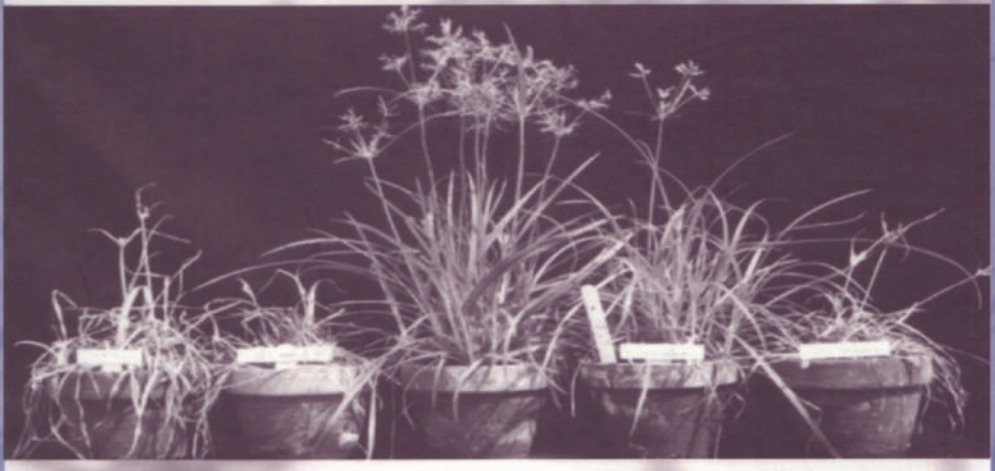
PESTICIDES IN AGRICULTURE AND THE ENVIRONMENT



EDITED BY WILLIS B. WHEELER

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Preface

This volume is designed to fill the niche established in the early 1970s by *Pesticides in the Environment*, edited by Robert White-Stephens, at the time a member of the Rutgers University faculty. The three-volume work represented a state-of-the-art description of the field of pesticides in a different time and different place.

The arena of pest management has changed dramatically in the past 30-plus years. *Pesticides in Agriculture and the Environment* is designed to summarize the state of the various aspects of pest management, some of which did not exist a generation ago and all of which have changed dramatically. It does not focus on the chemistry of the various pest management tactics as did White-Stephens's book. The present volume describes the current status of pesticide issues and those related to the broader topic of pest management. It discusses integrated pest management (IPM) and how it came to be, the current state of risk assessment, biological control techniques, the economics of pest management and pest management legislation, and the current state of analytical methods used by international regulators and offers a state-of-the-art description of the science of environmental fate. It also presents specific issues for pest management on "minor crops," the current approach and issues related to chemical application

technology, the important issues of resistance of pests to pesticides and management of that resistance, and, finally, a look to the future for both pest management chemistry and the state of the pest management industry. The authors of these chapters represent the best expertise in the field.

The enactment of the Food Quality Protection Act (FQPA) of 1996 has had a major impact on contemporary pest management regulation. Its far-reaching consequences are discussed in essentially every chapter. Owing to its importance, I summarize a number of its provisions in the following paragraphs.

The FQPA of 1996 amended the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug, and Cosmetic Act (FFDCA). These amendments fundamentally changed the way the U.S. Environmental Protection Agency (USEPA) regulates pesticides. The requirements include a new safety standard—reasonable certainty of no harm—that must be applied to all pesticides used on foods. The FQPA was designed to resolve the Delaney Paradox, protect children from pesticides, and address endocrine disruption. To accomplish these goals, the law provides that:

- The USEPA is to reregister pesticides every 15 years using the best available data.
- There is a specific definition of minor (use) crops: The definition includes crops grown on fewer than 300,000 acres *or* a minor use may be defined on an economic basis if the pesticide use on a crop is very limited. It may also be defined as minor if the pesticide use is the only alternative, or if it is safer than other alternatives, or if it is needed for IPM and resistance management. The FQPA also provided incentives to develop and maintain minor uses, and to implement a faster approval of reduced-risk pesticides and those used on minor crops.
- The zero-tolerance standard for certain pesticides in processed foods be eliminated (the old Delaney Clause) and that we establish new standards for setting tolerances in both fresh and processed foods.
- Tolerances (maximum residue value) must be safe, i.e., "provide a reasonable certainty that no harm will result from aggregate exposure." All tolerances must be reviewed by 2006, and the most toxic materials must be reviewed first.
- Risks from pesticides must be based on exposures to all chemicals that have a common mode of toxicity. In the past, exposure was based on pesticides in food only. Now all exposures must be considered: dietary, water, and household.
- Safety factors formerly included intra- and interspecies variation (ranging from 100- to 1000-fold); now safety factors must also include factors for infants and children. Thus additional safety factors can give a

1000–10,000-fold safety factor. To implement evaluation of the safety factor for infants and children, the USEPA has looked at the foods that make up large percentages of the diets of infants and children, including apples, peaches, soybeans, pears, and carrots.

