satisfactory, the proper genes from these plants are incorporated into varieties of acceptable commercial yields and retested to determine adaptability to various climates and regions.

Plant breeders have been successful in developing varieties, notably of wheat, corn, alfalfa, and potatoes, resistant to certain diseases. But in some cases even the best of the varieties so far developed are unable to resist massive infestation by insects, and chemical pesticides are required to provide effective protection. In addition, it is possible for a variety to demonstrate satisfactory pest resistance for several seasons, and then become susceptible again as the insect adapts itself, just as a disease-resistant variety can become susceptible to a mutant of the pathogen. In such cases the plant breeder and the pathologist or entomologist must begin again (*2*).

The contribution that successful pest-resistant varieties could make is so attractive, and the promise that developing knowledge holds for eventually accomplishing it is so encouraging, that plant breeders in laboratories of the world are eager to continue vigorous research in this field. Even so, it is apparent that we cannot depend solely upon plant resistance to pests as a reliable method for pest control for some time to come.

Meantime, cultural practices, the chief resort of farmers before other sophisticated methods were available, continue to be exploited for insect control. These practices include sanitation, early planting of crops, destruction of crop residues, tillage, crop and animal rotation, strip-cropping, destruction of volunteer plants, and specific harvesting procedures (*3*). These practices are still used to the extent that circumstances warrant it, but in the current system of monoculture they are totally inadequate unless used in conjunction with other methods. Most frequently chemical control is also used.

Biological Controls

For many years, we have been attempting to develop ways to use insect parasites, predators, and diseases to prey upon damaging pests and thus control their numbers. The work includes world exploration to discover parasites and predators that might be useful; introduction of these organisms into the United States; evaluation of the effectiveness of pest control provided; and the distribution and establishment of the organisms so that they become part of the environment and contribute to the control of destructive insect pests. We have also explored ways of protecting native beneficial insects which aid in counteracting destructive pests. A few examples will illustrate the extent of progress.

Over a period of more than 80 years, attempts have been made to introduce parasites and predators of about 80 pests into the United States. Of about 520 species imported, 115 have become established, but only about 20 have provided significant control of some of the most destructive pests (*4*).

Recent research is aimed at mass production and release of parasites or predators in order to make sufficient numbers available at the critical time for effective control. For example, recent tests have shown that the release of 200,000 aphid lions (*Chrysopidae*) per acre for a sustained period was as effective against the bollworm as the available insecticides (*5*).

In another study, 100 million parasitic wasps were produced and released on 18,000 acres of alfalfa to control the pea aphids which are vectors of pea enation mosaic virus and pea streak virus that overwinter in alfalfa. The parasites suppressed populations of winged aphids, delaying their migration to pea plantings, and thus protecting some 130,000 acres of peas from the virus diseases (*6*, *7*).

Current studies are evaluating a special strain of *Bacillus thuringiensis*, which, under laboratory conditions, is about 100 times more virulent to bollworm and certain other insects than strains now commercially available (*8*). The effectiveness of this new strain under field conditions must be determined before its practical value can be properly assessed. So far, results from applications of the commercially available bacterium to cotton have not been entirely satisfactory.

Field studies of a polyhedrosis virus for control of the cotton bollworm and the cabbage looper have shown that this highly selective disease organism is potentially just as effective and economical as insecticides. However, until criteria are established for standardization of formulations and the registration and approval for exemption from tolerance for this insect virus, its use must be held in abeyance. Experimental evidence to date indicates that this virus poses no hazard to man or other forms of life (*9*). However, more extensive toxicological data must be submitted to provide complete assurance of safety before this and other insect viruses can be approved by the Food and Drug Administration and the U.S. Department of Agriculture for use on food crops.

An ARS entomologist explored Argentina in search of insect enemies of alligator weed, a pest in the southern region of the United States that chokes reservoirs, canals, and other waterways, spoiling their use for recreation, wildlife, and commercial activities. He found that a flea beetle (*Agasicles*) is a damaging enemy of the weed. Tests were made to determine that it would not be harmful to other plants, and the beetle was released in 1964 in Florida and South Carolina. The beneficial insect has already multiplied sufficiently to make important contributions to the control of alligator weed in some areas (*10*).

