THE FUTURE OF COTTON IPM

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The management of pests has been an integral part of the evolution of the cotton industry in the United States. Particularly since the turn of the century, pest control at certain times has dominated the culture of this high-value crop. Perhaps more than any other crop, cotton has been central to the development of IPM as a science and a philosophy. The intense competition for resources between the plant and the myriad of pests affecting the plant has called for the marshaling of scientists from every discipline within the agricultural sciences. Scientists from the land-grant universities, USDA, and private industry have been relatively successful in developing strategies and techniques to control arthropod, plant pathogen, nematode, and weed pests. Despite significant gains in managing individual pest species, scientists have begun only within the last decade to view cotton production as a system. Cotton production is a highly complex biological, physical, mechanical, economical, and political system in which pests play a significant role. It is at this level that the CIPM project initiated research in 1979. The goal of the project was to develop a better basic understanding of the crop–pest system in order to establish and implement cost effective pest management strategies that increased profitability and were environmentally safe. The primary objective was to examine pests as part of the cotton production system and then to develop control tactics that were in harmony with the system. As this volume attests, CIPM and the preceding Huffaker Project have made significant strides toward achieving this goal and objective.

The cotton industry has undergone considerable change in the last 15 years, and as we look to the future, will undergo even more change as the end of this century approaches. For example, there is a distinct trend for cotton to be produced on larger farms (OTA, 1986). The market share of farms with sales greater than $500,000 increased from less than 7% in 1969 to 48% in 1982 (OTA, 1986). In the same period sales from small farms ($20,000 to $99,000) declined from 56% to 14% of the market. The change in farm size will directly affect management decisions and will have to be taken into consideration in designing IPM systems. In some ways larger farms may facilitate the management of pests by allowing a more centralized, homogeneous approach to pest suppression.

State and federal pesticide regulations have become more stringent. Concerns over human and animal health will continue to escalate as the public demands tighter safety controls on the development and use of pesticides. Because of this, the registration and reregistration process will be more demanding and costly in the future. It appears that there will be a consolidation of pesticide manufacturers into a few large companies that have the research and resource base to meet the regulatory requirements and remain competitive in the production of pesticides. Pesticide manufacturers in general have become more supportive of IPM and see the value of IPM programs as vehicles for the appropriate use of their products.
in the future will find that alignment with IPM programs will continue to be in their best interest.

The use of pesticides near urban centers will become more of a problem in the future as cities expand farther into agricultural lands. This will be particularly true in the cotton-producing states of California, Arizona, and Texas. Specially designed IPM programs will need to be developed that rely less on pesticides at the urban–rural interface. Further, escalating concerns over farm worker safety in relation to pesticide exposure will require more emphasis on precise scheduling of pesticide applications or a switch to non-pesticidal control techniques.

By far the greatest concern is that U.S. cotton has lost its competitive edge in the world market. Developed and developing countries in Africa, South America, and Asia can produce cotton and finished cotton goods more cheaply than we can in the United States. Human capital in terms of labor and management is priced proportionally lower in these countries than in the United States. These countries also subsidize cotton production because they are attempting to gain exports. Cotton is one of the few commodities that they can export for currency which is needed to develop their industrial base. Typically, developing countries tend to rely on a strong, sustained agriculture before they expand into the manufacturing industries. The United States, through various foreign aid programs, has successfully exported its cotton production and processing technology. As a result, the supply of raw cotton and finished goods far exceeds world demand. As demands for cotton increase, hopefully, this situation will correct itself.

The loss of markets for U.S. cotton, tighter pesticide regulation, shifts in farm size, urbanization of agricultural lands, water availability for irrigated cotton particularly in the west, energy needs, and the high per unit cost of production are major factors that will influence U.S. cotton production as we move into the twenty-first century. If the U.S. cotton industry is to survive, new ways must be found to reduce risk in cotton production and make it more efficient. This will call for a reevaluation of research priorities, not only in IPM, but in all areas of cotton production, marketing, and agricultural policy. The future will call for an integrated crop management system that addresses these priority areas. Research must focus on the production–marketing system level. Component research must be well planned so that it fits into and addresses the needs of the overall system.