- Endocrine disruptors are compounds that mimic or block the effects of hormones, such as estrogen, or act on the endocrine system and may cause developmental or reproductive problems. These must be considered when registering a pesticide.

Pesticides in Agriculture and the Environment discusses issues that are essential components of the contemporary pest management arena. The chapter topics include:

Chapter 1: A description of the major policy considerations that have shaped federal IPM programs over the past three decades.

Chapter 2: A description of the approaches to nonchemical pest management; discussions of definitions of biological control, benefits and limitations, and its ecological basis.

Chapter 3: An in-depth discussion of major pesticide use trends in the United States; the effects of such factors as pesticide productivity, farm programs, and pesticide regulations on use; and changing law and policy.

Chapter 4: An introduction to pesticide safety and the framework of health risk assessment, specifically pesticide risk assessment and ecological risk assessment.

Chapter 5: A description of the processes of transport and fate of pesticides in the environment. It examines dissipation, leaching, and degradation and models for predicting these processes.

Chapter 6: A discussion of the analytical process as it is practiced in the regulatory arena, including approaches to monitoring the food supply in many countries around the world.

Chapter 7: The issues of pest management related specifically to low-acreage, high-value crops. There are economic and other issues for pesticide manufacturers and producers of minor crops.

Chapter 8: A discussion of the importance of pesticide resistance for pest management in agriculture and human health protection and description of a publicly available resistance database.

Chapter 9: A review of efforts to increase pesticide applicator safety and to improve the efficacy and effectiveness of the application techniques.

Chapter 10: An analysis of the current state of the crop protection industry and a projection of the future. The discussion includes company mergers and acquisitions, generic pesticide producers, seed companies, new

chemistries of pesticides, plant biotechnology, and major trends in the industry.

It is my hope that readers will find this book an informative reference on pest management in the modern world.

Willis B. Wheeler

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Three Decades of Federal Integrated Pest Management Policy

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1 INTRODUCTION

The scientific and technical development of integrated pest management* (IPM) methods during the twentieth century were covered by several publications of the 1990s [1–4], but the policy aspects of IPM have received less attention. This is unfortunate, because policy and politics have been as much a part of the history of IPM in the United States as the science. This chapter provides a summary of the major policy considerations that shaped federal IPM programs over the last three decades of the century.

A great deal of discussion preceded the first major allocation of federal funds for IPM programs in 1972. A review of policy documents from this period provides a fascinating look at a national debate regarding the hazards of pesticide use. Then, as today, policy makers and technical experts struggled over the trade-offs between agricultural productivity and environmental impacts. Perhaps Dr. Gordon Guyer, a professor of entomology at Michigan State University, best

* The terminology has evolved over time, but the basic concepts have remained fairly constant. For consistency, this chapter uses the term "IPM" in most cases.

summed up the dilemma during his testimony before Congress in 1971: "Whereas chemicals have allowed for the greatest agricultural production in history and made major contributions to world health programs, they have also contaminated the environment" [5]. Policy discussions during the early 1970s conveyed a sense of urgency in dealing with serious environmental impacts of the use of pesticides but never lost sight of the importance of maintaining agricultural productivity and profitability.

In recent years, the sense of purpose that underlays the policy discussions of the early 1970s appears to have been replaced by debates on whether IPM programs have been true to concept or to the goals established in the early 1970s [1–3,5–7]. This chapter traces the evolution of federal IPM policy over the past three decades in an attempt to understand the goals established for federal IPM programs. Considerable attention is given to the early 1970s, when policy objectives for federal IPM efforts were first articulated. Perhaps by better understanding the evolution of federal IPM policy we will be better prepared to guide IPM programs in the decades to come.

2 A CALL TO ACTION

The late 1960s and early 1970s were pivotal in the evolution of the policies that still serve as the basis for federal IPM programs. There were several reasons for the attention given to pest management issues at this time. Public concerns about the environmental effects of pesticides were at a high level, heightened by the publication of *Silent Spring* [8] in 1962 and other emerging evidence concerning the environmental impacts of highly persistent chlorinated hydrocarbons such as DDT, Dieldrin, Aldrin, and Mirex. President Nixon reflected public concerns about pesticides in his Environmental Message of 1971 [9]:

> Pesticides have provided important benefits by protecting man from disease and increasing his ability to produce food and fiber. However, the use and misuse of pesticides has become one of the major concerns of all who are interested in a better environment. The decline in numbers of several of our bird species is a signal of the potential hazards of pesticides to the environment. We are continuing a major research effort to develop nonchemical methods of pest control, but we must continue to rely on pesticides for the foreseeable future. The challenge is to institute the necessary mechanisms to prevent pesticides from harming human health and the environment.

