CONSTRAINTS TO THE IMPLEMENTATION OF IPM PROGRAMS IN THE U.S.A.: A COURSE OUTLINE

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ABSTRACT


To develop and implement the pest management programs of the future, students in crop protection should be educated about the economic, social and institutional contexts in which these programs will operate. To this end, an overview of selected constraints to the implementation of IPM in the U.S.A. is presented. A broad range of constraints is addressed, including institutional conflicts, cosmetic standards, the lack of incentive to develop and use alternatives to chemical control, difficulties in communication and acceptance by growers, risk-aversion, difficulties in organizing area-wide control programs and the complexity of agroecosystems.

INTRODUCTION

"It is evident, therefore, that he who undertakes pest control should do so with a 'global' mental picture that connects all aspects of the proposed enterprise — commercial, technological, managerial, sociopolitical, biological and economic" (P.W. Geier, 1981)

Biological knowledge is not enough. If today's students are to develop and implement practical pest management programs in the future, they must understand the context in which these programs will operate.

Consider the requirements for implementing a new IPM program. In order to be successful it must, of course, be biologically and technically feasible. But what about the other requirements? Institutions and individuals must be ready to promote the program and provide the necessary labor and resources. It must be effectively communicated and accepted. In order to be accepted, it must not conflict with other goals of the agricultural system, including profit making, stabilizing income, meeting cosmetic and
quality standards and controlling other pests. It must operate within legal restraints set by environmental, agricultural and other agencies. It must survive opposition by any groups whose interests are not served. How well are we preparing students to recognize and deal with these requirements?

Miller (1983) discusses the limitations of forestry students who, like many students of pest management, have had technical training, but little introduction to the economic and social ramifications of their science. These students, when presented with different views of a controversial issue, react by simply dismissing opinions contrary to their own, instead of seeing the value of different points of view and making appropriate compromises. Students of pest management should realize that IPM is intended to serve a variety of constituencies (farmers, consumers and society as a whole) and is carried out with the cooperation of several different institutions (universities, the government and private pest management operations). Discussion of the objectives set for IPM by these different groups and the practical constraints to the realization of these objectives should help students to decide for themselves what the appropriate role of pest management should be, and how best to achieve that role within the limits of these constraints.

This study presents an overview of a seminar course, developed jointly by students and faculty, on obstacles to the implementation of IPM in the U.S.A. Many of the same obstacles have been reviewed by Corbet (1981), on an international basis, and by Goodell (1984), for developing countries. IPM professionals in other countries should examine these constraints in relation to their own economic, social and political systems and discuss how their problems and solutions may differ from ours.

HISTORY AND CONCEPTS

As an introduction, early classic papers by Isely and Baerg (1924), Wigglesworth (1945), Pickett et al. (1946) and Stern et al. (1959) were read. These examples illustrate that many of the concepts of pest management have been around for a long time. Isely and Baerg (1924) advocated an action threshold (10–15% of the squares damaged by boll weevil), careful scouting and area-wide destruction of hibernation sites. They recognized that heavy use of calcium arsenate destroys the natural enemies of the cotton aphid, causing the aphid to become a secondary pest. Wigglesworth (1945) predicted how the arrival of DDT would change pest control practices, and the danger it posed to wildlife and beneficial insects. Pickett et al. (1946) brought to insect control an ecological and interdisciplinary approach, realizing, for example, that fungicides for apple scab affected insect and mite control. They were strong advocates of selective pesticides to avoid inducing outbreaks of secondary pests. Stern et al. (1959) brought together these elements and combined them with further ecological and economic theories to establish the basic philosophy used in pest management today.
More recently, Rabb (1972) outlined the stepwise development of a pest control program, from emergency control measures to the development of economic thresholds and proper timing to avoid harming natural enemies, integrating other methods of control and, if needed, area-wide population management. He listed the new factors which should be incorporated in future pest management as: an interdisciplinary approach; systems science as a means to deal with complexity; and the continuing interplay of research and extension in developing and improving programs.

