Chapter IV

Present Problems, Concerns, and Most Promising Approaches

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In chapter II the crop protection problems and concerns for each of the seven regional systems are described. In this chapter these problems and concerns are grouped according to type of control tactic and strategy and are presented along with others generally recognized for pest control, which are followed by several areas of general concern. Finally, several approaches are presented that appear to be most promising.

SPECIFIC AREAS OF CROP PROTECTION

Cultural Controls

Crop rotations developed in the first half of the 20th century were practiced. in part. to centrol certain pests including weeds. For economic and other reasons many of these old rotations were replaced by' monoculture; (planting the same crop on the same land each year) or by rotation with different crops (e.g., the rotation of soybeans instead of oats with corn in the Corn Belt States). Such changes in the agroecosystem often have impacts on the incidence of pests, The studies of the seven regional systems clearly show that such impacts may be both negative and positive depending on the nature of the specific pests. They also show that the changes are not predictable and that a very serious knowledge gap exists in understanding the basic interactions between pests and their physical and biological environments. Until this information is available, pest management by habitat modification through cultural means can only be developed on a trial-and-error basis. When several pests are involved, as on most crops, this process is time-consuming and expensive.

Because of the rapid acceptance of new technologies by American farmers. there is concern that new cultural practices could c; ıuse excessive pest-caused losses over wide areas. The rapid adoption of no-till corn is an excellant example. By 1977 minimum t ill age (no-till) methods were used on over 300,000 acres of corn in Maryland, and many of these acres were show'ing enough insect and slug damage by these formerly very minor pests to warrant pesticicle applications. The only avaiable effective insecticide properly registerd for use in this situation was on the RPAR (rebuttable presumption against registration) list. Similar concerns exist for no-till corn in other areas and for other crops involved in major changes in production technology.

Such cultural changes may or may not be totally sound economically, environmentally. or socially. only time with further research and experience will provide the answer. However, the need to adapt pest management practices to new production methods must be considered early and given adequate attention. Crop cultivars resistant to new pa thogens, nematodes, and insects may be the long-term answer. but for the short term, appropriate pesticides must be used if available. If pest problems become a limiting factor, even the most promising new cultural practices may have to be abandoned.

Host-Plant Resistance

Concern over the present and future use of pest-resistant cultivars lies in two areas: 1) the effective use of known resistant germ plasm and 2) the identification and preservation of new sources of resistance.

The uses of pest-resistant wheat and corn cultivars on a large scale for both diseases and insects are classic success stories of host-plant resistance. However, recent trends in the Great Plains Wheat Belt are disturbing. The acreage of Hessian-fly-resistant wheats in Kansas and Nebraska has decreased from about 66 percent in 1973 to about 42 percent in 1977. Hessian fly infestations have increased where susceptible cultivars have been planted. In South Dakota in 1978, in an area not normally heavily infested, an estimated 1.25 million acres of spring wheat were infested resulting in losses of $25 million to $50 million, An even greater decrease in resistant-wheat acreage is expected in the next 2 to 5 years as a result of recent releases of cultivars that have improved agronomic traits and disease resistance but which are susceptible to Hessian fly, Insect resistance has not been a significant component of commercial breeding programs, and none of the new commercial wheats have resistance to Hessian fly, In 1972, U.S. Department of Agriculture (USDA) research on wheat stem sawfly was terminated. The resistant cultivars presently grown are expected to be replaced with susceptible cultivars, and infestations of this pest are also expected to increase.

A similar trend towards the use of corn hybrids more susceptible to corn borer is reported in parts of the Corn Belt with concomitant increases in infestations and insecticide use, The reduced use of resistant crops does not extend to all areas and all crops. For example, greater use is now being made of resistant cotton.