Concerns about pesticides were at least as strong on America's farms and ranches as they were in other communities. After all, the environmental damage and health effects attributed to pesticides were more likely to affect those who worked and lived on farms than the rest of the population. But of even greater

importance to this discussion, in the early 1970s agricultural producers were struggling with the loss or increased cost of their "old standby" pesticides as a result of pest resistance and greater scrutiny of their persistence, biomagnification, and toxicity to nontarget organisms [10].

In the late 1960s, concerns about pesticides took center stage in the federal policy arena. The federal government's first step in addressing the pesticide problem came in the form of the National Environmental Policy Act (NEPA) of 1969. NEPA established [11]

> a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources to the Nation; and to establish a Council on Environmental Quality.

Congress established the Council on Environmental Quality (CEQ) to promote "the advancement of scientific knowledge of the effects of actions and technology on the environment and [to encourage] the development of the means to prevent or reduce adverse effects that endanger the health and well-being of man."

The establishment of the CEQ proved to be a key event in the development of federal IPM policy. Soon after its formation, CEQ used the legal authority and rationale provided by NEPA to recommend that the federal government support the development and promotion of IPM programs. These recommendations were backed by a variety of governmental agencies, university researchers, industry representatives, and public interest groups who called for a concerted effort to develop and implement IPM methods nationwide. The basis for the CEQ's recommendation was solid: Published research results provided strong evidence that IPM methods worked. Scientists and research administrators had been advocating for federal funding to develop interdisciplinary systems approaches to pest management for several years, and a group of scientists from 18 universities had developed a proposal for a large interdisciplinary project; this project, later known as the Huffaker Project, proved to be a major stimulus for the development of federal IPM policy.

The case for increased federal support for IPM was further strengthened by the results from IPM "pilot" projects designed to refine, test, and evaluate available technology on crops where "intensive chemical pest control is presently practiced" [12]. The objective of the pilot projects was to "limit the use of pesticides to situations in which they are needed to prevent economic damage to a crop. This will not only result in savings in cost of production, but will also reduce the overall amount of pesticide being added to the environment" [12].

The development of federal IPM policy took a major step forward on September 20, 1971, when a subcommittee of the U.S. Senate's Committee on Agri-

culture and Forestry began a two-day hearing on Senate Bill 1794, "A bill to authorize pilot field-research programs for the control of agricultural and forest pests by integrated biological-cultural methods" [5]. The legislation proposed to direct the Secretary of Agriculture to conduct pilot field-research programs to (1) develop and test biological-cultural methods for the control of agricultural and forest pests, (2) determine the economic and environmental consequences of implementing multidisciplinary and integrated biological-cultural methods, and (3) develop methods for collecting and interpreting data obtained from the pilot research programs. The legislation also proposed to authorize the Secretary of Agriculture to reimburse farmers and ranchers for any losses resulting from their participation in the pilot research program. The bill authorized the appropriation of $2 million per year for up to five years to the U.S. Department of Agriculture (USDA) for this effort, plus $2 million per year for up to five years to the National Science Foundation (NSF) to expand its fundamental research on integrated biological-cultural principles and techniques to control agricultural and forest pests.

The Congressional hearings on Senate Bill 1794, which were titled "Pest Control Research," were a crucial step in the development of federal IPM policy. A total of 35 witnesses—senators, government officials, farmer representatives, environmentalists, and university researchers—provided 174 pages of testimony during the hearings. Together, the witnesses represented one of the most experienced and knowledgeable panels ever assembled to discuss what was then referred to as "integrated control" (the term "integrated pest management" would become the predominant term after President Nixon used it in his 1972 Environmental Message) [3]. The hearings were introduced by the author of Senate Bill 1794, Senator Gaylord Nelson of Wisconsin, who remarked that the bill had strong bipartisan support from its 24 cosponsors. Senator Nelson said the bill would provide for the establishment of demonstration projects and expanded basic research in the principles of integrated pest control. He remarked that leaders in agriculture and the environmental movement were in agreement on the need to provide "food and fiber for a growing society without depending on broad-spectrum, persistent chemicals to control insect pests" and further stated that "with the single strategy of chemical pest control we have not only saturated the environment with deadly poisons that endanger a wide spectrum of living organisms, including man himself, but we have begun to seriously disrupt the economic stability of the farming community." Nelson then articulated the goal of the proposed effort:

> There is a compelling and urgent need to reconsider our approach to pest control by recognizing a very basic ecological principle. That is, each integral part of the natural system survives in balance with—not at the expense of—the other parts. I believe that integrated control offers

> the alternative that recognizes this principle. Integrated control offers the use of the best-suited combination of alternate pest control methods to suppress pest insects in a given crop situation below the economically disruptive threshold. We are not talking about a unilateral, one-method approach that we have become accustomed to in the application of broad-spectrum chemicals. And we aren't ruling out the use of chemicals in an integrated control program, because some situations may call for selective chemical applications during a particular phase of the overall program. But the use of chemicals—particularly broad-spectrum chemicals—necessarily is very limited in integrated pest control so as not to interfere with other aspects of the program, most notably the use of beneficial insects.

