Chapter 30

COTTON INSECT MANAGEMENT: A LOOK TO THE FUTURE

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INTRODUCTION

Integrated pest management (IPM) is the most logical, ecologically as well as environmentally, approach for arthropod population management presently and in the foreseeable future. IPM, which is based on coordinated use of multiple tactics to keep arthropod pest damage below economic injury levels, is focused on long-term sustainability. History has shown that unilateral use of single tactics, that typically offer only short-term, quick-fix solutions for pest problems, often result in disastrous consequences, i.e., resistance to insecticides and acaricides, pest resurgence, secondary pest outbreaks, and environmental concerns. (Newsom 1975, Luckmann and Metcalf 1982, Rabb *et al.,* 1984, Graves *et al.,* 1991a).

Because IPM is resource management under an umbrella of sound ecological practices, it requires little thought to discern how complicated it is to develop and maintain economically and environmentally acceptable arthropod management systems. By the time increments for a control system are researched, tested and found to be adequate, the cropping scheme may have changed substantially. For example, an increase in a particular crop's acreage or a decrease in another alters the ecosystem, often causing a substantial change, quantitatively and qualitatively, in insect and mite populations. Moreover, weather patterns shift, new technology becomes available, additional regulations are enacted, sociological changes occur, marketing expectations may not be realized, international interactions occur and so on, *ad infinitum.* Despite these complications, future IPM systems ultimately must evolve to address pest complexes rather than just individual pests (Newsom 1980, Phillips *et al.,* 1989).

FUTURE COTTON IPM SYSTEMS

Future cotton IPM systems will of necessity be different when one considers: (a) the dynamic nature of cotton production systems; (b) the ever present threat of insecticide and acaricide resistance; (c) the slow rate of development and registration of new, efficacious compounds; (d) the general public expectations for an abundant supply of a variety of wholesome food and quality fiber; (e) the incredibly complex and self-serving national and international political systems dictating agricultural program development; (f) the environmental concerns such as endangered species, water quality, worker protection, and wetlands; and (g) the improvement of plants and animals by genetic engineering.

Development, refinement and adoption of sophisticated IPM systems that will be needed in the future cannot be fully realized without increased commitment of personnel and resources for interdisciplinary research, more trained IPM practitioners to implement IPM programs on individual farms and greater cooperation among cotton producers, researchers, extension personnel, private agricultural consultants, universities, USDA, ARS, industry and regulators, etc. (Newsom, 1975; Huffaker *et al.,* 1978, Smith 1978, Phillips *et al.,* 1989).

Financing the level and intensity of research and development required to evoke a significant change in our present arthropod management strategies challenges the most astute leadership. The assumption that federal and state governments will increase support to land grant institutions and the USDA, ARS may be unrealistic (Huffaker *et al.,* 1978). Cotton "Check-Off" funds seem to be one practical method for providing necessary funding.

Regardless of how sophisticated technology becomes or how effective it may be in the research phases of the program, a well-trained cadre of personnel must be in place in the field to implement the new technology at the user level. Producers cannot be expected to understand all the technical ramifications of the various disciplines involved in complex IPM systems. Land grant institutions must accept the challenge of educating IPM practitioners that are capable of implementing highly sophisticated IPM programs involving every facet of cotton production (Newsom 1975; Huffaker *et al.,* 1978; Smith, 1978, Phillips *et al.,* 1989).

A cooperative atmosphere must be pervasive in developing IPM and production systems. Everything possible should be done to stimulate cooperation and effective interdisciplinary research within the academic community as well as the USDA, ARS. Cooperation among extension personnel, consultants, industry, regulators and, most importantly, cotton producers, enhances the implementation of IPM. Cooperative extension service personnel will be unable to meet all the demands expected of them, because no individual has all the expertise required. Undoubtedly, private agricultural consultants will become an indispensable entity in the adoption of new IPM programs. These consultants are key individuals in any arthropod management venture. County extension personnel should be glad to have them in their area assisting producers with insect, disease, and weed and nematode problems (Newsom, 1975; Phillips *et al.,* 1989).Our emphasis on the need for interdisciplinary cooperation should not be interpreted as an attack on the need for agricultural disciplines. We are simply trying to emphasize the fact that perhaps the lines of the disciplinary fields should be less sharply focused and the lines of interdisciplinary cooperation more sharply focused (Newsom, 1975).