The reasons for the reduced use of known germ-plasm resistance for such important insects as the Hessian fly, wheat stem sawfly, and the corn borer are complicated. Because resistant cultivars have been effective in reducing damage and pest populations for many years, there is little recent evidence of the potential destructiveness of these insects. As a result. new generations of farmers do not demand resistant cultivars, This trend has been abetted by the deemphasis of breeding programs in many State experiment stations and USDA laboratories. The latter development was based in part on the assumption that commercial seed companies could do the necessary work to maintain and increase pest resistance. Experience indicates that this was not a correct assumption. The trend away from plant resistance-breeding research in publicly supported institutions has been abetted by the erosion in Federal support for agricultural research and the concept among administrators and researchers that plant-breeding research of this nature is less prestigious than basic studies. Lacking demand by growers and the stimulus and information from Federal and State experiment stations, commercial seed companies have also deemphasized efforts to incorporate insect and even some disease and nematode resistance into new cultivars, The result of this trend could have disastrous consequences not unlike the southern corn leaf blight epidemic of 1970. Although the corn blight epidemic required only 1 year to correct (the problem was one of cytoplasmic susceptibility), insect, disease, and nematode epidemics brought on by the use of susceptible cultivars could take several years to correct.

Development of pest-resistant crops with good agronomic characters is a lengthy and expensive procedure, However, the cost/benefit ratio, especially the cost in terms of use by growers, is very small. And perhaps of more importance, resistant cultivars can be used by small as well as large growers and even by gardeners. Adequate funding of public research to ensure continued development of resistant crop cultivars appears to be not only desirable but imperative for long-range effective pest management and the public good.

Germ plasm resistant to many diseases, nematodes, insects. and mites is not available for a number of crops. This is most pronounced for crops that originated outside centinental North America. Areas where plants and their pest coevolved are good sources of resistant germ plasm. In some cases, wild progenitors of our cultivated crops in which resistance may be found are being lost. In order to find and preserve these sources, search and conservation projects are needed. These efforts should include vegetables and fruits as well as major crops such as wheat, corn, and soybeans. A new opportunity exists with respect to soybean as improved relations with China afford considerable promise in developing programs to locate pest-resistant germ plasm where soybean originated,

Present USDA/State plant introduction programs do not adequately meet the need for developing pest-resistant crops. Recent efforts to increase introductions and establish germ-plasm banks have been underfunded and developed slowly. Programs such as the one for rice at the International Rice Research Institute in the Philippines where thousands of genetic lines are maintained and evaluated for resistance to pests are needed. Such projects could be cooperative with other countries with similar interests. The costs of these programs are high but the almost certain potential benefits are much, much greater.

Biological Controls

Just as the major emphasis on breeding for host-plant resistance in the past has been for disease control, the greatest effort in biological control has been on insects and mites. Recently however, more attention is being given to biological control of pathogens, weeds, and vertebrates.

A few spectacular successes in biological weed control have occurred—i. e., the control of prickly pear cactus in Australia through the introduction of insects that feed on this plant and that are indigenous to the area from which the weed originated. Another example is the control of alligator weed in irrigation canals and ponds in the Southeastern United States through the introduction of a leaf- and stem-feeding flea beetle from South America. Biological control works best when only one weed species is the problem, as opposed to having several species involved. Good examples are lantana and the prickly pear cactus, which are primary weeds that take over certain habitats. Control of these by any specific means including biological is satisfactory. However, the use of specific controls for single species in agricultural crops is not satisfactory because other weeds quickly take over niches left by the controlled species.

Biological control of plant pathogens and nematodes may be more promising than was thought earlier. A recent breakthrough is the use of one bacterial species (Agrobacterium radiobacter) to control crown gall on apple and other crops caused by another bacterial species in the same genus IAgrobacterium tume~aciens). The lack of knowledge of the basic interactions among species of micro-organisms limits judging the potential of this approach for control of these pests.

Vertebrate pests are normally held in check by predators, parasites, and disease. Attempts to use specific biological control measures have had few successes and many failures. The introduction of the ferret predator into Puerto Rico failed to control rats and actually added a new pest to the island. The introduction of' myxomytosis disease to Australia to control rabbits succeeded initially, but over several years strains of rabbit evolved that were resistant to the disease, The rabbit is still a pest but is not as serious a problem as formerly.

