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XI

Progress, Problems, and Prospects for Integrated Pest Management

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The inequality of food demand and food supply has persisted in parts of the world since the dawn of man's history, but in modern times the populations of developed countries have felt secure in their escape from hunger. This situation changed in 1974 with some food commodities in short supply on a worldwide basis. A high world population growth rate (currently about 2%) and major regional crop failures because of adverse climate and damaging pest attacks (principally insects and diseases) has brought the world feed and food grain reserves to their lowest levels in two decades (Revelle, 1974). Although the actual magnitude of the world food problem is not known, famine is reported in many developing countries, and the death rate is actually rising in at least 12 and possibly 20 such nations in Africa and Southern Asia (NAS, 1975). This imbalance in the world food–people equation has focused unprecedented attention to increased agricultural production in both developed and developing nations. Regardless of whether we succeed or fail in reducing significantly human population growth, the immediate challenge of the United States and the World is to optimize agricultural and other renewable resource productivity per unit of land area, water, fertilizer, energy, and time (Wittwer, 1975). These efforts to increase productivity of the land in both developed and developing countries will accelerate the development and adoption of production practices that gen-

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erally intensify crop protection problems. The magnitude of agricultural crop losses to pests has not been measured adequately even in the most highly developed countries, but these losses are recognized as being substantial.

In spite of improvements in crop protection technology, there is evidence that the losses due to insect and disease pests have increased in the United States since the 1940s, both in gross amount and as a percentage of crop value (CEQ, 1972). It is thus assumed that improved crop protection has been offset by other changes in crop production technology that were prompted by increased production goals but which have enhanced vulnerability of the crop to pest damage through physical, biological, and genetic changes in the agroecosystem. Factors that have enhanced agroecosystem vulnerability to pests are: (1) greater reliance on "monocultures" of major agricultural crops; (2) greater use of fertilizers; (3) improved water management to increase crop yields; (4) multiple cropping; (5) strong selection pressures on yield in developing new varieties which has narrowed the genetic base of principal crops; (6) reduced tillage; (7) introduction of disease, insect, and weed pests into new areas; and (8) dependence on chemical pesticides and other single tactic approaches to crop protection.

The pre- and postharvest crop losses due to pest damage in the developing countries probably average 30% of potential production, but often are much higher on some crops in certain areas. As an illustration, data compiled by the Peruvian Ministry of Agriculture for 1970 (Apple and Smith, 1973) indicated that the loss in potential production due to all classes of pests was 38%, with the breakdown as follows: diseases—11%; insects—16%; nematodes—6%; and weeds—5%.

Achievement of higher levels of adoption for modern agricultural production practices in the developed nations and especially the introduction and adoption of "green revolution" technology in the developing nations will bring increasing pressure on crop protection programs. There is already evidence that the transition of "traditional agriculture" to modern methods in the developing nations is accompanied by an intensification of pest problems (Apple, 1972; Smith, 1972). Since modern agricultural practices require higher capital investments and since the world food balance is critical, the fluctuation in output that may be caused by massive pest attacks cannot be tolerated. Consequently, more comprehensive, effective, and efficient systems of crop protection must be developed and implemented on a worldwide basis.

It is from this milieu of increased cognizance of world food problems, of increasing losses in potential food production due to pests, of enhanced knowledge concerning the ecology and biology of individual pests, and of the inadequacies and hazards of present approaches to and delivery systems for crop protection that the motivations for new crop protection tactics and strategies have emerged. A small but scientifically strong international group of scientists have for several years provided philosophical and programming leadership for these new tactics and strategies under the rubric of integrated pest management (IPM). They have at times been accused of "bandwagon" tactics and of applying new jargon to long-established practices, but they have demonstrated that the application of ecological principles to crop protection in the form of IPM is sound strategy. As a result, IPM is now finding a place in agricultural production systems throughout the world.

Huffaker and Croft (1975) have described a series of phases in the evolution of an IPM program. These phases reflect the fact that IPM programs generally have a simple beginning. The first approach is an approximation of an ideal system that is subjected to field testing. The difficulties encountered identify problems that must be researched, and in that way IPM systems can be developed step by step. A brief description of the phases of Huffaker and Croft will be useful in subsequent discussions of specific programs or activities.

1. *Single-tactic phase*. Emphasis is generally placed on control of a single pest utilizing a single tactic. This phase does not represent IPM, but the limitations in this approach may lead to its development.