Neslon concluded his statement by saying,

> The idea of a pilot program has been under discussion for several years and it has not happened. I think the real import and the real importance of this matter is that it directs the establishment of a pilot project which would involve various crops in the South, Southwest, Midwest, East, and Far West, so that we can have a genuine, scientific demonstration program to discover what successes we can have and to educate farmers and the country on the effectiveness of a rational use of a scientific integrated program.

The hearings on pest control research represent a guidebook on integrated control that remains relevant to this day and should be considered required reading for anyone involved in pest management policy, research, or implementation. In spite of the large number of witnesses and diversity of organizations represented, all were in agreement on two points: (1) The problems associated with the use of broad-spectrum pesticides had to be addressed, and (2) the programs authorized by S 1794 were greatly needed, but needed to be authorized at a higher level of funding than was provided in the bill. Selected statements* made by several witnesses are provided below to illustrate the thoughts and concerns that helped shape federal IPM policy at this early stage in its development.

2.1 Selected Statements Made by Senators

Senator John Tunney of California, one of the sponsors of S 1794, stated

> Pesticides are most valuable tools when used properly and in the context of the entire ecological system of an environment, but they are not ulti-

* Quotes are true to the published transcript. However, in some cases sentences from separate portions of the testimony are merged together to enhance readability.

> mate solutions to pest control. Their widespread use has brought a number of pressing problems, including pollution caused by toxic chemical residues and the development of insect resistance to such chemicals. We must develop methods that integrate not only chemical and biological control techniques but all other control procedures and agricultural production practices that man has developed through the ages into single systems approaches aimed at profitable production of high-quality products in a manner not inimical to our environment. . . . We must continue to recognize that there will continue to be a role for pesticides in agriculture, but we must also develop integrated pest control techniques that make use of chemicals as only one of a number of tools without disruption of the ecological systems in our agricultural production areas.

Senator Lawton Chiles of Florida, one of the sponsors of S 1794, indicated that pilot field projects would demonstrate integrated biological-cultural methods to facilitate a

> change in our present method of attack of agricultural insects—a change in strategy—a change directed toward helping the farmer, who is bearing the burden of increasing costs of pesticides and yet what he receives for his product seems to be the same; a change aimed at reestablishing the natural ecological balance now being damaged on an appalling scale and rate; a change that would provide the much needed funds and leadership to substantially reduce our single prolonged reliance on pesticides. It is about time we face the fact that pest control practices have been fraught with many grave problems. Ecological disaster can and must be prevented. The farmer can and must be helped to produce a reasonably pest-free crop efficiently and ecologically. This legislation offers the framework and incentive to prevent that disaster, and offers assistance in an expending of energies and funds in a positive direction: research for ways and means of controlling our agricultural pests, using natural predators and parasites of harmful insects in a correct balance. We must seek practical, economically and ecologically feasible alternatives to pesticides. This bill would aid that search.

Senator Chiles also emphasized his belief that the federal government has a responsibility to replace pesticides lost as a result of regulatory action with the following rhetorical question:

> Do you feel Government has a responsibility then, to at a time we say to the farmer, you cannot use DDT or you cannot use one of these pesticides that you have used, that Government owes the responsibility to him to try to give him an alternate method of trying to control the pests, if Government is going to take away his right, restrict his right? For

> Congress to say to the farmer to unilaterally stop using pesticides, without making a sincere effort to help the farmer find alternate means of pest control, is grossly unfair. I feel we owe a responsibility to the farmer by giving him an acceptable viable alternative to the use of pesticides. We had to use more and more pesticides in attempting to control the pests, and therefore to the farmer we tremendously raised the cost and the frequency with which he then had to apply the pesticides, and also increased greatly the resulting harm that happened to the environment because of the tremendous usage.

Senator Allen of Alabama, one of the sponsors of S 1794 and chairman of the subcommittee, stated that

> encouraging the use of the integrated control methods to control insects and pests probably offers the best mechanism for a reduction in the use of pesticides and insecticides that could cause damage to our environment. So rather than having overkill with insecticides and pesticides, under this system, you could use a small amount of the chemical and integrate that with the biological control and in that way get at the problem better than resort to only one method.

Senator Allen further stated, "I am sure the ultimate purpose of it is to provide for the gradual withdrawal of the use of pesticides."

2.2 Selected Statements by Farmer Representatives

Mr. Harry Bell of the National Cotton Council said, "The cotton industry has for years recognized that there should be better alternatives to wide-scale poisoning with broad-spectrum insecticides." But he also was careful to include pesticides in describing the focus of the research effort when he stated that cotton producers support "biological-cultural-chemical approaches." In describing the goals for the effort, Bell said, "In our opinion, the development and use of practical integrated control techniques would reduce our production costs, cut environmental contamination, lessen pesticide residues in cottonseed, avoid or delay the onset of pest resistance to chemicals, and reduce toxicity hazards to people and other animal life."