As mentioned earlier, the greatest effort in biological control has been against insects and mites. So-called "classical" biological centrol—i. e,, the introduction of agents to control exotic or native pests—has produced the most spectacular results. The control of the cottony cushion scale on citrus in California through the introduction of the Vedalia beetle in 1899 is perhaps the best known example, There are recent successful examples such as the control of the alfalfa weevil and citrus blackfly with introduced parasites. The other phase of biological control is to increase naturally occurring agents through manipulating the environment or by artificially propagating and distributing them. Spores of the bacterium causing milky disease of Japanese beetle larvae have been used for many years to reduce populations of this introduced pest. Currently efforts are underway to propagate and disseminate virus diseases of certain insects and tiny wasp parasites of the eggs of several insect pest species.

A substantial number of the major insect pests of agricultural crops in the United States are introduced, and there is good reason to believe that they can be effectively controlled by biological agents introduced from their points of origin. The major obstacle to greater success is the low level of support available for facilities, personnel, and operational funds to identify, investigate, introduce, and establish these beneficial organisms. The USDA 1979 budget for classical biological control is $2 million. With the exception of California and Hawaii, the States do not have strong programs, Also, according to some experts, the effort within USDA could be improved by a vertical rather than a primarily horizontal approach—i.e., having the same scientist or team conduct the total effort from discovery through establishment rather than different groups being responsible for each operational stage. In view of the potential benefits to be derived from the successful introduction of biological control agents, the low levels of Federal and State efforts seriously limit the progress of this important program. An evaluation of past efforts indicates that the benefit/cost ratio has been 30 to 1 In addition to the direct dollar benefit, there has been a reduction in both crop losses and the use of insecticides. While biological controls are not permanent or uniform each year, they tend to be more permanent than most other tactics and require little or no further expense once established.

Quarantine

A study of tables 2 to 14 shows clearly that many of our major weed, insect, mite, pathogen, nematode, and vertebrate pests are introduced. Some are serious in the United States but are of little importance in their native habitat. Lack of biological control agents, the presence of more susceptible hosts, more favorable environmental conditions, and other reasons are cited as causes for this phenomenon. But regardless of the reasons, the potential for serious and even disastrous crop losses that result from the introduction of additional new pests is very real. There are many identified potential pests and undoubtedly many others of unknown potential.

The rapid movement of people, food, fiber, and other goods about the globe makes effective quarantine a difficult task. As a consequence, present efforts and methods are not considered to be as effective as formerly. There is a need to develop and implement improved technologies for preventing the introduction of undesirable organisms into the United States. Also a need exists to improve survey and identification capabilities for exotic pests in order to find new introductions before they become too widespread and well-established to be eradicated,

Eradication

Large sums of money have been, and still are being, spent in attempts to eradicate insect and weed pests. Successes have been limited to a few situations such as elimination of the Mediterranean fruit fly from Florida and California and the screwworm from the Southeastern States. In all these instances, newness or restricted winter survival area (screwworm survived winter only in southern Florida) limited the infestations. Eradication efforts against barberry and the imported fire ant failed. Large sums of money and much manpower are now being utilized in a second boll weevil eradication experiment. With present technology, many knowledgeable scientists consider the probability of successful eradication of this widespread, well-established insect pest of cotton to be extremely remote.

Eradication is attractive because success offers a permanent solution to a pest problem, at least until the next introduction. Eradication programs are politically attractive because of their visibility and because, while in progress, they offer short-term relief from attacks of the pests involved, but permanent success is difficult, if not impossible, to attain for most pests using present technology. Also, the potential hazards to human health and the environment must be considered. There is much concern that funds and manpower so badly needed for other crop protection efforts will be wasted on technically unsound eradication projects that are doomed to failure from the beginning.

pesticides

Present problems and concerns for pesticides for agricultural crops focus on health hazards, environmental hazards, and availability and effectiveness. While this report has concentrated on crop protection technologies and strategies, concerns about human and environmental hazards associated with the manufacture, distribution, and use of pesticides have been expressed by assessment panel members, by participants in a public meeting, and by the public media.

Health problems associated with pesticides involve acute (or subacute) and chronic low-level effects. In the United States, where medical services are readily available and poison control centers have been established, acute effects are relatively clear-cut and can be identified correctly. There are concerns, however, that some effects, particularly the subacute, are not identified and reported. Also some concern exists that some illnesses are incorrectly ascribed to pesticide intoxication.