2. *Multiple-tactics phase*. This phase embraces a variety of tactics—cultural, mechanical, physical, chemical, biological, host resistance, regulatory, etc.—in manipulating pest populations. Many IPM systems have not gone beyond this phase.

3. *Biological monitoring phase*. This phase introduces monitoring of pest, natural enemy, and host plant (phenology) populations as the basis for timing the application of various control tactics. This procedure was initiated with the early cotton scouting of 50 years ago but has become greatly elaborated and sophisticated in recent years, as exemplified by the extension pilot pest management projects discussed in this chapter.

4. *Modeling phase*. This involves the conceptualization of the processes involved in pest management systems through mental, pictorial, flowchart, and mathematical models. The earliest integrated control programs depended solely on mental models, but as the volume and complexity of data increased, more sophisticated modeling techniques became necessary.

5. *Management or optimization phase*. This process involves the construction of a functional IPM system utilizing compatible subsystems in optimizing the integration of this IPM system with the overall crop production system. In the past this has been done intuitively, but now mathematical IPM models utilizing techniques for economic analysis and optimization can be utilized.

6. *Systems implementation phase*. This is the ultimate phase through which optimal systems are unified for delivery to and utilization by the grower. According to Huffaker and Croft, this ultimate phase of IPM system development has not been achieved.

Implementation Status of Integrated Pest Management in the United States

Other chapters in this volume refer to various IPM research and extension projects in the United States and elsewhere. We will make brief reference to some of the significant IPM activities in the United States other than those treated in other chapters and comment on the impact on crop protection programs.

A Multi-Institutional IPM Research Project Entitled "The Principles, Strategies, and Tactics of Pest Population Regulation and Control in Major Crop Ecosystems" *

This is one of the most ambitious cooperative research projects ever undertaken in the history of United States agriculture. It involves 18 state universities, the Agricultural Research Service and the Forest Service of the USDA, and industry. The project, popularly known as the "Huffaker Project," is coordinated through the University of California with Dr. C. B. Huffaker as Project Director and Dr. R. F. Smith as Associate Project Director. It was funded at $1.9 million for the first year (1971–72) through the National Science Foundation (NSF), the Environmental Protection Agency (EPA), and the USDA. It has been funded in subsequent years by NSF and EPA at approximately $1.6 million annually. These grant funds, however, represent only a portion of the total cost of this project since each participating institution is providing substantial support from other funding sources. The project will continue in its present form through February, 1977. Although commonly referenced as an "integrated pest management" project, it focuses principally on insect pests of six major crop or forest ecosystems in the United States, i.e., cotton, citrus, alfalfa, pome and stone fruits, soybeans, and pine (bark beetle). Mathematical modeling and systems analysis have received major attention under the project and have provided the research planning matrix through which critical ecosystem relationships and interactions are discovered, data voids identified, and research priorities established.

A review of project results after nearly four years of activity reveals significant accomplishments. The project has demonstrated that major research projects comprising multidisciplinary teams can be implemented and carried out successfully on an interinstitutional and interagency basis. Acceptance and en-

* This information has been obtained from the "Project Reports"; Smith *et al.*, 1974; Smith and Huffaker, 1973; and through the personal involvement of the authors.

thusiastic pursuit by participating scientists attest to its validity. Replication of this research format in other projects, both state and federal, further attests to the distinction gained by this project through its research output. Significant progress has been made in applying advanced technology and systems science to the development of descriptive and predictive models as the basis for deploying pest control tactics, including a more rational use of pesticides. Management systems developed for the major insect pests under study show great promise in pilot IPM extension programs now underway in several states, and some of them have demonstrated a substantial reduction of pesticide usage as compared to presently used traditional systems. This has been accomplished by selecting management tactics from a variety of ecologically compatible and potentially effective alternatives that include: (1) the establishment of an economic need as the basis for remedial action; (2) plant breeding to develop crop varieties resistant to insects and certain plant pathogens; (3) use of parasites, predators, and pathogens (conventional biological control); (4) more selective use of conventional insecticides and fungicides to achieve compatibility with modified programs for insect IPM; (5) new types of cultural controls; (6) use of behavior-modifying chemicals (pheromones) both to monitor and reduce pest populations; and (7) improvements in techniques for measuring population dynamics as the basis for predictive modeling and IPM decision-making.

Although not structured primarily as a graduate education activity, this project has provided 40–50 graduate student assistantships. These students have contributed greatly to the research objectives of the project, but of even greater importance they have been exposed to modern crop protection technology and to the philosophy of an ecological approach to the management of pest populations. This experience has molded their professional attitudes and philosophies, and they undoubtedly are destined to have a major impact on the crop protection sciences in the future.