Giese et al. (1975) expanded on the need to apply systems analysis and to use computer networks for communication, storage of biological and weather data, and forecasting future events. Huffaker and Smith (1980) emphasized systems science and computer technology, but advocated a shift of focus from pests to the crop production system. They sought both the optimization of pest control, based on long-term economic, environmental and social costs and benefits, and greater profits for the farmer, by minimizing the use of expensive and often counter-productive pesticides.

Through the 1970's, the concept of IPM grew to include area-wide management of pests, the use of computers and modelling and incorporation of pest management into the broader perspective of crop production. Rabb (1972) warned of the possibility that the boom in popularity of pest management could result in general disappointment if the high expectations being generated were not rapidly fulfilled. In considering constraints to implementation, we should remember that implementation will necessarily seem slow if our initial expectations were too high.

SELECTED CONSTRAINTS

Institutional conflicts

The potential for conflict in the development and implementation of pest management exists both within and among the three major institutions involved: government, the university and the private sector. Three examples of the need for collaboration and coordination of effort were examined.

(1) At the federal level, there is potential for conflict between the U.S. Department of Agriculture (USDA) and the Environmental Protection Agency (EPA), both key agencies involved in IPM, but with different goals and perspectives. An Office of Technology Assessment report (1979) describes the USDA as concerned about the environment, but its chief mission is to ensure that farmers have adequate protection against pest damage at reasonable cost. The top priority of the EPA in dealing with pest management is that production be carried out in a way which protects the environment, within economic limits. This report outlines possibilities for oversight or interagency review groups to coordinate the efforts of these and other agencies (Food and Drug Administration, National Science Foundation, Council for Environmental Quality, etc.) involved in IPM and to propose a national plan.
(2) Within universities, a variety of plant protection and crop production disciplines, along with the integrating disciplines of economics, systems science and ecology, must cooperate in research and development of IPM programs, in training students, and in moving programs to implementation via extension. Miller (1983) discusses some of the difficulties involved in interdisciplinary work, including disciplinary rivalry, differences in "cognitive styles" between empirical and theoretical scientists and the use of the interdisciplinary group as a vehicle for promoting individual work within a single discipline. He also mentions the pressure from peers and departments to remain in one's own discipline, which can result in punishment for those with interdisciplinary interests.

(3) Some difficulties in coordinating the efforts of government, universities and the private sector to set up effective delivery systems for IPM are outlined in the Office of Technology Assessment (OTA) report (1979). Publicly-supported pilot pest management programs have been effective in making farmers aware of the concept and creating a market for private services, but they must be careful not to compete with the private sector. Private commercial and grower-owned services face problems with possible liability for crop damage, making sure prospective consultants or practitioners are adequately qualified, and developing a sufficiently large market or cooperative to allow efficient use of people and equipment and allow for a reasonable income.

The OTA (1979) points to the lack of trained personnel, including field scouts, scout supervisors and trainers, pest management practitioners and extension workers as a major obstacle to establishing delivery systems. IPM has a higher labor requirement than conventional pest control programs, involving large numbers of scouts to carry out the biological and environmental monitoring, practitioners to interpret the data and give personal advice and services, and scientists to provide applied research and technical support.

Cosmetic standards

Cosmetic standards in the fruit and vegetable industries may severely limit the pest manager's options by allowing so little pest contamination or damage that heavy use of pesticides is unavoidable. The questions arise: (1) Who sets the standards, and on what basis? (2) What is the relationship, if any, of insect contamination to the health and safety of the consumer?

Van den Bosch (1976) describes the complex system of quality standards for fresh market produce in the U.S.A. Minimal standards are set by government agencies, with more stringent standards set by the marketing order or cooperative, the private marketing organization and the retail buyers for supermarket chains. For processed foods, van den Bosch (1976) and Pimentel et al. (1977) discuss Defect Action Levels set by the Food and
Drug Administration (FDA), which regulate the content of the final processed product. Van den Bosch (1976) also discusses the standards written by the processors into their contracts with the growers. The van den Bosch report points to many factors involved in setting standards for produce: the desire of the supplier to maintain a reputation for a high quality product; the ideas of consumers about size, color and surface perfection as indicators of quality; and high quality standards during periods of oversupply in order to maintain a high price for superior produce. Van den Bosch and Pimentel agree that high cosmetic standards and low tolerances for insect contamination involve hidden health and environmental costs to consumers and society as a whole. They argue that education of consumers could result in reduction of costs and wider options for low-priced, imperfect produce on which less pesticide may be used.