SYSTEMS RESEARCH—THE FUTURE

Integrated pest management has served as a useful biological, economical, and political paradigm for the last 20 years. The next logical paradigm that will carry us into the twenty-first century is to consider cotton production, and the research supporting cotton production, as a highly complex and dynamic system. Researchers and managers can no longer afford to take a
narrow focus. The control of a single pest species involves much more than the selection and application of a pesticide. Financial, environmental, and social costs must be considered. The multiplicity of complex factors that make up the cotton production system should not hinder researchers from addressing the problem. In fact, much of the groundwork to examine the cotton production system systematically in its entire biological, physical, mechanical, economical, political, and social construct has been established through the application of systems science to pest control. As this book attests, one cannot even consider the theoretical base or management actions without at least attempting to understand relationships within the entire cotton system.

**Integrated Crop Management Systems**

El-Zik and Frisbie (1985) proposed an integrated crop management system (ICMS) approach to cotton production. The goal of ICMS is to maintain and protect plant health by coordinating all interacting crop production and pest control tactics. In the form of a conceptual model, the authors identified the significant agronomic and pest management practices necessary to achieve this goal. Chapter 3 provided the theoretical and conceptual basis for the biological and economic interactions within the production system. They examined the problem in terms of energy flow budgets and economic budgets among the various trophic levels within the cotton–pest system. Naegle et al. (1986) suggested that the migration from IPM decisions to decisions at the production/marketing system level would require new and unique computer decision aids, such as decision support systems and artificial intelligence—specifically expert systems. To address the system at this level, knowledge that supports decisions must be available in the form of technical information, simulation models, and expert opinion.

The question then becomes how to construct a system that is capable of addressing the primary biological, economic, and policy issues embodied in the efficient and profitable production of cotton? Using artificial intelligence technology, a farm-level expert system for cotton is being developed for the southern Blacklands of Texas (Stone et al., 1986, 1987; Frisbie et al., 1987; Richardson et al., 1987; Sporleder and Malick, 1987). The expert system COTFLEX is a prototype integrated expert system shell for cotton production that incorporates production-level, marketing-level, and policy-level decisions. The system integrates and subjects technical information and output from biological simulation models and econometric models to expert interpretation before providing a user with recommendations. Users will be cotton growers, financial institutions, extension personnel, and as will be discussed later, research administrators and strategic planners. Stone et al. (1986) described COTFLEX as having five basic components: the user interface, the inference engine, a modular knowledge base (rule base), a simulation controller (simulation driver) interface with an economics component
In order to identify the major events and decisions that COTFLEX addresses, a Production Decision Timeline (PDT) was developed, based on the El-Zik and Frisbie (1985) model and expanded by Stone et al. (1986) and Frisbie et al. (1987). The PDT (Fig. 14.1) divides the production system for the entire year into five major categories termed “advisors”: agronomic practices, pest management (diseases, insects, and weeds), crop-mix decisions, marketing decisions, and policy decisions. The PDT not only identifies the major decisions or production events for each advisor, but also identifies the decision linkages between advisors; hence the integration of decisions at various levels is addressed. The translation of the PDT into COTFLEX requires a modular design of the five principal advisors, consisting of sets of component expert systems (CESs) that allow COTFLEX to address broad problems while keeping the detail and scope of individual CESs tightly defined (Stone et al., 1987). Component expert systems can be inserted into the COTFLEX shell and delivered to users as they are developed: for example, pest management advisor (Stone et al., 1987), crop-mix advisor and farm policy advisor (Richardson et al., 1987), and marketing advisor (Sporlider and Malick, 1987).