Since the research base for IPM, especially the modeling component, is necessarily long-term, the principal benefits from modeling and systems analysis are probably yet to come.

Pilot Pest Management Research Program of the Agricultural Research Service (ARS)–USDA

This program was funded during 1971–72 by the USDA for development of new tactics of pest suppression and detection through large-scale trials. It was implemented largely as a series of "in-house" projects within ARS, but some of the activity involved research through cooperative agreements with state agricultural experiment stations. In 1974, 25 projects were in process, and the program was funded at $1.6 million annually. This activity has provided a number of important accomplishments as illustrated by the following (Klassan, 1975): (1) advanced the use of gypsy moth (*Porthetria dispar*) pheromone for detection and population suppression, (2) improved the technology for combating the boll weevil (*Anthonomus grandis*) of cotton through ecological studies, and (3) demonstrated that a plant growth regulator is effective in reducing overwintering of the pink bollworm (*Pectinophora gossypiella*) on cotton. These and numerous other pest management tactics have emerged from this pilot research program. Further, these research efforts helped demonstrate, within federal agencies and state institutions, the validity of the IPM approach to crop protection.

Pilot Pest Management Implementation Projects (Extension)

An important incentive for the development and implementation of IPM programs in the United States was the initiation in 1971 of the pilot pest management implementation projects by two federal agencies, the Animal Plant Health and Inspection Service and the Federal Extension Service, and the agricultural extension services of the land-grant universities. All of these project activities were carried out cooperatively with the states and were funded jointly by federal grants, state funds, and participating farmers. These pilot projects initially involved only insect pests, but some of them have evolved to include all classes of pests consistent with the broadened IPM concept. During 1974, there were 39 pilot pest management projects in 29 states concerned with the following crops and pests (Good, 1975): insects of cotton—14; insects and weeds affecting corn—6; insects and weeds affecting grain sorghum—4; insects, diseases, and weeds affecting peanuts—2; insects and diseases of fruit—6; insects of vegetables and potatoes—4; insects of alfalfa—2; and insects, diseases, weeds, and suckers of tobacco—1.

The pilot projects have introduced large numbers of research and extension crop protection specialists to IPM principles and have stimulated a broad base of interest in and support for IPM programs. As initiated and in their current status of implementation, the above projects represent a wide range of sophistication and application of IPM principles, which is a reflection of the complexity of the pest systems involved and the status of the research data base applicable to their control. Considerable research has been conducted in the past on each of the target pests of the pilot projects, but this has been largely disciplinary research without effective agroecosystem integration. This has left data voids that have in some instances deterred the effectiveness of the pilot projects.

Most of the pilot projects have been limited to one or two classes of pests;

in fact, all of them have involved one or more insect pests but few were directed at all classes of pests. We recognize that implementation of a full-scale IPM program might best be phased over time with initial attention to one or two economically important pests of a single class (e.g., insects) and then evolving to include other classes (e.g., weeds and pathogens). This has been the history of several of the pilot projects. But many of these projects are still too restricted in scope and lack the interdisciplinary collaboration and integration required to achieve the optimal condition. Some of them have not evolved beyond the "single-tactic phase" of Huffaker and Croft (1975).

Good (1975) summarized the experiences of the 39 pilot pest management projects as follows: (1) growers are now recognizing the advantages of IPM; (2) most growers will apply pesticides on an as-needed and timely basis when properly advised; (3) practices that have indirect or delayed effects and which represent additional production costs, such as diapause control or crop destruction, are not generally adopted on a free-choice basis but require regulatory authority; (4) growers have become more aware of the economics of crop protection practices and of the need to utilize economic guidelines in making IPM decisions; (5) progressive growers are willing to pay for improved IPM advisory services by participating in grower cooperatives or by contracting a private IPM consultant; and (6) in order to be both practical and economical, an IPM program should include all the important crops in a given area that have common pests and should include all the important pest classes—weeds, insects, diseases, and nematodes.

IPM Programs Through the State Agricultural Experiment Stations

A principal source of research results that are critical to the development of IPM programs has been the state agricultural experiment stations, a system established through the Hatch Act of 1887 and partially funded by federal grants appropriated under authority of that act. Historically, much of the crop protection research has been disciplinary-oriented, but without this knowledge base on individual pests, the development of IPM programs would not be an option. The multidisciplinary, ecosystem approach ascribed to IPM does not obviate a thorough knowledge of the biological and physical parameters of the agroecosystem, quite the contrary. The availability of information derived through disciplinary research now makes possible the construction of IPM programs, and the continuation of that research will be essential to the maintenance and further development of IPM.