The safe use of pesticides has received great emphasis in the United States over the past 25 years. The effort has succeeded despite the vast increase in the availability and use of pesticides during this period; the incidence of fatal poisonings directly attributed to pesticides has dropped continually—from 152 in 1956 to 31 in 1976—while total population and total accidental poisoning deaths have more than doubled. The meager data that are available from developing countries indicate much higher death rates, even though pesticides are not used as extensively as in the United States. Although acute toxicity episodes can be minimized through education, they remain a continuing hazard, especially where educational and medical facilities are minimal.

The phenomenon of delayed neurotoxicity for a few pesticides has received considerable attention in recent years following the discovery that permanent weakness, ataxia, and paralysis can be induced by a single sublethal exposure to leptophos, an organophosphate insecticide. EPN, also in the same chemical group, has caused similar effects in test animals. Fortunately, most organophosphate pesticides do not cause these delayed problems.

The long-term exposure of humans to comparatively low levels of many pesticides in the environment and in the body is of great concern because of known and suspected potential harmful effects. These effects are many and may include eye irritation, neurological and reproductive impairment, teratogenic effects, cancer, and others.

Real human hazards that result from long-term pesticide exposure are extremely difficult to assess. For example, the induction period for cancer may be in the range of 20 to 30 years with complications resulting from exposure to other synthetic and natural potential carcinogenic agents. Thus, human epidemiological studies are difficult to conduct and produce inconclusive results. In spite of the fact that chlorinated hydrocarbon insecticides, particularly DDT, have been in the environment and present in human tissue for more than 30 years, and certain inorganic pesticides for nearly a century, no detectable effects on the human population have been proven. However, this does not prove that no effects have occurred or that none will occur.

The organochlorine insecticides (DDT, aldrin, dieldrin, endrin, heptachlor, and chlordane) are persistent chemicals and have been commonly found in human foods and human tissues. Since most uses for these products have been discontinued in the United States, a steady decline has occurred in the concentration of these materials or their metabolizes in human adipose tissue. Extensive toxicological studies on several experimental species including mammals, birds, and fish must be conducted before pesticides can be registered for use, Currently there is much concern and controversy about extrapolating from animals to humans, particularly regarding carcinogenicity.

With the exception of the inorganic and organochlorines, pesticides or harmful metabolizes are relatively short-lived in the environment. A few herbicides persist in the soil up to 12 to 18 months but most disappear in considerably less time. Less is known about residues in air that serve as a global transport medium for pesticides. Water pollution by pesticides exists in most surface waters in the United States at very low levels, Organochlorine insecticide residue levels reached a peak in 1966 and declined in succeeding years as the use of these products was reduced,

Pesticide residues are also found in plants and animals. The phenomenon of "bioaccumulation' '—i. e., the process in which low levels of a chemical in organisms, such as algae, at the bottom of the food chain accumulate through the food chain until extremely high levels occur in animals such as fish or birds at the top of the chain—has resulted in serious losses of some wildlife species.

Until the 1960's detailed evaluations of the impacts of pesticides on the environment had not been done. Because of this and because the world ecosystem is large and complex, only limited knowledge is available on the subject except in the area of acute toxicity. Generally, acute toxicity problems for wildlife are known and managed at acceptable levels except for accidents or misuse.

On the other hand, much concern exists about known and unknown chronic effects on wildlife from low levels of exposure to pesticides. These can be subtle effects such as the eggshell thinning in the bald eagle, the peregrine falcon, and the brown pelican which seriously reduced the reproductive potential of these species. A comparable reproductive problem developed in a variety of fish and food-chain-dependent mammals. These reproductive disorders have declined with the elimination of DDT and most other organochlorine pesticides from agricultural and forest uses. Concerns have been expressed for other chronic effects such as growth inhibition, acute nervous stress, oncogenesis, and others. Indirect effects of pesticides on wildlife are also thought to be significant. Suppression of food, obviously, is a potentially harmful effect,

Capabilities for detecting and measuring pesticide residues in the physical and biological environment now extend to parts per billion or less. Unfortunately, little is known of possible hazards of such low residues. Risks must be weighed against benefits to determine whether or not specific chemicals should be approved for use in agriculture. Thus, their use should be limited to essential needs where risk/benefit ratios are favorable and where other control tactics are insufficient.