The potential value of such biological controls is promising. Parasites are usually specific in action, and so far there have been no known damaging effects on the environment from those already released. The prognosis for various disease-causing organisms is good enough to encourage continuing research. However, the relatively meager successes demonstrated over the years and the complex obstacles to be overcome—notably the difficulty of mass-producing biological agents—indicate that we are still a long way from being able to depend on these methods for practical pest control.

Insect Sterility

The manipulation of insects for their own destruction, by inducing sexual sterility or introducing other harmful genetic traits, is a relatively new approach to insect control and holds considerable promise. Two distinct methods of using sterility as a control are being studied. One method is based on rearing massive numbers of a pest species, sterilizing them with gamma radiation, and releasing the insects to compete for mates in the natural population. The resulting eggs do not hatch and the insect population dwindles. The second method involves the application of chemosterilants to native populations at a central source; the treated insects then disperse and serve to reduce the reproduction of target pests in the environment.

The first method was used to eradicate the screwworm from the southeastern United States and is now employed to suppress this livestock pest throughout the southwestern region of the United States. In view of the long flight range of the insect, a continuous barrier of sterile flies must be maintained against reentry of the screwworm from Mexico. Before these programs for eradication and suppression were undertaken, beginning in 1958, this pest was costing livestock producers up to $120 million a year (*11*).

The sterility method is also being used to replace insecticide spraying in preventing the entry of the Mexican fruit fly into Southern California. The sustained release of sterilized flies has also been proved effective experimentally in eradicating the melon and oriental fruit flies from islands in the Pacific.

Considerable work is now being done to develop this method for use against the pink bollworm. Preliminary investigations are under way to determine the potential of the sterility method for suppression of the boll weevil, corn earworm, tobacco hornworm, tobacco budworm, cabbage looper, fall armyworm, and hornfly (*12*).

The sterility principle and other genetic methods for insect control are most attractive, but before such methods can be developed for practical use, scientists must have a thorough knowledge of the biology, ecology, and population dynamics of each target insect. They must study the problems of mass-rearing and sterilizing the billions of insects that are often needed to flood adequately the target insect population. One of the obstacles to achieving successful mass-rearing and sterilization is the difficulty in preserving healthy and aggressive characteristics in the released insects to enable them to compete for mates in the native population. Another limiting factor is the fact that the method is effective only when the target population is at a natural low ebb or when the population is first reduced by insecticides or other methods of control. The sterility technique is usually successful as a tool for eradication or continuous suppression of an insect only when used in conjunction with other methods of pest control or when insect populations are reduced by natural causes.

In explaining how and why the sterility technique is most useful, Dr. E. F. Knipling, originator of this technique in pest control and director of entomology research for ARS, describes it as follows (*13*):

> In most situations, the natural population of a pest, even at the lowest level in the population density cycle, may be so high that it would not be practical to rear and release enough sterile organisms to start a downward population trend. In such event the prior use of an insecticide or some other method of control would be more efficient and practical than the release of sterile organisms. However, the release method should become more practical than insecticides at some point in the natural population density level. We may illustrate this by citing some hypothetical figures. A 90 percent kill of a million insects in a population would mean the destruction of 900,000 insects the first treatment. In terms of numbers killed this would be highly efficient. The second treatment, however, would destroy only 90,000; the third, 9,000; the fourth, 90; the fifth, only 9. Thus, as the population declines each insecticide treatment becomes less efficient in terms of the number of individuals killed.
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> At some point in the population density level, the rearing and release of sterile insects should become more efficient and perhaps more desirable than the continued use of an insecticide.

Attractants and Hormones

One of the newest trends is research to identify and develop attractants and hormones for insect control. Scientists are investigating insect responses to various chemical substances in the plants the pests feed upon, to chemical sex attractants, to light, and to sound.

Naturally occurring attractants are highly specific and active in infinitesimal amounts. Intensive effort is being devoted to the isolation, identification, and synthesis of several sex pheromones so as to obtain sufficient amounts for practical use in the control of important pests (*14*). Sex attractants have already been demonstrated for such major pests as the cabbage looper, pink bollworm, tobacco hornworm, Japanese beetle, lesser peach tree borer, European corn borer, fall armyworm, corn earworm, boll weevil, and gypsy moth (*15*). Field studies on the use of appropriate sex pheromones in combination with blacklight traps for the control of the tobacco hornworm and cabbage looper have been encouraging (*16, 17*).