The address by Crosby (1982), an official in the National Food Processors Association, presents insect contamination from a different perspective. The food processor must face the powerful negative reaction of consumers to finding an insect in processed food, and must pay claims and legal fees, as well as suffer a loss of reputation. The consumers do not accept noticeable insect contaminants in processed food, so the processor cannot accept them either.

As for the relationship between insect contamination and human health, standards are not set on the basis of human health and safety, but on an aesthetic basis. Gorham (1979), however, points out the large gaps in our knowledge of the effect of insects on the nutritional value of food, possible production of toxins and allergens by insects and transmission of disease via contamination by insects. He also distinguishes between field pests and processing pests, particularly mobile insects like flies, cockroaches and ants, which are more likely to spread disease to humans.

Lack of incentive to develop and use alternatives to chemical control

IPM originally grew out of a desire to integrate biological and chemical control (e.g. Stern et al., 1969), and later developed to encompass all viable methods of control (e.g. Rabb, 1972). Thus, IPM implies not only more effective use of chemical controls, but also use of alternative methods of control wherever possible. Examination was made of the extent of use of “bioenvironmental” controls (Pimentel, 1976) in the U.S.A., the economic returns of bioenvironmental and pesticidal control, and social, political and psychological factors acting against the acceptance of alternatives to pesticides.

Pimentel (1976) argues that on the basis of the area managed, bioenvironmental controls are as important as pesticides, and, for plant pathogens and weeds, bioenvironmental methods (host plant resistance and crop rotation for pathogens, cultural control for weeds) are of primary importance. While this may be true for all pests on all cropland in the U.S.A., the present
authors believe that insect pest management programs rely heavily on chemical controls.

Oelhaf (1978) and Reichelderfer (1981) cite impressive figures on returns on government investment in research on host plant resistance and biological control (although Reichelderfer is critical of the methods used in the original reports). Oelhaf (1978) shows that much more money is spent on pesticide research and development (including private sector research) than on research into bioenvironmental controls, because to ensure an adequate return for the private investor, the pest control technique must be patentable, with a large potential market. Therefore, private companies invest in patentable, broad-spectrum pesticides.

The high cost of discovery of new chemicals, the uncertainties and cost of registration, the costs of production, and competition with highly effective, fast-acting products already available act to discourage innovation in the pesticide industry, even though high profits result from a marketable new product (Hammock and Soderlund, 1984). The result is that the pest manager is handicapped by a low diversity of chemicals, particularly selective chemicals that would be more compatible with alternative controls.

Reichelderfer (1981) discusses a variety of factors affecting economic feasibility of biological control. For example, because natural enemies require that a low-density population of hosts remain, biological control is more feasible for continuously occurring, indirect feeders that inflict relatively low damage per individual. In general, the absolute yield benefit of biological control is less than with chemical control, but the private costs are also lower. Thus, net benefits to the farmer can be greater than with chemical control.

Besides economic factors, various human factors play a role in favoring chemical over bioenvironmental methods of control. Oelhaf (1978) points to the power of advertising, the ease of using chemical controls and the rapid, highly visible results. Perkins (1982) compares chemical control and "TPM" (Total Population Management, i.e. area-wide population suppression measures) with IPM in terms of their economic, political, social and philosophical ramifications. Chemical control is philosophically based on a sense of nature dominated by human technology. It also supports the traditional organization of American agriculture in which pest control is a private matter, used by individual farmers in competition with each other. In contrast, IPM is derived from a more naturalistic philosophy in which people cannot totally control nature. It also breaks with tradition by sometimes requiring cooperation among farmers and by increasing labor requirements in agriculture.