Mr. B. F. Smith of the Delta Council indicated that his organization supports the development of effective control methods that have a reasonable cost and make limited use of insecticides. He said, "Farmers certainly are willing to give up the use of insecticides and pesticides if acceptable and effective methods can be discovered or developed to combat the pests and insects" and that he believed that this would result in less pollution, less resistance, and better biological balance between insects on different crops so minor pests do not become major pests.

Dr. Weldon Barton of the National Farmers Union said,

> Farmers Union urges effective regulation—in combination with governmental research and educational programs—aimed at proper use of pesticides, herbicides, fertilizer, and other chemicals if they constitute a source of pollution. The development and usage of integrated methods, whereby we attempt to eliminate agricultural pests by working primarily with biological means from within their cultures rather that by applying chemical insecticides "from the outside," is increasingly being recognized as essential . . . for at least two reasons: (1) because the continuous usage of chemical insecticides and pesticides pollutes our water, land, and other natural resources: and (2) because from a strictly economic standpoint, farmers can be the real losers from the continued reliance on nonintegrated chemical applications. For the benefit of farmers as well as the protection of our natural environment, we must develop integrated pest control methods that can help us to move away from this spiral of chemical pesticide usage.

Mr. Charles Frazier of the National Farmers Union urged that

> we not undertake to resolve the future of all chemicals in agricultural production by sweeping, widespread actions based on emotional reactions . . . but rather it would be preferable to approach each of the major insect problems in some realistic and dispassionate manner that would move the control of insects of such economic importance to the nation from chemicals to biological means or to combinations of the methods that may be available.

2.3 Selected Statements by Environmentalists

Mr. William Butler of the Environmental Defense Fund supported S 1794 and emphasized the "intense need for more research on integrated biological-cultural methods of insect and pest control to complement, reduce, and in some instances entirely supplant current overreliance upon chemical controls for pests." He also said that overreliance on pesticides has resulted in resistance, destruction of natural enemies, and environmental harm to nontarget species.

Ms. Linda Billings of the Sierra Club indicated that conservationists support the legislation and reminded the subcommittee that they have long protested the "exorbitant" use of chemical pesticides. She stated that the "reckless use of chemical pesticides has wrought ecological havoc and . . . threatens production of vital food and fiber crops, forest products, and endangers human health." She further stated, "I hope the lessons of the past will not be ignored by those developing new pest control methods and that care will be taken to note and guard against adverse environmental effects."

2.4 Selected Statements by University Researchers

Dr. Carl Huffaker of the University of California stated that

> the long-term interests of the grower and of the environment are both served by a balanced biological and multidisciplinary approach to pest control. The goal of this program is to place pest control on a more scientific basis, wherein the grower can manage his crop pests in a more reliable and predictable manner without need for the extensive use of broadly disturbing toxic chemicals.

Dr. Gordon Guyer of Michigan State University acknowledged the enormous benefits resulting from the use of synthetic pesticides but indicated that undesirable side effects have not been fully assessed:

> Whereas, chemicals have allowed for the greatest agricultural production in history and made major contributions to world health programs, they have also contaminated the environment. It is generally agreed that the use of pesticides should be reduced and only used when and where necessary. However, few effective alternatives have been developed which compare with insecticides as being quick acting, consistently effective, economically feasible, technologically adaptable to grower implementations and applicable to a broad range of crops under diverse environmental conditions. One alternative approach to the unilateral use of pesticides is integrated pest control, which envisions maximum use of nonchemical—biological, cultural, genetic, et cetera—control methods and the minimization of chemical control tactics. This philosophy is advanced . . . as the most practical and realistic alternative for reorienting plant and animal protection practices away from the excessive use of chemicals.

Dr. Charles Lincoln of the University of Arkansas said that

> primary dependence on broad spectrum insecticides, which makes that cheap program possible, is no longer a tenable approach to insect control, however. Resistance of insect pests to insecticides, pollution, and disruption of populations of nontarget species have reached critical levels. We must, therefore, place much more emphasis on biological and cultural methods. In a pilot program, all available methods of cultural and biological control will be brought together to obtain acceptable yields of crops and forest products. Insecticide use will be kept to a minimum, with emphasis on the use of safe, selective insecticides. In a pilot test, it will be necessary to monitor populations of many of these species. . . . A pilot test must, therefore, include several hundred to a

few thousand acres as a minimum, and require a great deal of manpower and instrumentation.

Dr. Perry Adkisson of Texas A&M University spoke of the pesticide resistance problem, saying,

> As insects become resistant to pesticides, the common reaction is to apply more toxic pesticides in greater dosages at shorter intervals. The result is increased production costs, increased hazards to applicators and farm laborers, and increased contamination of the environment. Many of these hazards may be averted by a system of pest management known as integrated control. This system, which brings all known suppression measures to bear . . . offers the greatest promise for keeping our agricultural production viable and environmental contamination by agricultural chemicals at a minimum.