Expert systems such as COTFLEX; CALEX, a cotton expert system for California (Plant et al., 1987; Wilson et al., 1987; Goodell et al., 1987); and COMAX/GOSSYM, an expert system/cotton plant simulation model for the midsouth (McKinion and Lemmon, 1985), represent approaches to addressing IPM within the context of the entire production system. This work signals a major breakthrough in holistic decision making at the farm level by providing a method of identifying, assembling, and making available technology useful to the grower and manager. The process of constructing expert systems is very useful in identifying missing information, thus forming the basis for the strategic planning of future research needs. Expert systems allow an overview of the cotton production system which is quite useful in identifying component research and making priority assessments necessary to enhance production efficiency and profitability.

Simulation Modeling

The development of crop and pest mathematical simulation models has been the center of systems-oriented research for the last 15 years (Chapters 3 and 4). As a result, an extensive theoretical knowledge base has developed that has led to a much improved understanding of the fundamental biological and ecological processes that govern plant growth and pest population dynamics. Simulation modeling will remain an excellent tool for identifying conceptual weaknesses in understanding crop-pest systems. Modeling, along with well-targeted field experimentation, is a very efficient way of developing relationships or biological understanding when the collection of field data may
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Figure 14.1 A production decision timeline for designing the cotton expert system: COTFLEX.
be too time consuming or expensive. Modeling enables interpolation of data from limited but well-defined field experiments. Data from experiments allow the appropriate bracketing of a biological response that in turn may be simulated through modeling.

There will be even more of a trend in the future to use simulation models for real-time management decisions and for strategic planning and evaluation of pest management alternatives. Simulation models will be embedded in larger, crop production–oriented computer decision aids. The previous discussion on farm-level expert systems serves as a good example. Crop and pest, or linked crop–pest models will also become more available as stand-alone decision aids. Models will also be used on a regional basis to evaluate area-wide trends in crop yields and the pest impact.

Of great significance, will be the integration of biological and economic simulation models (N. D. Stone and J. W. Richardson, pers. comm.). Significant biological factors, such as simulated loss of yield from a pest(s) will be linked to econometric models, which in turn will provide an instantaneous assessment and recommendation of the optimum economic strategy to follow. The usefulness of simulation models will become more apparent as they are adopted by cotton growers using computer technology. As individual models and larger systems become more publicized, the extension services will be called upon more frequently to provide training to farmers.

**COMPONENT RESEARCH NEEDS—THE FUTURE**

Component research is still the level at which most researchers contribute. It is essential, however, that component research show a relationship and consider linkages to other components within the entire production system. In brief, component research must take on a systems perspective. In particular, biologists working in cotton production and protection research must gain a sense of how their work relates to the economic structure of the crop. If the U.S. cotton producer is to regain a competitive edge in the U.S. and world market, research must be directed toward producing an acceptable yield at the lowest per unit cost. Although economics and U.S. and world agricultural policy will continue to overshadow cotton production even more acutely in the future, researchers must also be cognizant of external social and environmental factors that have a bearing on production. The following sections summarize future research and educational needs and address major trends for component research relative to IPM and cotton production.

**Genetic Improvement of Cotton**

The cotton plant is the fundamental integrator of all resources supplied by nature and human beings. The goal of geneticists and plant breeders will continue to be to produce germplasm that possesses the characteristics of
high yield and superior fiber and seed quality. Technological advances in the spinning and weaving of cotton has set the terms for acceptance by the industry. To meet these terms, heritable fiber quality traits in need of improvement are strength, tenacity, length and length uniformity, elongation, fineness, and maturity.