There are serious concerns about the future availability and effectiveness of pesticides. For all the crops included in this report on which pesticides are used extensively, there was concern that effective materials are lost because of regulations, resistance, economics, or combinations thereof more rapidly than replacements are found, developed, and introduced. This situation is most critical for insecticides and miticides, is potentially very critical if present RPAR's fungicides are lost, and is least critical for herbicides. The lack of safe and effective rodenticides and avicides is also a problem. For short periods during the past few years, no effective insecticides were available to control insect complexes on cotton in parts of Texas and Mexico, and no miticides were available for control of mites on apples in Washington. Several emergency registrations of new insecticides on fruit, vegetables, and cotton were necessary because existing materials were no longer effective or registered.

The number of registrations of new molecular structures for pest control for agricultural crops has dropped sharply during the past 10 years. With the continuing loss of effectiveness of current products due to resistance, and losses due to regulations and economic factors, the situation is likely to worsen, especially on minor crops.

To date the problem of acquired Weed resistance—i. e., the evolution of weed strains resistant to an herbicide—is not serious in weed control even though examples exist. The major resistance problem in chemical weed control occurs when naturally resistant weed species survive, thrive, and soon take over without competition from other weeds. Such problems are managed by using combinations of herbicides, changing herbicides, and crop rotations. The loss of inexpensive selective herbicides, such as the phenoxv materials **2,4-I)** and **2,4,5-T',** would create a difficult problem for a number of agricultural and nonagricultural users.

A major overall concern about pesticides is the lack of availability of compounds possessing the required range of activity against pests. This is particularly the case in developing pest management systems that involve the use of pesticides. For some situations, an insect icicle or miticide with a verv narrow range or short residual toxicitv is required to reduce a pest species without disrupting biological control agents. In other cases, pesticides may be required that control a broad range of weeds, pathogens, or insects. Sometimes short residual contact materials are required while for others, as for control of soil insects or season-long weed control. residual effectiveness may be required for several months. When no pesticide with appropriate activities is available, substitutes often have to be used at higher rates with repeated applications and sometimes with harmful effects on beneficial species. A limited range of pesticides restricts the potential for pest management on many crops.

The inefficiency of pesticide application technology is another concern. In some applications as little as 25 percent of the toxicants reach the target. This inefficiency is not only wasteful but can cause secondary health and environmental problems outside the target area,

The difficulty in obtaining registrations of pesticides for minor crops and minor uses is another serious problem that the 1979 Amendment to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is designed to alleviate. A further concern is the problem of developing and registering new and novel types of control agents such as insect pheromones and hormones or antihorrnones, allelopathic materials, and microbial pesticides.

GENERAL PROBLEMS AND CONCERNS

Pest-Caused Losses

The amount of land now cultivated is 50 percent greater than would be required if there were no pest-induced losses. The amounts of fertilizers, energy requirements, labor, capital, and other inputs are also correspondingly greater. The total direct cost to this Nation is enormous. Secondary costs may, in the long run, be even greater. For example, soil erosion losses that result from cultivation of marginal, sloping lands and tillage for weeds and other pest controls represent significant costs to society while the costs of pesticide use in terms of health and the environment have only recently been addressed.

The economic impacts of increased losses that would occur if no pesticides were used on grains and soybeans have been estimated based on economic models (see Volume 11—Corn). Food grain, feed grain, and oilmeal prices would increase 60 percent, 200 percent, and 171 percent, respectively. Consumer welfare would decrease by over $38 billion annually, but farm income would increase by $27 billion with a net economic efficiency loss of about $11 billion annually. These estimates were made on a short-term basis; the long-term impacts are not known.

Although estimates were not made of the impacts of reduced pest-caused production losses as a result of the use of alternative pest management strategies, improved pest control can be expected to favor consumer welfare and eventually the entire community, For example, if pest-induced losses could be reduced by one-half, current production could be maintained with a 30-percent reduction in agricultural land use.

A major problem with the above type of estimating and generalizing is that crop losses are not uniform across crops nor are the methods of control. As stated earlier, pesticides are the primary control tactic for specific pests on some crops while host resistance, cultural, or biological control may be basic for others. Also, direct measurable losses for some crops are thought to be minimal, while for others there are appreciable known losses against which no economically feasible controls are available.