Communication of IPM

In order for IPM to work, the grower has to be sufficiently convinced of its value to pay for pest management services, to organize with neigh-
bors in regional cooperation or to change time-tested practices in favor of new techniques. Some of the factors Rogers and Shoemaker (1971) mention that affect the communication of an innovation and its rate of adoption are: (1) the degree to which the communicator and the receiver are similar in beliefs, values and education; (2) the characteristics of the innovation, as perceived by the receivers; and (3) the social system of the receivers, which influences both the rate of adoption and the pattern of adoption within the system.

The rate of adoption of a new idea is increased by the perceived advantage of the new idea over previous methods, how obvious that advantage is, the degree to which the idea may be tried out on a limited basis and its compatibility with existing values, experiences and needs of the receivers. Complex innovations, for which the receiver has to develop new skills and understand new concepts, are more slowly adopted. As we saw in the previous section, many aspects of IPM would tend to slow its acceptance by farmers, including its naturalistic philosophical basis (Perkins, 1982), its lack of readily observable, obvious advantages and its complexity.

Rogers and Shoemaker (1971) point out that mass media are effective in promoting knowledge and changing attitudes toward innovations, but inter-personal contact is usually necessary to persuade someone to take action on a new idea. An EPA survey of corn and soya bean farmers in the Midwest showed that information from university extension specialists, county agents and university meetings did not reach many farmers. Pesticide labels and retailers were the main sources of information. Although extension services were considered useful, the shortage of extension people restricted direct contact (RvR Consultants, 1974). Turpin and Maxwell (1976) confirmed that, after the farmer's own knowledge, the chemical dealer was the main source of information for insect control decisions, with the county agent a distant third. They also pointed out that the farmers who relied most heavily on chemical dealers for information about insecticides were more likely to use them, illustrating a possible conflict of interest for pesticide dealers acting as farm advisors.

**Risk**

Pest management programs have been justified by their ability to increase profits, either by increasing the yield or quality of the product, or by reducing costs. Increasing mean profits over the long-term may not be the only important criterion, however. Pesticides are used by growers not only to maximize profits, but to stabilize them (Norgaard, 1976; Carlson, 1978). This results in "insurance" treatments, in which the cost of the treatment is not justified by the expected value of damage, but the treatment is made to protect the farmer against a low probability of devastating damage. An examination was made of farmers' attitudes about decision-making involving risk and the possibility of protection from risk by means
other than prophylactic pesticide use, including acquiring information about the state of the crop and its pests and crop insurance programs covering pest damage.

Mumford and Norton (1984), after reviewing various economic models of pest management decision-making, find that none of these models adequately explain the farmers’ behavior. They suggest that growers use trial and error and simply eliminate strategies that gave unsatisfactory outcomes in the past. They also point out that the large number of managerial decisions required of farmers may result in their adopting "standard operating procedures" to minimize decision-making effort and the likelihood of making a mistake.

Mumford and Norton (1984) do believe that economic models, particularly those based on decision theory, have an important role in planning research and extension strategies. Bayesian decision theory models are useful for finding the value of additional information in reducing the level of uncertainty (which is perceived as risk) and substituting this information for some fraction of insurance pesticide use.

Carlson (1979) discusses alternatives to using pesticides for insurance, including actual insurance for crop loss (possibly government subsidized) and information for improved pest control. Market insurance for crop loss has a number of difficulties, including the high costs involved in claims adjusting and producing actuarial tables, the difficulty of spreading the risk potential for pests that attack wide areas, and the low private (as opposed to social) costs of chemicals as a substitute for insurance. Private provision of pest control information also has market difficulties because it is not possible to control the spread of private information to non-paying farmers, and because information currently provided by public sources tends to reduce the profitability of private information.

In spite of these difficulties, private consultants do provide information to their clients for a fee and reduce their clients' pesticide costs. Carlson (1978) presents data indicating that clients of private consultants and other users of pest management have, over the long-term, equal or slightly lower mean profits (in some cases profits have been much higher, e.g. Adkisson et al., 1982), but increased stability (decreased variance) of profits compared to farmers using calendar spray programs.