The ability of the plant to tolerate biotic and abiotic stresses is essential to the economic production of cotton with acceptable yield and fiber qualities. Plant breeders and geneticists have made tremendous strides (Chapter 8) in the development of germplasm that is resistant or tolerant to pest, environmental, physiological, chemical, and nutritional stresses. There is still much to be done in the future. The cotton plant of the future will have to be a more efficient user of water, nutrients, and solar radiation. As water becomes less available, drought resistance must be increased in both irrigated and dryland production systems. A better understanding of the plant’s nutritional requirements and its efficiency in converting solar radiation to plant energy will require that plant physiologists and cotton geneticists work together more closely. The future will also call for more aggressive approaches of acquiring, maintaining, and distributing diverse and usable germplasm. Novel methods must be found to modify germplasm through classical genetic manipulation and biotechnology (genetic engineering). Plant cell and tissue culture methods such as protoplast isolation, fusion, and culture are essential for the regeneration of plants containing genetically altered material. Systems of breeding must be developed that focus on developing germplasm with multiple stress resistance. The multi-adversity resistant (MAR) breeding program is an example of such a system (Chapter 8).

More demands will be placed on geneticists and cotton breeders to incorporate higher levels of pest resistance. The control of insects, plant pathogens, nematodes, and weeds still represents a significant portion of production costs. The development of cultivars that inherently resist stresses induced by pests is one of the most cost-effective means of minimizing damage and maintaining plant health. The incorporation of pest resistance into cultivars that possess high yield and improved fiber and seed characteristics is yet another challenge.

The recent deemphasis on cotton genetics and breeding by federal and state research agencies and the private sector will be a major obstacle in taking advantage of the newer biotechnologies. This curtailment will severely retard historically strong cotton breeding programs. If U.S. cotton producers intend to be serious contenders in the cotton markets of the world, they must insist on an immediate expansion of genetic improvement programs. These programs represent the future of the U.S. cotton industry.

**Cultural Management and Pest Control**

Cultural management of a crop is one of the most significant ways that farmers suppress or control pests. There are strong interrelationships be-
tween cultural tactics used to suppress insects, plant pathogens, and weeds (Chapter 2). The actions taken by the farm manager, be it crop rotation sequence, site selection, cultivar selection, plant population choice, planting and harvesting date preference, water and fertilizer amount and scheduling, pesticide selection and timing, or phytosanitation practices, all relate to pest management. The selection of cultural tactics and their sequence forms the active basis of integrated crop management systems. This is when the fruit of all the systems and component research and experience is borne out in the actual management of the crop.

The tremendous knowledge base on cotton production, and pest management as part of production, does little good unless the research community, and eventually the farm manager, carefully evaluate the impact of single decisions on related decisions within the context of a total cotton production and marketing system. The ability of the farm manager to identify and integrate information into timely decisions will make the difference between profit and loss, or even the survival of the farm as an enterprise. To reiterate, the research base to support these complex decisions again must take on a systems perspective. The production package delivered to farmers via computer or conventional means must be the result of well-planned interdisciplinary systems research among biologists, computer scientists, economists, and in some instances, social scientists.

Quantitative Sampling Procedures and Economic Thresholds

Reliable, simple, and easy-to-use sampling procedures will continue to be a highly necessary requirement of IPM systems in the future (Chapter 5). Biological sampling will form the field-level data base upon which crop and pest management decisions are made. Sampling techniques will continue to be used to build and validate simulation models. Sampling will be of ever-increasing importance in quantifying the relationships of pest effects on plant growth and development. As discussed earlier (“Systems Research—The Future”), damage estimates from field sampling must be translated into real-time economic terms. This will call for a reevaluation of the economic threshold concept to allow the decision maker to assess the costs and benefits of pest control in addition to related crop management decisions (Chapter 6).

Although considerable progress has been made in developing useful and efficient sampling techniques for arthropod and nematode pests, much work needs to be done in developing quantitative techniques for plant pathogens and weeds. Reliable sampling techniques are necessary to describe crop damage functions for most pest classes in order to establish more precise economic injury levels and thresholds (Chapter 6). Sampling techniques that accurately assess natural enemies must be further refined in order to measure their effects on pest mortality and incorporate these effects into the decision criteria. This will necessitate studies of plant, pest, and natural enemy physiological interactions and behavior.
The greatest need for future insect management research resides in the area of multiple pest attack. When two or more species are simultaneously attacking the plant, a threshold(s) must be established that accounts for this phenomenon. Finally, and possibly the greatest challenge of the future, will be greater understanding of damage caused by two or more groups of pests, such as insects and weeds. The use of simulation modeling (Chapters 3 and 4) and expert systems to dynamically integrate pest damage functions is one way to address these problems.