Programs at several of the state agricultural experiment stations have evolved to include both disciplinary and multidisciplinary research on crop protection problems. As an example, the majority of the "principle investigator" scientists contributing to the Huffaker Project are faculty at land-grant institutions, and major costs of the Huffaker Project are provided through the state agricultural experiment stations.

IPM research has also been stimulated through the state agricultural experiment stations by designated federal grants administered through the Cooperative State Research Service of the USDA. The extension pilot IPM projects in the various states have also created an awareness of the need for integrative IPM research to fill the backstopping role required in the respective states.

IPM research in state agricultural experiment stations has now evolved to the point that several research projects have been developed and funded with existing resources. There are also several "regional" research projects within the experiment station system, wherein two or more states have combined their resources to research a common problem. In response to motivation from crop protection scientists in the land-grant institutions and from grower groups, IPM research has become "institutionalized" in the agricultural experiment station system and undoubtedly will persist and flourish as a recognized research problem area.

Pest Management Curricula in the Land-Grant Universities

The IPM philosophy has had major impact on instructional programs in crop protection at the land-grant universities in the United States. At least 22 of these institutions now have undergraduate curricula either in plant protection or pest management, 3 have M.S. programs, and several others have undergraduate and graduate (both M.S. and Ph.D.) programs under consideration.* The land-grant institutions anticipated a demand for persons broadly educated and trained in the ecological approach to crop protection and are responding with the creation of new educational programs.

Many of the undergraduate academic programs in plant protection or pest management were initiated cooperatively by combinations of departments representing plant pathology, entomology, and weed science. The first multidisciplinary plant protection curriculum was initiated at North Carolina State University in 1959 and included pathogens, insects, and weeds. Most of the curricula established before 1972 were entitled "plant protection" and none were entitled "pest management," and most of them comprised existing rather than new courses reflecting the integrated approach to crop protection. Sub-

* Results from a survey conducted by the senior author in October, 1974.

sequent to the 1972 RICOP * sponsored workshop on "Systems of Pest Management and Plant Protection" (Browning, 1972), many new undergraduate programs were established. Some of these were entitled "pest management" and some of the earlier established curricula were retitled to reflect pest management. The RICOP workshop also stimulated broader disciplinary integration in pest management curricula and contributed to the development of team-taught interdisciplinary courses at several institutions.

The pest management and/or plant protection undergraduate curricula in most of the offering institutions have not attracted large numbers of students. This probably reflects inadequate employment opportunities in broad pest management programs and the potential employment hazard, from the view of the student, of receiving generalist *versus* specialist training and thus not meeting the employment criteria for more specialized positions. However, as action pest management programs are expanded and further developed, the demand for supportive field and laboratory technicians should increase to the advantage of the B.S. graduates in pest management. There are now a number of indications that these employment opportunities are materializing.

Land-grant institutions have been cautious in developing doctoral level programs in pest management. The feasibility has been discussed extensively but without consensus conclusion. There is a growing number of private pest management consultants, and some of them (Cox, 1971) are strong advocates of the need for broad doctoral degree training in pest management (perhaps a professional rather than a Ph.D. degree). But others feel that the traditional Ph.D. programs in the crop protection disciplines offer sufficient flexibility to accommodate a good educational base in pest management. As pest management action programs evolve and as the role of the private sector in the pest management delivery systems become more clearly defined, there will undoubtedly be increased opportunities for doctoral level pest management specialists; however, we believe that the traditional Ph.D. degree programs of the land-grant universities in crop protection disciplines will require considerable modification to provide the training experience appropriate to this need.

Implementation Status of Integrated Pest Management Programs Outside the United States

IPM activities are not unique to the United States. Operational programs have been developed in several of the agriculturally advanced countries and in some of the developing countries. We shall make no effort to present a compre-

* RICOP is the Resident Instruction Committee on Policy of the Division of Agriculture, National Association of State Universities and Land-Grant Colleges.

hensive inventory of such programs but refer to some of the more significant international programs.

Programs of the International Organization for Biological Control in Western Europe

For about 15 years, the West Palaearctic Regional Section of the International Organization for Biological Control (IOBC) has been taking the leadership in Western Europe in the development of IPM (Braber, 1974 and 1975). Following the early successes obtained in apple orchards, pest situations in other crops have been studied for the possibility of applying IPM techniques.