Instability of Pests and Pest Control Tactics

Without doubt the overriding problem and concern in crop protection on agricultural crops is the ephemeral nature of most control tactics. This is due in large measure to the evolutionary process by which organisms adapt to their environments. The process has been going on as long as life itself, but in agriculture, evolution of pest species is accelerated by intense selection pressures either for resistant strains or resistant species. The practices of plowing and cultivating soon result in the elimination of perennials and great increases in high seed-producing annual weeds. The use of stem-rust-resistant wheat cultivars eventually results in rust strains capable of overcoming such resistance. Continual exposure of pests to disease or other biological control agents can lead to resistant pests as in the case of rabbits to myxomytosis in Australia, The rapid evolution of pesticide-resistant insects and mites is documented by the long list of species with acquired resistance. A similar pattern is developing for some plant pathogens. Some rodents are now resistant to anticoagulant control agents. Many pesticides, especially insecticides and miticides, have been short-lived relative to long-term crop protection.

In addition, there are the problems of the spread of pests into new areas, of the introduction of exotic pests, of the adaptation of indigenous species to cultivated crops and changes in agricultural practices, crops, and cropping systems that impact on the nature and intensity of pest problems. Weather, too, can drastically change pest problems from year to year and even within the same year.

Thus, pest problems and solutions are continually changing and evolving and always will. The great concern is whether adequate control tactics and strategies can be made available to avoid serious or catastrophic losses. The present national effort, both public and private, may not be adequate to maintain present levels of crop protection, let alone reduce losses caused by pests.

Inadequate information to Develop and Implement Effective Pest Management Systems

Another general problem and concern in crop protection that emerged from the original crop studies is a lack of knowledge that must be available as a basis for developing effective, economical pest management systems for agricultural crops. The identified knowledge gaps are:

- basic biology of pest organisms;
- interactions between pests and hosts;

- interactions between pests and their bio logical environment;
- pest detection and monitoring capabilities;
- prediction capabilities;
- economic thresholds, particularly for multiple-pest complexes;
- impact of crop rotation, tillage, pesticide use, and other production practices on pest problems; and
- prevention or delay of pest resistance to control tactics, especially pesticides.

Not all of the above information is needed to initiate pest management; relatively simple systems can be put in practice with moderate levels of information. However, further advances will occur largely on the basis of new knowledge in these areas.

Lack of Manpower

All the regional study teams reported that there is not enough available scientific manpower to significantly increase the rate at which pest management is now being developed. Estimates of the number of additional scientific man-years required to fill the knowledge gaps in a reasonable length of time and to make significant gains in crop protection indicate that appreciable increases are needed for all the cropping regions considered.

Another manpower problem is the number of persons needed for integrated pest management (IPM) implementation to perform scouting, consulting, and other components of pest management on agricultural crops. The USDA/Science and Education Administration/Extension Service estimates there will be over 3,600 private farm advisors (consultants) and 63,000 seasonal scouts needed by 1986. The Extension Committee on Organization & Policy (ECOP) Pest Management Planning Committee estimated 5,000 advisors and up to 70,000 seasonal scouts. Recently the National Agricultural Chemicals 1PM Committee estimated a need for 7,600 to 10,600 supervisory personnel and 61,300 to 82,600 scouts to fully implement 1PM on cotton, corn, sorghum, soybean, alfalfa hay, peanut, rice, commercial vegetables, fruits and planted nuts, and tobacco. The three estimates are remarkably close. The assumption is made that most scouts and advisors or consultants will be in the private sector and supported by the primary beneficiaries, the producers.

The above estimates of personnel requirements may not be very accurate, but even if the demand should be only 50 percent of these, a sizable number of persons must be trained and paid. The added manpower will replace "insurance applied" pesticides and other tactics used to ensure that unacceptable crop losses will be avoided. In other words, manpower is to be substituted for unneeded pesticide use, tillage, etc., and to ensure maximum effectiveness of all tactics. The eventual level of substitution will depend on economics and the value to the producers of the crop protection service provided by the private sector.