**Biological Control of Pest Populations**

As we enter the twenty-first century, perhaps more than any other single pest suppression tactic, biological control has the greatest potential for research and expanded use. Secondary pest outbreaks, pesticide resistance, and building environmental and social concerns about the use of chemical pesticides is causing the research community and the agricultural chemical industry to reexamine the role, usefulness, and profitability of using biological control techniques in cotton pest management programs. Naturally occurring, endemic, and introduced biological control agents have tremendous suppressive effects on all insect, plant pathogen, nematode, and weed pests (Chapter 7). Benefits that have accrued to the U.S. cotton grower as a result of these agents is astronomical. These benefits will continue to accrue in the future.

To better understand the value of endemic biological control agents, more research is needed to measure and quantify their mortality effects on pests. The rates at which predators consume prey will help establish their efficiency as mortality agents. Once these efficiencies are understood, sampling the number of predators relative to prey will be more useful in making pest management decisions.

The commercialization of microbial pesticides has been most widely exploited in the area of microbial insecticides, most notably nuclear polyhedrosis viruses and certain strains of *Bacillus thuringiensis* (Chapter 7). With few exceptions, microbial insecticides have rarely been as effective as synthetic organic insecticides. Most IPM advocates appreciate the biological control value of microbial insecticides, but from a practical standpoint they have not been that useful in cotton pest management. This will probably change in the future. New techniques in genetic engineering show great promise for selecting or genetically altering insect pathogens to be used as microbial pesticides. Incorporating genetic material from microbial pathogens directly into the plant genome has considerable potential. As a result, insect pathogens will have greater potency or virulence and therefore will be much more attractive for commercialization by pesticide manufacturers. Ideal biological control agents for cotton pathogens and nematodes should grow and thrive in the rhizosphere of the plant and protect against a broad spectrum of soil pathogens.
Strategies and Tactics for Pest Suppression

There has been a great deal of work devoted to the biology and ecology of arthropod, plant pathogen, nematode, and weed pests. Much of this work has formed the basis for the strategies and tactics of pest suppression. As discussed several times earlier, many of these strategies involve several tactics, such as genetic resistance by the cotton plant, cultural techniques, sampling and economic threshold use for pesticide decisions, simulation modeling, and biological control. There remains considerable work to be done on individual pest species to better understand their relationship with the plant and the environment. This understanding will lead to improved pest suppression.

_Insect and Mite Management_ Chapter 10 identifies a number of strategies and tactics available for the suppression of key pests of cotton. Much of the discussion in Chapter 10 relates directly to discussions in Chapters 2 (cultural management), Chapters 3 and 4 (modeling), Chapter 5 (sampling), Chapter 6 (economic thresholds), Chapter 7 (biological control), Chapter 8 (genetic improvement), Chapter 12 (economic analysis), and Chapter 13 (IPM implementation). There are other areas not emphasized in these chapters that will affect the future of insect and mite suppression.

Insecticides and acaracides will continue to have a major role in pest suppression. Much of the work on sampling, economic thresholds, and simulation modeling is designed to help the farm manager make better decisions on the selection of pesticides and the appropriate timing of their use. The agricultural chemical industry has done an amazing job over the last 45 years in identifying, synthesizing, and commercializing insecticides for U.S. cotton growers. The future of insecticide development, and indeed all pesticide development, will change even more drastically by the turn of the century. Registration and reregistration of insecticides with federal and state regulatory agencies will become increasingly more difficult and costly. The public’s negative attitude toward pesticides as a threat to human health and the environment will be even more pronounced. This attitude will affect pesticide legislation, making it even more restrictive. Insect and mite resistance to insecticides will continue to be a problem in the future.