The first big step forward in apple orchards was the establishment of economic thresholds of the major pests through close international collaboration within the framework of IOBC. Based on these, programs were set up where control measures were taken only after assessment of the pest population. These supervised control programs allowed a reduction of 50% of the quantity of pesticides normally used while the quantity and quality of the crop was maintained. Later, selective methods for control of specific pests were introduced.

The IOBC Working Group in IPM distinguished three phases of development. The first research phase involved only research workers and consisted of an analysis of the pest situation and research on the possibilities of applying different control techniques and the construction of an IPM model. The second development phase involved testing of the model under field conditions to determine limitation and economic feasibility. During this phase, establishment of collaboration between research and extension service workers was essential. The third or application phase involved providing direct assistance to farmers. The main responsibility during the application phase must be taken over by an extension service agency, although a permanent dialogue between research workers and extension technicians will be needed. In addition to apple orchards, the application phase has been reached in the IOBC program with peaches, citrus, cereal, sugar beets, and glasshouse crops. Surely, the IPM approach of IOBC has had and continues to have a very significant impact on evolution of crop protection in Europe.

Programs of the Food and Agriculture Organization (FAO) of the United Nations

FAO initiated IPM * activities in 1963 in response to the growing concern about the undesirable side-effects of large-scale organic pesticide usage and the

* FAO used "integrated pest control" terminology to reference IPM-type activities. For purposes of this discussion, IPM and integrated pest control will be considered synonymous.

failure of this approach to provide economic pest control. An early significant activity was the organization of a symposium in October, 1965 (FAO, 1966) that stressed the urgency of promoting and developing IPM and which recommended the creation of a body of experts in this field. The Panel of Experts on Integrated Pest Control was established by the Director-General of FAO in 1966. The purposes of the FAO Panel are to advise the Director-General on matters pertaining to IPM policy and programs within FAO; to maintain purview of the evolution of IPM (principles, procedures, and techniques); to promote joint IPM research on major pests of international importance; and to collate, interpret, and disseminate information on IPM research and development. The Panel comprises a membership of 38 scientists appointed in their personal capacities for four-year terms. During the course of the six Panel sessions that have been held to date, IPM has been defined and general procedures for establishment have been suggested, the status of IPM research and implementation throughout the world has been reviewed, and recommendations for various actions have been made to FAO and its member governments.

FAO has developed and implemented 13 field projects on high-priority IPM problem situations in developing countries with the financial assistance of the United Nations Development Program (UNDP) and other organizations. The first of these projects was implemented in 1964. More than 80 international crop protection specialists have been involved in these projects.

At its Fourth Session (December, 1972), the Panel of Experts on Integrated Pest Control proposed a global project on integrated pest control as a followup to Recommendation No. 21 of the 1972 United Nations Conference on the Human Environment in Stockholm (FAO, 1973). A proposal for the establishment of a global project was submitted by FAO to the United Nations Environment Program (UNEP) in 1973. UNEP endorsed the concept and agreed to support preliminary activities. The Panel subsequently developed the framework for a "Cooperative Global Program for the Development and Application of Integrated Pest Control in Agriculture" at an *ad hoc* Session in October, 1974 (FAO, 1975). The Global Program "will aim at promoting the development and application of safer, more effective, and more permanent plant protection procedures and techniques, through the combined use of all compatible methods . . . and will contribute to the development of sufficient expertise in the application of the integrated pest control concept, so that developing countries will be able to develop and carry out integrated control programs for pests of major economic importance. Long-standing support by FAO for such programs will be expanded by direct assistance to national research and advisory bodies and, in particular, by continuing to help coordinate regional programs." The following criteria were developed for identifying priority crops under the Global Program (FAO, 1975): (1) vital national and regional importance to the economy and well-being of human populations, (2) seriousness of crop losses caused by pests and diseases, (3) environmental problems and impairment of pest control created by undue reliance on pesticides, (4) impending problems from rapidly accelerating pesticide usage in response to urgent needs to increase food production, and (5) realized or potential success in integrated control practices. In applying these criteria, the Panel gave highest priority to cotton, rice, and maize/sorghum. Other crops (cole, potatoes, grain legumes, cassava, sugar cane, and coconut palms) were also selected for inclusion in the program at a later stage. The Coordinator for the Global Program has been employed by FAO, and implementation funds are now being sought.