Both economic analysis and the experience of growers show that pest management information can reduce uncertainty about the potential for pest damage and thus reduce the need for pesticide treatments as insurance. Crop loss insurance could also reduce pesticide use. Both of these services, however, have difficulties in private markets.

Difficulties of area-wide pest management

It is common for the pest problems of one farmer to be affected by the practices of neighboring farmers. It would be advantageous for farmers to
coordinate their pest management efforts on a larger scale in order to take advantage of management strategies which are more cost effective on an area-wide basis.

Area-wide management can be organized by voluntary groups, as in grower cooperatives, or it may be encouraged or imposed via government agencies. As Rogers and Shoemaker (1971) state, innovations involving a community consensus take a long time for adoption, while innovations imposed by authority are rapidly adopted, but are more likely to be dropped or circumvented. Carlson (1979) describes a dilemma of centralized pest control decisions: what level of control should be provided, and how should the members of the group be charged? Pest severity is not likely to be equal on all farms in the area, and farmers differ in their tolerances for pest damage or risk of pest damage. If the organization must choose one level of pest suppression and charge growers accordingly, what are the choices? If a moderate level of control is chosen, farmers with a low pest severity or high tolerance for damage will not be well served. If they choose not to join the group, economies of scale may be lost. If they are required to join, they will be worse off, unless the economies of scale are large.

The Boll Weevil Eradication Experiment (Young, 1976; Guice, 1976; Bruer, 1976) illustrates the difficulties in an extreme case. The level of control chosen was complete eradication and 100% participation was required. With a massive public education effort, cooperation was apparently good, but resistance would probably have been much higher if the farmers had been expected to pay the full cost of the program. Taylor and Lacewell (1977), in an economic evaluation of the effects of eradication or IPM strategies on the entire U.S.A. cotton-producing region, show a hidden danger in pest suppression over a wide area. If eradication of the boll weevil from the U.S.A. had succeeded, it would have resulted, according to this model, in a large drop in land values in the aggregate as a result of producer surpluses of cotton.

Technique and their interactions in the agroecosystem

Pest control techniques often have side effects: additional (and often unexpected) interactions with the crop, other pests, other control techniques used on the same pest, the environment or human health. This makes pest management more difficult because it increases the complexity of the system and uncertainty about possible consequences of our actions.

Bergman and Tingey (1979) discuss a number of possible interactions between host plant factors and biological control. Brooks (1973) describes a complex web of interactions among the insect pests Heliothis zea and H. virescens, two species of parasites, two species of hyperparasites and three species of microsporidian pathogens. Pimentel et al. (1984) indicate a variety of possible environmental risks of biological and cultural controls, including health risks to humans (e.g. from increased levels of toxic com-
pounds or decreased nutritional value in pest-resistant food crops) and
damaging effects on the total environment (e.g. increased soil erosion or
water runoff from tilling the soil).

Shoemaker et al. (1979) give a straightforward example of how systems
analysis can be used in the management of a complex of pests when control
techniques have multiple effects. In this case, a choice among methods
(including chemical, cultural and biological controls) is needed in a system
where several of the methods can be used to suppress more than one pest.
Relying on available data and the experience of field experts, the authors
evaluate the possible combinations of techniques and determine the most
profitable strategy. Systems analysis is not as easy to apply, however, when
information on timing of control measures is needed. In that case, ex-
tensive data and more detailed models are required.

Systems science can help in dealing with complexity by providing tech-
niques to integrate information on complex systems, but the larger problem
is the sheer number of possible interactions in agroecosystems and the
time, effort and expense required to gather and comprehend information
on them all. Hence, the interest in guidelines about how much information
is required about an agricultural system in order to manage it effectively.

**Complexity: How much do we need to know in order to implement?**

IPM is a very ambitious program. Given the high level of complexity
of agricultural systems, these ambitions could lead to: (1) delayed im-
plementation while intensive research is conducted on the overwhelming
variety of possible interactions; or (2) implementation of programs in an
early stage of development that may or may not continue to improve, but
which are better than the previous pest control.