The synthetic lure, methyl eugenol, was used experimentally to eradicate the oriental fruit fly on the island of Rota. The chemical attractant was fortified with the insecticide naled and incorporated into small squares of fiberboard. The squares were distributed by aircraft, about 125 per square mile, every 2 weeks. Such releases were supplemented by treated pieces of cane fiber suspended from trees in village areas. The fly was eradicated within 6 months (*18*).

Another recent trend is research on hormones and hormone-like materials that may be used as insecticides to disrupt insect development rather than to cause immediate death. Sterility in adult insects may result soon after treatment with molting hormones or their analogs, but juvenile hormones act by interrupting insect development and producing monster insects that eventually die or, if they become adults, cannot reproduce because of their physical abnormalities (*19*).

Certain of these hormonal materials, which would not be expected to have a detrimental effect on nontarget organisms, are effective against specific pests at fantastically small dosages.

Recently, several new "hybrid" synthetic ethers, similar to juvenile hormones, were tested for their ability to block normal insect growth and development. These compounds are fairly easy to synthesize and are far more potent than the insect's own hormones (*20*). In addition, the antifertility effect of a synthetic molting hormone called triol was intensified 10 to 20 times when combined with synergists such as sesamex or piperonyl butoxide.

Insect physiologists of ARS and industrial scientists are working separately and cooperatively to push developmental research on juvenile and molting hormones and their analogs. There are at least two dozen chemical and pharmaceutical companies that are studying insect hormones, and perhaps half of them have under way extensive screening programs involving hundreds of compounds.

These examples indicate some of the interesting leads being followed in the development of useful hormones and attractants; at present they are hardly more than that. It will be some time in the future before some of these chemicals will be ready for practical and general use.

Integrated Control Programs

The opportunities for experimentation provided by the wide variety of insect control methods now available and the limitations of most of them have prompted investigation of integrated methods to place maximum pressure on insect populations. Integrated control is a compatible system of insect control in which various methods are used in proper sequence and timing so as to create the least hazard to man and the environment and to permit maximum assistance from natural controls. The objective is to keep the numbers of key insects in a given area below the level that can cause economic damage or, in some instances, to eliminate the population if feasible and advantageous. The development of techniques required for such integrated control programs on a practical scale is costly. Because there is limited profit in developing these techniques, they may not be of immediate interest to industry; thus, it is likely that most of the development will have to be undertaken by public agencies. Research by ARS is directed toward certain important insects in which this method of control seems practical.

Much research is needed, because for several major insect pests pertinent information is lacking on the life history, host plants, flight habits, population dynamics, role of natural enemies, numbers of different stages of insects per acre, nutritional requirements, requirements for mass rearing, comparative vigor and competitiveness of reared insects and native strains.

Much more information about the insects is required for development and application of integrated control methods than is generally required for use of insecticides. Areawide programs in which billions of sterilized insects, or biological control agents, or large quantities of natural sex attractant are used, will require housing facilities, development of suitable rearing media, and automated techniques for mass production of insects.

After the basic data have been obtained areawide control procedures for each insect must be tested in an isolated area, preferably an island. Then, with the cooperation of state agencies and growers, it will be possible to carry out a substantial experimental test. If results are favorable, it will be necessary to conduct a significantly large field test supported by a large-scale pilot test for production of the agent to determine the practicality of the entire procedure. At the conclusion of the testing, we decide whether the federal government should continue the work or turn the project over to private enterprise for further development. An obstacle to the rapid advancement of such means of insect control is the high cost. For example, such a test for integrated control of the boll weevil is estimated to cost nearly $2.5 million a year for 2 years.

Problems and Hazards of Pesticides

Although we have high hopes and great enthusiasm for the eventual development of effective alternative means of pest control, for the present we must depend on chemicals, used selectively and prudently. As we continue to use pesticides in agriculture we must be aware of the problems and the hazards that they can create for man and his environment.