Dr. Robert Van Den Bosch of the University of California at Berkeley said, "Perhaps the greatest attribute of integrated control is . . . it automatically assures a high level of environmental quality. . . . A second major advantage of integrated control is economy, which again derives from its heavy reliance on natural controls and minimal dependence on costly artificial measures." He also spoke of the "ever greater use of pesticides" resulting from pest resistance and cautioned that "there simply is no measure, method, or material which in itself will prove to be a panacea."

Dr. J. Lawrence Apple of North Carolina State University indicated that he was concerned about the focus on nonchemical approaches:

> I am concerned about some comments made in these hearings relative to the use of chemicals. We look upon a pest management system as one that will involve the use of all of the tools at our command in controlling pests. Undoubtedly, this shall continue to involve—and in some cases very heavily—the use of chemicals. We want to minimize the chemical load to the extent possible for several reasons. But for many of the major crops, we cannot foresee the day when we will no longer need chemicals.

He also stated that the tendency of farmers to overuse pesticides is understandable "in that they do not have the guidance that is necessary to make a rational decision as to when to use and when not to use pesticides. That is the type of information we need to supply the farmer." Dr. Apple also encouraged the subcommittee to broaden the scope of the bill to include all pests, not just insects.

Dr. Theo Watson of the University of Arizona cautioned that

> ecological disruptions have taken place which may take several years to correct. The gradual changeover to a truly integrated control program

> will encompass continued use of insecticides in the conventional sense, but with greater care exercised in their selection and use. It will also require greater emphasis on augmentation and conservation of natural enemies and the use of biotic insecticides. Cultural practices which are beneficial to crop production and which adversely affect the pest complex will need to be incorporated in the overall integrated system. The problem remains of how to obtain grower acceptance of this approach which necessarily requires more time and consideration in management decisions but on the other hand ultimately improves production efficiency as well as environmental quality. The reward . . . will be an agriculture aimed not at maximum immediate profit, but rather at optimum sustained production, year after year, with minimum detriment or hazard to nearby food-or-feed-producing enterprises, to agricultural workers, to wildlife, and to the general consumer. Integrated pest control will utilize all available tools, including the discriminate use of pesticides.

Dr. Ernest Bay of the University of Maryland spoke of the likelihood of yield reductions as biological and integrated control methods are developed. He also cautioned against "the widely held but seldom spoken skepticism that the term 'integrated control' is an ecological platitude, and that our only practical reliance can continue to be on strict chemical schedules."

Dr. H. T. Reynolds of the University of California at Riverside stated his hope that pesticide use could eventually be reduced by at least 50% on those crops that rely heavily on pesticides, such as cotton.

An important exchange regarding the use of pesticides in IPM systems occurred between Senator Allen and Dr. Bay:

> **Sen. Allen**: "Even an integrated system would not necessarily eliminate, certainly at the outset, chemical methods of control?"
>
> **Dr. Bay**: "No. Your chemical methods are entwined with this. The chemical method is absolutely a part of it."
>
> **Sen. Allen**: "You think with the gains the insects are making even under the integrated method of control, we are going to have to continue using pretty nearly the same amount of chemicals?"
>
> **Dr. Bay**: "I would like to think not, but maybe we would be at least able to develop a system where we could hold our own. But without the use of integrated control, the use of chemicals will have to be increased with the population increase."

3 FROM POLICY TO PROGRAMS

By the end of the congressional hearings on pest control research, the nature of the pesticide problem and the need for federal support for IPM research and

extension had been well established. The momentum created by the hearings had an effect on budget priorities at the USDA and the Office of Management and Budget. On January 1, 1972, Agriculture Secretary Butz announced that funding would be provided for a new pest management action program and an expanded research program [13]. The news release stated that the programs will "help farmers control pests more economically and effectively. At the same time it will reduce the amount of DDT and other chemical pesticides currently being used." The new pest management effort was conducted jointly with the USDA, the NSF, and the USEPA and in cooperation with state departments of agriculture, state agricultural experiment stations, and state extension services.