To address this dilemma, three discussions of the general problem of
complexity of ecosystems were studied. All three agreed that one can never
know everything about an agroecosystem, and therefore research and im-
plementation should continue to interact as programs run into new problems
in the field. Where these authors differ is in their ideas of “adequate know-
ledge” — how much information about a system they believe can be known,
and how much information is required to manage it properly.

Way (1973) argues for taking as simple an approach as possible and
building up the integrated control program step by step. Each step is based
on a hypothesis about the value or harmfulness of a particular component
in the system and a critical experimental test of that hypothesis. He asserts
that quantitative and ecological models should be reserved for basic and
explanatory studies and possibly for a last resort if empirical and qualitative
attempts should fail.

For Geier (1981), the crucial factor is that the pest manager keep a
comprehensive view of the entire production system — including the com-
mercial, technological, social, political and economic aspects, as well as
the biological side. Geier's requirements for adequate knowledge of pest control are that the proposed program be realistic and that it provide benefits not outweighed by social and environmental consequences. Knowledge of pest control need not be more precise than the level required to sustain the overall production system, because the performance of the system cannot exceed the efficiency level of the most poorly controlled component. Few production systems, he asserts, are so finely tuned as to repay the cost of incorporating all of the newest discoveries and technology of pest control.

Holling (1978) does not believe that a precise understanding of the system is necessary, or even possible. Because interactions are unpredictable, and biological, economic and social contexts are continually shifting, the most essential knowledge is the qualitative structure of the system: What components are connected to each other and how are they connected? Beyond this, he advises maintaining flexibility in the design of the system wherever possible, and continual monitoring and adaptation once the system is implemented.

The cautions of Geier (1981) about the limits of what we, as pest managers, can hope to accomplish within the crop production system, and of Holling (1978), about the limits of our certainty, are certainly true. However, it is not clear to the present authors how best to use Geier's standard to evaluate the value of future information to the entire production system.

Examples of specific programs

To conclude the seminar, examples of implemented programs were looked at to see how the above constraints and obstacles had been dealt with. The instructors hoped to provide the students with examples of how the constraints could be overcome in successful programs, but unfortunately these issues are seldom addressed in published reports. Instead, implemented programs overcame the constraints by new opportunities. These opportunities appeared for various reasons: as a result of changing production practices, from increases in funding or the development of new technologies, or as a result of a crisis — a failure of insect control.

The first example was pest management of cotton in Texas. The most striking thing about this program, in the historical perspective provided by Adkisson et al. (1982) and Walker et al. (1979), is the interplay between pest problems and other factors in the overall production system. Pest problems were, at times, so severe that they changed the entire production system. The invasion of boll weevils forced production to shift to low-rainfall regions and early varieties. Effective pest control, provided for a time by insecticides until resistance developed, allowed farmers to adopt a high input, long-season strategy with high potential yields. Later, the switch to once-over harvesting with mechanical strippers, along with new compatible varieties, created the opportunity for an IPM system based
on the original short-season, low-input strategy, now made more profitable by improved varieties and machinery.

A crisis stimulated adoption of this new IPM system — the resistance of tobacco budworm to all registered insecticides in the late 1960's and early 1970's (Adkisson et al., 1982). This accounts for the rapid acceptance in the 1970's of ideas which would ordinarily be difficult to implement: (1) toleration of a moderate level of bollworm and budworm damage, rather than risking destruction of their natural enemies; (2) area-wide cooperation with uniform planting dates, stalk destruction and autumn insecticide treatments to kill diapausing weevils; and (3) acceptance of a production system with reduced yield potential, but also reduced inputs and risk from pests (Walker et al., 1979; Frisbie, 1981; Adkisson et al., 1982).