The extensive nature and visibility of the complex of FAO-sponsored programs in IPM and related activities have given great impetus to the concept on an international basis.

The Pest Management and Related Environmental Protection Project—University of California

This is a contract project (briefed as the UC/AID Project) funded by the United States Agency for International Development (USAID) through the University of California at Berkeley with Dr. Ray F. Smith as Project Director. It was initiated in 1971. Other U.S. institutions or agencies participating in the Project through consultants and subcontracts have been Cornell University, University of Miami School of Medicine, University of Florida, North Carolina State University, and the U.S. Department of Agriculture.

The principal Project goals are to provide developing countries with assistance in devising and implementing ecologically sound and economically valid IPM systems for the economic control of agricultural pests (insects, pathogens, and weeds) so that their long-term agricultural productivity goals can be achieved. These goals are to be attained by developing their in-country scientific and institutional capacity to handle diverse pest problems in the following manner: (1) through training and retraining of crop protection personnel from participating countries; (2) establishment of technical assistance and extension projects aimed at specific crop protection problems; and (3) assisting local personnel and their institutions in establishing or improving research, training, and extension programs in crop protection. The Project is complementary to the commodity improvement projects funded by USAID, the international agricultural research network funded through the Consultative Group, and food crop improvement projects financed by other donors for purposes of increasing the food supply in the developing nations. (The latter objective cannot be realized until the major pests of important food crops are identified, studied, and brought under management control.)

The UC/AID Project activities have included the following: (1) provided advisory services to assist AID/Washington in developing improved pesticide as a system to reduce substantially the use of pesticides in agriculture, undoubtedly the chemical industry would seek to deter the wide-scale implementation of IPM. But we counter this assumption, firstly, with the firm assertion that IPM is not antipesticidal in mission. It may result in reduced pesticide usage, but only if these materials are now being used in excess or as substitutes for other more effective and economical methods. Secondly, if IPM does hold potential for improved pesticide usage, all segments of the agricultural enterprise and the consumer will benefit in the long run.

The misconception of IPM as a panacea applicable to all pest problems also stirs conflict. IPM is not a panacea; further, it is not a fixed, patterned approach but a concept sensitive to the needs of the problem situation. There are probably only a few crop ecosystems and pest complexes that can justify or would require application of the total spectrum of pest management strategies and tactics. The management strategy must be developed for each pest complex within each crop ecosystem, and that strategy may be conditioned year to year by prices of commodities and purchased inputs, legislation, social issues, and other factors. Many crop production enterprises cannot justify the resource cost requisite to a sophisticated IPM system. But regardless of crop enterprise scale or nature of the pest problem, the ecological principles implicit in IPM can be applied to the limits of economic justification.

The mislabeling of some traditional crop protection projects as IPM has done much harm to the image and has diluted the performance record of valid IPM projects in the eyes of some decision-making persons in the United States. Some of the funds appropriated for action IPM programs through the extension services have been used to support project activities that could hardly qualify as IPM. Unfortunately, comparable and parallel funding was not allocated to the counterpart agricultural experiment stations in the "pilot project" states; consequently, the research backstopping component was often deficient. In many situations, these extension projects did not evolve to higher levels of IPM achievement because the critical companion research was not funded. These facts have given the critics of IPM a substantive basis to oppose continuation of federal appropriations for support of both extension and research IPM projects.

Application of the IPM concept is often based on an estimated population density and on the probability of resultant economic damage. Since these probabilities are based not only on the pest population density but also on other biological and physical factors of the agroecosystem, the accuracy of the projected loss will not be 100% correct. Although many benefits will accrue to farmers and society at large from the application of IPM, individual farmers could incur economic loss resulting from an erroneous pest population or loss estimate. In order to relieve the individual farmer of this loss hazard, some type of "crop protection insurance" must be available to protect against economic loss. This is a dimension of IPM that has not been provided by insurance underwriters except in a few areas. Such protection must be available at a cost, when added to that of the IPM program, that is competitive with the conventional chemical control approach. Lack of such insurance could deter the adoption of IPM by many farmers who are not willing to hazard the risk of action decisions based upon probabilities.

We have pointed out these several factors above that have deterred the implementation of IPM research and extension programs in the United States. We are convinced, however, that the most important of these deterrents are political and parochial factors rather than faults of the IPM concept. We are encouraged by the implementation record for IPM to date and predict that it will become increasingly important as an agroecosystem management strategy.

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