All of the problems related to the development and use of insecticides in the future will call for broad-based research and educational programs in the area of “pesticide management.” Pesticide management will become a major area of focus within IPM. Pesticide management will stress ways to improve pesticide application to reduce nontarget drift; identify pesticide combinations with improved activity; evaluate pesticides with improved, local systemic activity; develop strategies for pesticide resistance management; determine how pest behavior influences pesticide control; understand how the plant affects the toxicity of pesticides; determine the interactive effects of insecticides, herbicides, fungicides, and nematicides on plant me-
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tabolism; and better integrate chemical and nonchemical controls in IPM programs. Pesticides as an IPM tactic are too valuable to lose through misunderstanding and misuse.

As discussed in Chapters 3, 4, 5, 6, and 10, the economic injury levels and economic thresholds of the future will have to be dynamically responsive to changing crop and economic conditions. This will require specific and directed field sampling to provide input data to drive linked biological and econometric simulation models. A better understanding of the pest’s effects on plant damage, both direct loss of fruit and physiological effects, as well as the effects of natural enemy mortality and abiotic mortality, will have to be better defined. Entomologists will need to work more closely with plant breeders to identify behavioral characteristics of pests that can be disrupted by different cotton plant types.

Plant Pathogen Management Chapter 9 describes the biology, ecology, epidemiology, and suppression tactics of plant pathogens attacking cotton. Future research will be directed toward improved understanding of host–pathogen–environment interactions, mechanisms of resistance, and recognition between plants and pathogens. Because many of the pathogens attack the roots of the cotton plant, the basic biology of the organism and its relationship to the rhizosphere–rhizoplane will have to be explored in greater depth. This basic information will be of great help to plant breeders in developing germplasm that is resistant to plant pathogens. This knowledge will also help develop better techniques to disrupt the life cycle of the pathogen through cultural manipulation and other means.

There remains a great need to better quantify changing pathogen populations. This implies improvements in sampling techniques that will allow us to follow the dynamics of the pathogen population and its relationship to the plant. The pioneering work in modeling verticillium wilt (Chapter 3) has already lead to improvements in pathogen–host understanding, spatial distribution of the pathogen, sampling techniques, and pathogen management strategies. The construction of simulation models for other plant pathogens should be the subject of more research in the future. These models will eventually be simultaneously linked with models of other pest groups (insects and weeds). Current techniques in biotechnology that will be useful in developing plants with disease resistance include protoplast fusion and Agrobacterium-mediated gene transfer. Transposon mutagenesis and restriction fragment length polymorphism may be used to identify genes coding for disease resistance and location of genes on a chromosome.

Weed Management Chapter 11 aptly describes the economic importance of weeds as pests, their competitive effects, and the amalgamation of control tactics in an integrated weed management system that is complementary to an economically efficient cotton production system. Research in these areas will continue in the future, particularly on quantifying the competitive effects
of weeds. Inroads have been made in modeling the competitive effects of a single weed species on the cotton plant. This and modeling the competitive effects in time and space of single and multiple weed species should be the subject of future research.

The authors of Chapter 11 took great care to point out the important consequences of weed management strategies, particularly the use of herbicides, to the crop and the environment. Limited information on the interaction of herbicides with other pests and pesticides, both positive and negative, strongly indicates the need for much expanded research in the area of pesticide interactions. Pesticide interactions between diverse groups of pests and other pesticides is further evidence of the need to plan future research using interdisciplinary teams of researchers who have a view of the total crop production system.

Economics of Cotton Production and IPM

The adoption of cotton IPM programs is directly dependent upon increasing grower’s net return and reducing risk. Chapter 12 clearly documents the positive economic impact of insect pest management programs to individual farmers, states, regions, and the nation. The total dollar return from the adoption of IPM programs far exceeds the cost of investment by state and federal research and extension agencies and the U.S. cotton producer. The future will require constant analysis of the economic and environmental benefits not only of insect management programs, but of total crop management programs that embrace the management of all pests.