If the experience of IPM of apple can be applied to cotton, then Texas should watch for backsliding of farmers on the IPM program. According to Whalon and Croft (1984), in the history of apple IPM there have been repeated crises, resulting in change, followed by "implementation entropy" — the gradual decay of innovative programs. An early crisis in Nova Scotia, arising from low prices and export restrictions, motivated Pickett and his group to create a program that minimized production costs, primarily by reducing insecticide use and making better use of natural controls (Pickett et al., 1946). Another crisis occurred in Washington, when mites became resistant to all available acaricides. Fortunately, it was recognized that pesticide-resistant predatory mites could be managed to control the pests. Again, a program was rapidly developed and adopted, but began to decay when new, effective acaricides became available.

In recent years, implementation has been pushed by greatly increased funding of pilot programs and by technological developments, including pheromone traps for monitoring and improved computer models and networks for communication (Whalon and Croft, 1984). An example of a program which took advantage of the new technologies and funding available is the tree fruit project in Wayne County, New York, described by Tette et al. (1979). Special funding of a mission-oriented program was required to put diverse management practices together into a package, train and supervise the scouts and farm advisers and convince the growers to participate. Despite this effort, some of the above constraints are still limiting progress. An attempt to reduce pest populations by area-wide removal of abandoned and wild apple trees failed, partly because of a lack of cooperation from local landowners. Cosmetic standards are unchanged, and dictate a large number of sprays to fresh-market apples. A program to train pest management assistants to help extension agents in other parts of New York to monitor pest and weather conditions failed because of the difficulty of finding and training enough suitable people for a seasonal job.

Thompson and White (1982) evaluate the economic feasibility of taking the next step: moving the university pilot pest management program on apple to the private sector throughout the northeast. They conclude that
there are substantial savings to participants in the pilot programs, and one-third to one-half of the growers are willing to participate in fee-for-service programs. Nevertheless, a private sector program depends on other factors: the size of the local market, the proximity of the participating growers (to allow efficient use of time and equipment), and the amount of competition — including free information from extension programs as well as chemical salesmen.

What is the future for the implementation of IPM in the U.S.A.

There are serious obstacles to the implementation of IPM programs and most will not easily be overcome. Based on the theory of diffusion of innovations, IPM would not be adopted rapidly because of its complexity, its lack of dramatic, obvious results and its differences in philosophy from traditional agriculture in the U.S.A. The lack of resources for extension and the difficulty of establishing self-supporting programs in the private sector have also slowed acceptance.

We have indicated a number of ways in which private markets fail to provide sufficient incentive to develop or implement IPM programs, even in cases where IPM could be beneficial to the growers. This means that many IPM programs will be at least partly dependent on university and government support for the foreseeable future. For that reason, we need to work to maintain political and public interest in pest management, and to determine what kinds of public sector support would bring the most benefit for the least cost without interfering or competing with private pest management operations.

Some of the originally perceived obstacles have been partially overcome. The use of systems analysis to handle complex interactions, and the use of computer networks to allow rapid communication across an entire state are two prominent examples. The ability to patent genetically altered organisms and the Plant Variety Protection Act have raised the prospects for the private sector to profit from biological control and host plant resistance. The slow process of education and public awareness has brought IPM to the attention of a broad segment of the public and a generation of agriculture students.

Most important, the problems that inspired the push toward IPM are still present. Corbet and Smith (1976) pointed to the failure or impracticality of chemical control as the motivating factor in adoption of IPM programs. Resistance to pesticides, not only in insects, but also in pathogens and weeds, continues to increase (Georghiou and Mellon, 1983). Induction of secondary pests is still a problem (Croft and Hoyt, 1978). Concern for the environment will not disappear. The financial risks of farming will continue to increase and the pressure to decrease the cost of production will intensify.

The students in this course, through the process of researching and dis-
cussing these constraints, now have a broader understanding of the difficulty of implementing IPM programs in the U.S.A. The present authors believe they now understand that implementation does not flow directly and easily from biological knowledge, but it is a difficult process, limited by the social and economic contexts in which the program must operate. The expectation is that the students are better equipped to recognize and deal intelligently with the constraints they will encounter in the future, and decide which they must accept and which might be successfully overcome through their efforts.

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