The lack of manpower required for teaching and training personnel needed to develop and implement improved crop protection tactics and 1PM systems is also a problem and concern for those institutions responsible for such activities.

Lack of Alternatives to Chemical Pesticides

There are enough known and potential problems with the use of most pesticides to indicate that research efforts must be increased to develop alternative control tactics. The regional studies illustrate that there are many insect, disease, nematode, and weed problems for which there are no alternative control techniques to pesticides. Without the use of pesticides, diseases and insect pests of apple and potato, boll weevil on cotton, strawberry diseases, insects and weeds, all classes of pests on vegetables, and weeds in wheat, corn, and soybean would take intolerable tolls in production of these crops. The lack of alternatives is not only a concern but creates the potential for a major dislocation in food production should critical pesticides become unavailable for use. Potential alternatives, as indicated in earlier sections, may take years to develop.

MOST PROMISING APPROACHES

It is not practical to concentrate on any one control tactic to the exclusion of others. If crop losses in the United States and elsewhere are to be reduced, efforts must be made on all fronts. The availability of a suitable array of control tactics is essential for the future of crop protection and pest management programs.

The primary responsibility for developing, implementing, and maintaining these tactics lies in the public sector, in the private sector, or in both sectors. Those depending on public sector teaching, research, and extension efforts are host-plant resistance, cultural controls, biological controls, monitoring, modeling, and prediction technology. Industry often interacts to enhance these, especially in designing and producing equipment, Quarantine and eradication programs are almost entirely publicly supported.

The private sector has primarily developed and introduced traditional pesticides, while the public sector has greatly influenced and controlled the use and regulation of these materials. Application technology efforts have been supported by both.

The development and use of microbial pesticides, hormones, antihormones, pheromones, and allelopathic agents have resulted from the efforts of Federal, State, and industry scientists.

The need for an integrated approach to crop protection is becoming more and more evident as the problems of unilateral controls are being discovered. Therefore, a basic requirement for maintaining present levels of crop protection and reducing present losses is the availability of feasible pest management programs for all of our crops. These will require multidisciplinary efforts by scientists in the crop protection, crop production, economics, and related disciplines as well as the cooperation of private industry.

An essential component of any system to ensure reduced crop losses due to pests is an appropriate and adequate farmer advisory capability. This must involve the cooperative extension system, weather service, private consultants, scouts, and the pesticide industry.

And the final essential element to improve crop protection is a teaching capability adequate for the task. Appropriate instruction and information are needed for all persons including farmers, county agents, extension specialists, industry personnel, consultants, scouts, and crop protection researchers.

A study of the seven regional reports suggests that the development of pest-resistant cultivars offers significant promise of reducing losses on a long-term basis from diseases, nematodes, insects, and perhaps mites. The results obtained on several crops when realistic efforts have been made are impressive: examples from this assessment are found on cotton, wheat, corn, vegetables, and potato. Useful resistance has been bred into tobacco, rice, and many ornamental. Tolerance of attack by pest organisms can be useful in reducing losses. It has been demonstrated experimentally and in actual practical use that control tactics, such as pesticides and time of planting, are more effective on plants with even a modest degree of resistance than they are on susceptible plants grown under similar conditions.

The classical biological control approach on insects and mites, especially exotic species, is one that should be stressed to reduce losses by these arthropods. The augmentation of existing natural enemies is another underdeveloped area that offers much promise for reducing insect and mite losses. This can be accomplished by propagating and releasing parasites and predators, creating favorable environments, and using pesticides in a manner least harmful to beneficial organisms. Biological control is particularly adapted to those pest organisms that can be tolerated in low numbers on crops, Less success has been obtained against direct feeders such as the codling moth, cabbage worms, cabbage looper, and European corn borer. The ultimate role of biological control of plant pathogens and nematodes is unclear, but enough successes have been obtained to suggest that considerable effort should be made in this area.

By singling out host-plan resistance and biological control as those ta ctics offering the greatest potential in pest management strategies, we are not suggesting that other tactics are unimportant or do not warrant further research and development. Rather, we emphasize that their potential justifies a greater degree of effort than in the past and that excellent gains toward improved pest management are possible through increased efforts.