Research projects such as the Huffaker Project and the Consortium for Integrated Pest Management created a climate and a resource base to carry on IPM-oriented economic research. In fact, in the early 1980s there were over 100 agricultural economists in the United States working on analyzing IPM programs (K. Reichelderfer, pers. comm.). There are probably fewer than 20 agricultural economists working on IPM today. This trend must be reversed in the future. Federal and state funding agencies are calling for more accountability. These agencies will have to fund more research that will provide this accountability in the future.

Discussions in an earlier section ("Systems Research—The Future") pointed out the need for the farm manager to incorporate economic considerations on a real-time, day-to-day basis. It is important to reemphasize the need for providing growers with information for marketing, policy, crop-mix, and financial planning decisions. The future calls for teams of agricultural economists with specific training in marketing, policy risk analysis, and decision theory to join with crop production and pest management researchers to provide farmers and policymakers with information to support these important decisions. A reassessment and refinement of economic injury level and economic threshold concepts (Chapter 6) will require the same multidisciplinary approach.
Implementing IPM

The last 15 years have seen an institutionalization of IPM in cotton production. This institutionalization has come about as a result of federal and state support of Cooperative Extension Service (CES) IPM programs and the privatization of IPM by pest control advisors (agricultural consultants). A natural migration of IPM field services (pest monitoring, soil sampling, and overall consultation) away from CES to the private sector has occurred. CES's current and future role will be the delivery of technology developed by the research community (Chapter 13). The Cooperative Extension Service IPM programs have made substantial progress in developing interdisciplinary IPM programs. This trend must continue in the future and be redirected, to follow research trends, toward establishing integrated crop management programs.

The CES IPM specialist of the future must become more involved in planning and participating in the research process. Research objectives must be set that will directly benefit modern cotton production (Chapter 13). The only way that CES can expect to affect the direction of research will be as an active partner. This will call for some institutional restructuring within the land-grant universities and require them to offer more joint research-extension appointments. It will also require that universities provide equitable professional credit for research and extension activities toward promotion.

In the past, means of technology transfer have been through one-to-one contact, group meetings, and through the electronic (radio and television) and printed media. These methods will continue to be used in the future; however, there will be more of a need for CES specialists to be better trained in computer science. The computer will be used as a communications device, a data processor, and a tool for delivering computer decision aids such as computer simulation models and technical information. Computers will also be the vehicle for delivering sophisticated integrated expert systems as whole-farm decision aids, in which CES specialists will have a major role in developing and delivering.

The CES specialist will be called upon more in the future to help design and implement regional or area-wide IPM programs (Chapter 13). This work will focus on area-wide suppression of an endemic pest (e.g., boll weevil and *Heliothis* spp.), reduction of new pest introductions or reintroductions (e.g., boll weevil and pink bollworm), and regional pesticide resistance management programs. These programs will require specialists to work with diverse groups such as state and federal regulatory agencies, grower organizations, pest control advisors, pesticide applicators, and individual producers.

CONCLUSION

The discussion in this chapter and the entire volume supports a major shift in the philosophy of IPM. The many authors from highly diverse disciplines
and with varying perspectives have independently arrived at a similar conclusion. Integrated pest management can no longer be held separate and apart from management of the entire crop. The economic control of all pests is inextricably bound to the cotton production system; it is inseparable from other management considerations, both agronomic and economic. Future research and education, without doubt, should be included in the context of the cotton production system. It is through this direction that the U.S. cotton producer will benefit most. In fact, it is essential for providing the cotton growers of the United States with the technology that will make them the most competitive in the world. Cotton and other agricultural commodities are a major part of the U.S. economic base. Recent financial problems encountered by the American growers make it even more important that research and educational institutions strengthen programs to increase the flow of technology to agriculture. Further, and of great importance, state and federal government must renew their commitment in support of agricultural research and education programs for the future. The availability of new technology has and always will provide the needed competitive edge for U.S. agriculture.

REFERENCES