Pesticides have their shortcomings. One of the first problems to be recognized in the use of the most effective organochlorine pesticides was the development of resistance by insect pests. Differing reactions of individual insects to insecticides was recognized as early as 1897 (*21*), and the possibility that insects can develop resistance was pointed out in 1914 (*21*).

Development of resistance to DDT and related compounds was most spectacular. The repeated and widespread use of such insecticides created an intolerable environment for many species of insects, and some species evolved a stronger resistance with each succeeding generation. Finally, certain insects, including the housefly and the boll weevil, became almost impervious to the originally potent effects of these insecticides. Some 224 species of insects and acarines in various parts of the world have developed resistance to one or more groups of insecticides; of these, 127 are agricultural pests and 97 are pests of medical and veterinary importance (*22*).

The more effective persistent pesticides are said to have a "broad spectrum" in that they often affect many organisms other than the target pest. Some of the more specific pesticides in use today are more acutely toxic to man; the use of the more specific chemicals requires use of a different pesticide for almost every different pest that attacks a given crop or area. The long-term result of shifting away from broad-spectrum pesticides may be creation of greater immediate hazards to man and the need for more chemicals than are now used.

A report on pesticides made to the Secretary of the U.S. Department of Health, Education, and Welfare by a special commission (*22*) included the following findings in relation to human health:

> The available evidence concerning such human exposure to pesticides derives from three main sources: planned and controlled administration of pesticides to human subjects; case reports of episodes of accidental or other acute poisoning; and epidemiological studies, which in turn comprise surveys of occupationally-exposed groups (in accordance with a variety of retrospective and prospective approaches), and studies of the general population . . .
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> A detailed survey of case reports of incidents involving accidental poisoning by organochlorine pesticides reveals that their general action is to increase the excitability of the nervous system. Some of these compounds also damage the liver. Their capacity to penetrate intact human skin varies from one compound to another; in the case of endrin, for example, percutaneous penetration plays an important part in clinical intoxication. With the organochlorine group of compounds there is a wide range of potential for acute toxicity: DDT is relatively safe in terms of acute intoxication, while dieldrin and endrin have produced many cases of serious poisoning. Lindane presents a special problem, inasmuch as it has been implicated, largely on the basis of circumstantial evidence, in the causation of hematological disorders. A characteristic of organochlorine poisoning is the difficulty of establishing the correct diagnosis. This is especially true in cases of mild poisoning that result in nonspecific symptoms and signs, since except in the case of dieldrin there are no established criteria for diagnosis on the basis of blood levels. Specific therapeutic measures do not exist . . . .
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> . . . The longest studies on record have lasted less than four years and the results can only reflect the period of study. Consequently, the findings, especially when they are negative, are open to question when taken by themselves. It appears, however, that present levels of exposure to DDT among the general population have not produced any observable adverse effect in controlled studies on volunteers. The same is true of aldrin-dieldrin. These findings acquire greater force when combined with observations on other groups, such as occupationally-exposed persons.

Despite the lack of unequivocal evidence of harmful effects upon man, public concern over the use of DDT and its relatives has continued to grow, largely because another problem has become increasingly apparent as the experience with the pesticide has lengthened. Residues of DDT and related pesticides do not readily break down; therefore they dissipate very slowly. Residues have been accumulating in the environment, in adipose animal tissue, and in milk. Residues of DDT have been found many miles from any point of known use, for example, in tissues of polar bears and other wildlife in the Arctic.

The residues of DDT and several other chlorinated hydrocarbons are harmful to certain beneficial insects, including pollinators and parasites or predators of pests. Some fish and birds have been harmed by residues of persistent pesticides.

The previously cited commission reporting to the Secretary of the U.S. Department of Health, Education, and Welfare, and other competent scientific study groups have noted additional reactions of nontarget organisms to persistent pesticides in the environment. Species react differently to specific pesticides. For example, DDT can cause thinning of eggshells in ducks and falcons, but not in pheasants and quail (*22*). Pesticides from the air, water, and soil may be absorbed and concentrated in the bodies of organisms. The concentration in the tissue is frequently increased as one species feeds on another and passes the pesticide from one link to another one higher in the food chain. In this sequence some predators, like birds and fish, may be exposed to levels several thousand times the concentration in the physical environment.