The foundation for federal IPM policy was prepared by NEPA, the CEQ, the congressional hearings, and agricultural scientists, but if one specific point in time were picked to mark the "ribbon cutting" for federal involvement in IPM, it would be February 8, 1972, when President Nixon transmitted the Environmental Message to Congress [14]. The President's Environmental Message represented the final piece in the IPM puzzle because it signified that the executive branch and Congress were in agreement on the need for a concerted federal IPM effort. In a section of his Environmental Message titled "Making Technology an Environmental Ally," President Nixon announced a comprehensive IPM initiative, including funding for research and development, field testing and demonstrations of new techniques, and the development of training programs for crop consultants. Nixon reflected the heightened environmental awareness of the time when he said, "Our destiny is one: This environmental awakening has taught America in the first years of the seventies. Let us never forget, though, that it is not a destiny of fear, but of promise." Referring to pesticides as an "example of a technological innovation which has provided important benefits to man but which has also produced unintended and unanticipated harm," he declared that "new technologies of integrated pest management must be developed so that agricultural and forest productivity can be maintained together with, rather than at the expense of, environmental quality." He went on to state, "Integrated pest management means judicious use of selective chemical pesticides in combination with nonchemical agents and methods. It seeks to maximize reliance on such natural pest population controls as predators, sterilization, and pest diseases." He announced a plan to

1. Launch a large-scale IPM research and development effort to develop integrated pest management techniques. (USDA, NSF, and the USEPA with leading universities)
2. Increase field testing of promising new methods of pest detection and control and the incorporation of new pest management techniques into existing federal pesticide application programs. (USDA)
3. Develop training and certification programs for crop consultants at ap-

propriate academic institutions. (USDA and the Health, Education, and Welfare Department)

4. Expand the field scout demonstration program to cover 4 million acres by the upcoming growing season. (USDA)

President Nixon's Environmental Message was followed nine months later by a CEQ report on IPM that provided the policy analysis and recommendations that shaped federal IPM policy for the following three decades [10]. The report acknowledged the "dilemma of increasing food production on the one hand and maintaining environmental quality on the other" but cautioned against being "complacent about environmental damages and health threats that can occur from pesticide use, especially when pesticides are used improperly." The report concluded that "the accumulation of pesticides in the food chain, the possible reduction in the populations of some fish and wildlife, and the potential threat to man's health posed by some pesticides have shown the need to seek new methods of pest control to supplement current practices."

Based on an analysis of published research findings and the preliminary results from pilot pest management projects, the CEQ report concluded, "In general, the use of integrated pest management should lead to greatly reduced environmental contamination from pesticide use and to many fewer problems with pest resistance and secondary outbreaks while maintaining or improving our current ability to prevent pest damage." The report went on to state that "pest control can be improved, with reduced environmental impact and often at lower costs to the user." The report also stated that IPM represents an improved method of pest control but does not accomplish this through the elimination of pesticides, which are an important component of IPM programs when used properly and only when needed. Finally, the report indicated that although the evidence of the "overall economic advantage of integrated pest management is still incomplete, it seems reasonably well established for crops such as cotton, apples, and citrus" and predicted that the economic incentive would be smaller for crops using less pesticide.

The CEQ report defined IPM as "an approach that employs a combination of techniques to control the wide variety of potential pests that may threaten crops" and went on to say,

> It involves maximum reliance on natural pest population controls, along with a combination of techniques that may contribute to suppression . . . to affect the potential pests adversely and to aid natural enemies of the pests. Once these preventive measures are taken, the fields are monitored to determine the levels of pests, their natural enemies, and important environmental factors. Only when the threshold level at which significant crop damage from the pest is likely to be exceeded should suppressive measures be taken. If these measures are required, then the

> most suitable technique or combination of techniques, such as biological control, use of pest-specific diseases, and even selective use of pesticides, must be chosen to control a pest while causing minimum disruption of its natural enemies.

The report anticipated the multitude of debates and discussions that would ensue in the following decades by stating "the purpose of integrated pest management is not to avoid the use of chemicals but to use the most effective and environmentally sound pest control technique or combination of techniques for long-range pest control. A pest management system is not simply biological control or the use of any single technique."

Finally, after several years of consideration, the federal government was ready to begin implementing its IPM policy. The first significant federal support for IPM programs resulting from the new federal IPM policy came in fiscal 1972, when funding was provided for a project that was titled "The Principles, Strategies, and Tactics of Pest Population Regulation and Control in Major Crop Ecosystems" but was better known as simply "the Huffaker Project." The IPM effort was conducted in partnership with a number of the nation's leading universities and included extensive field tests of promising new methods of pest detection and control. Six major cropping systems were included in the project: alfalfa, citrus, cotton, pine, pome and stone fruits, and soybeans. The project was jointly funded by the NSF, the USDA, and the USEPA. The federal agencies coordinated their efforts, with NSF supporting basic research and the USDA supporting applied research, development, and testing. Over the course of this seven-year project, the federal government provided $13 million for research conducted by 18 universities on six crops (representing approximately 70% of pesticide use). By the end of the project, advances had been made in methods for timely application of insecticides, the development of insect-resistant crops, new appreciation for biocontrol tactics, and the design of methods for the evaluation of the economic and environmental impacts of IPM programs [15].