Increased Precautions

In the light of all this, a guideline is emerging with which most agree: Persistent pesticides should be released into the environment only when necessary—that is, when the need is immediate to protect human health or life-supporting food supplies and when no satisfactory alternative is available. Most also agree that research on the long-term effects of persistent pesticides in the environment should be intensified since, even with this guideline, we will continue to need and use some persistent pesticides.

We are moving in the direction indicated by the guideline. Actions are being taken to accomplish an orderly reduction in the use of persistent pesticides without sacrificing essential uses. One of the safeguards is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) administered by ARS. The original federal legislation on pesticides was enacted in 1910 and amended in 1947 under the designation FIFRA. Additional amendments have been added as needs have arisen. The purpose of the Act is to assure the safety and efficacy of pesticide products sold in interstate commerce.

In making decisions concerning the registration of chemicals proposed for specific uses, our scientists carefully evaluate the detailed data submitted with each application and consult with scientists in other agencies concerned with public safety—most frequently the Department of Health, Education, and Welfare and the Department of the Interior.

The following are examples of the actions taken in recent months relating to FIFRA and other ARS responsibilities concerned with pesticides:

1) On 20 November 1969, registration of DDT was canceled for use against pests of shade trees, tobacco, house and garden, and aquatic sites such as marshes and swamps. As provided under the law, five manufacturers have appealed this decision through a request for either a review by a panel of experts, nominated by the National Academy of Sciences–National Research Council, or a public hearing. On 25 November, the Department announced its intention to cancel all other uses of DDT except those needed for prevention or control of human disease and other essential uses for which no alternative means of pest control are available.

2) On 23 April 1970, the Department of Agriculture announced that pesticide manufacturers and formulators had been notified that federal registration of certain 2,4,5-T products used for weed control is suspended. The suspended products include liquid formulations for use around the home or recreation areas; and all formulations for use in lakes, ponds, or on ditch banks. The action was taken because 2,4,5-T was reported to cause birth defects when injected at high doses into experimental pregnant mice. Pregnant rats were unaffected. No data on humans are available.

3) A review of uses of all persistent pesticides in federal-state pest-control programs was made, with the result that less persistent chemicals will be used wherever possible in all such programs.

As we continue increasing our criteria for safety—particularly for keeping the use of persistent pesticides to the minimum—judgments will be made on the basis of the best scientific knowledge available. But decision-making cannot always wait until all scientists agree. In the traditional and leisurely scientific winnowing process, scientists argue their data and conclusions with each other and discuss and test them until shreds of truth can be aggregated to establish fact. In the case of pesticides, this process is now being hastened under the glare of the public spotlight in which controversial and complex scientific issues are being debated by scientist and layman alike.

Basic to the speedy resolution of these controversial issues is knowledge, now lacking, that can come only through research. We do not know, for example, what the long-term effects of persistent pesticides upon man will be nor their ultimate fates in soil, water, and other parts of the ecosystem. Crucial to the resolution of questions of environmental pollution—particularly, as they concern pesticides—is the establishment of the significance in man of the results of toxicological experiments on laboratory animals. We need to have settled, among other things, some questions concerning cancer and carcinogens, species specificity, significance of dose size and route, and the effect of substances to which the living organism is concomitantly exposed. We need knowledge to enable us to cut through the present scientific complexities and arrive at an acceptable practical answer to the question, "How safe is safe enough?"

This is far from an academic question, but it is one that must be faced repeatedly in administering programs for pest control and in regulating the use of pesticides. These decisions, based on scientific knowledge, must be made in the light of what is best for the overall welfare of man, his environment, and the creatures with which he chooses to share the environment.

Summary

Agriculture is expected to maintain and increase efficiency of production in order to feed the increasing millions in our country; the needs in underdeveloped countries are even more drastic. Meeting these needs requires more than ever effective control of agricultural pests. We can no longer afford to give up so large a share of the potential world food supply to pests and diseases. At the same time, with more people crowded closer together the need for protecting the environment from pollution is more acute. We must have an effective program for combating the diseases and pests that plague mankind and his food supply, but we must also preserve and protect the quality of our environment.

References and Notes

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