In addition to providing funds for the Huffaker Project, the USDA expanded the pilot pest management program in fiscal years 1972 and 1973 to include cotton in all major cotton-producing states and initiated demonstration projects for alfalfa, apple, citrus, corn, grain sorghum, peanut, potato, sweet corn, tobacco, and some vegetable crops in 17 states. These demonstration projects were structured so that participating farmers would help pay the cost of scouts during the first three years of the demonstration project, then assume the full cost. There were three goals for these projects: (1) Ensure maximum production of food and fiber; (2) reduce farm operating costs; and (3) enhance the quality of the environment [16]. From 1971 to 1974, a total of 39 three-year pilot pest management projects were conducted. The USDA provided funding for addi-

tional "pilot application" projects in fiscal 1975 and established the following objectives [17]:

1. Develop and implement effective integrated approaches to "prevent or mitigate losses caused by pests through use of biological, cultural, chemical, and varietal methods of control."
2. Field test a combination of suppression tactics.
3. Provide "grower exposure" (information and training) to gain their support and the adoption of IPM practices.

A fourth objective was added in fiscal 1976: "To monitor field population levels of pests" [18]. An excellent summary of the organization and accomplishments of the pilot pest management projects was prepared by Dr. Joe Good, the Extension Service's Director of Pest Management Programs [19].

Federal IPM policy took another step in its evolution in 1977, when President Carter stated that "environmental protection is no longer just a legislative job, but one that requires—and will now receive—firm and unsparing support from the Executive Branch" [20]. He then announced a "coordinated attack on toxic chemicals in the environment" and instructed the CEQ to "recommend actions which the federal government can take to encourage the development and application of pest management techniques which emphasize the use of natural biological controls like predators, pest-specific diseases, pest-resistant plant varieties, and hormones, relying on chemical agents only as needed." In response, the Secretary of Agriculture issued a 1977 memorandum that declared, "It is the policy of the U.S. Department of Agriculture to develop, practice, and encourage the use of integrated pest management methods, systems, and strategies that are practical, effective, and energy efficient" and "to seek adequate protection against significant pests with the least hazard to man, his possessions, wildlife, and the natural environment" [21]. The Secretary's memorandum was followed by the establishment of the Work Group on Pest Management to provide leadership and information exchange among the 11 USDA agencies actively engaged in pest management programs and to coordinate USDA pest management activities with those of the USEPA and other federal and state agencies [22].

4 THE REALITIES SET IN

The 1970s were a decade of great optimism and creativity as IPM research and extension programs responded to a call to action issued by a country concerned about the effects of pesticides. By the end of the decade, however, the euphoria of a new effort had faded and the practical realities of altering pest management practices on millions of farms became apparent. At congressional hearings in late 1977, environmentalists complained that IPM was moving at a snail's pace [23].

Witnesses at the hearing provided estimates on what it would take to speed up implementation of IPM methods on farms across the country. Dr. Fowden Maxwell of the University of Florida indicated that one Extension pest management specialist would be needed in each of Florida's 67 counties to fully implement IPM methods. Dr. Joe Good of the USDA Extension Service estimated that 300–400 Extension IPM specialists, 3,000 private consultants, and 63,000 scouts would be needed to adequately handle about one-third of the nation's agricultural lands. Dr. Good later indicated that it would take 10 years and 500–600 additional Extension IPM agents and specialists (including 53 state and federal IPM coordinators and 330 area Extension IPM agents) to implement a well-planned IPM effort to increase IPM implementation nationwide; he estimated that this level of effort would cost $20.4 million per year [19].

Confusion over the meaning and goals of IPM programs was already apparent in the late 1970s. One of the architects of the USDA IPM effort cautioned against portraying IPM in an abstract way "as a technological fix, a placebo, a mystical cure for environmental and agricultural problems attendant to pest control" and stressed the need to "start developing specific IPM practices and programs with prescribed methodologies and technologies" [24]. He further stated, "Frequently, we hear the 'use of IPM' will protect the environment. However, it will be possible to develop specific pest management practices or regulatory procedures to protect the environment when *and only when* specific pesticide related environmental problems are identified and understood. The specific problem or need must be identified before a corrective program can be launched."

In 1979 the CEQ published a second report on IPM [25] that cautioned,

> The recent accomplishments of integrated pest management and continued public interest in alternatives to conventional pesticide programs have resulted in some uncritical endorsement of IPM programs without regard to their feasibility and in some confusion about the concept. IPM is not a panacea; nor is it a term which embraces all programs that employ more than one control technique.

The report concluded that "the lack of understanding and support for interdisciplinary research projects and companion educational and demonstration programs at public institutions is a major impediment to IPM" as is the fact that "public agricultural research and extension institutions are frequently required to produce quick, simple answers to complex problems that are not well understood because of pressure from commodity groups or from elected federal and state officials."

The incorporation of biological control methods into IPM strategies had already become a point of contention among IPM supporters and critics by the late 1970s. The IPM leadership at the USDA were concerned about the tendency to think about IPM as being synonymous with biological control. "Too often the term IPM is equated with biological control or nonchemical control. In most