IPM CONSTRAINTS AND OPPORTUNITIES

Eight of the many important areas covered in preceding chapters of this book are discussed below in relation to, and with emphasis on, future research and development of new technologies for cotton insect and mite management systems.

1. SAMPLING PROCEDURES. For many years, we have relied primarily on the sweep net and examination of individual plant parts to assess pest populations. These sampling procedures are not only slow but often lack precision for many pests. More rapid and more precise methods for sampling arthropod populations are desperately needed. We must broaden our vision in seeking improved sampling technology (Kuno, 1991; Hutchins, 1993; Pedigo, 1993).

Pheromones undoubtedly will have an increased role in sampling technology (Campion, 1994; Ingram, 1994; King, 1994; Smith and Harris, 1994). However, quantification of catch data from pheromone-trapping devices must become much more precise and timely. The development of sensors that can detect the presence of insects does not seem unreasonable. Perhaps in the future, permanent sensors could be placed in fields and the information gathered fed to a model for assessment and evaluation. Portable sensory devices may be a more realistic expectation for the near future.

Whatever the technology developed, it must be far more precise and timely than presently available. If we are to initiate action on numbers, then we must have an accurate means to determine those numbers. To reemphasize, little if any significant improvements in our existing pest management systems for cotton insects, or for any insect, will be realized until more dependable, precise and timely insect sampling techniques are developed. Adequate assessment of beneficial organism populations is equally important as is the assessment of pest complex populations.

2. ECONOMIC INJURY LEVELS. The greater the emphasis placed on managing insect populations, the greater precision must be for assessing the potential loss from a given population density. In addition, these population density thresholds must be based to a large degree upon the expectations of the cotton producer and his financial situation. We must provide him with the technology that apprises him of what a population of pest insects means with regard to potential yield and quality losses. The producer then must decide if he is willing to take the loss or initiate the necessary control strategies. The same type information must be forthcoming for the beneficial insect and mite populations. The producer must be apprised of the levels of natural enemies including expected impact on pest species and their damage. Some computerized advisory systems already have been developed that aid producers in making treatment decisions (Gutierrez and Wang, 1984; Naegele *et al.*, 1985; Mumford and Norton, 1994).

We must develop a much improved data base for the interaction of pest species with various cotton cultivars. The database must be developed around an ability to understand and interpret growth and fruiting patterns of the cotton plant. We already know that the cotton plant provides indicators of such important phenological events as fruit set, fruit retention and "cutout". There can be much more improvement in economic injury levels once we understand better the biology and physiology of the cotton plant (Reynolds *et al.,* 1982; Wilson, 1993; Matthews, 1994). Economic injury levels for pest complexes also must be developed. One approach already being used is to lump pests that cause similar damage together, *i.e.,* defoliators and pests causing fruit loss. (Newsom, 1980; Newsom and Boethel, 1985).

3. AREAWIDE PARTICIPATION. Data are available to show that with some pest species, e.g., boll weevil, tobacco budworm, bollworm and pink bollworm, the larger the area involved in a management program, the more effective the program (Newsom, 1975, 1980; Frisbie, 1985). Substantial planning and coordination are required in areawide programs, but the results justify the effort. Within an areawide approach, there are a number of production practices that need coordination. Three of these practices are covered below.

Variety Selection—Variety selection is the initial step to an effective IPM system. If the variety is beyond the producer's capabilities for planting, in-season cultural practices, and harvest, then an IPM approach is severely handicapped. In selecting the variety, a producer must consider the following points: resistance to pests, earliness, soil type, equipment capabilities for planting and harvesting, irrigation, and a general understanding and commitment to IPM procedures. Under some conditions, it may be advisable to have more than one variety in a single operation. However, the more uniform the fruiting characteristics, the more effective IPM tactics might be for any given area (Newsom, 1975, 1980; Matthews, 1989; Graves, 1994).

Uniform Planting Date—One should avoid late planting. Insect and mite population densities are generally highest during late season and the likelihood of encountering populations tolerant or resistant to commonly used pesticides is greatest. Uniform planting aids in synchronizing the occurrence and management of major pests such as the bollworm, tobacco budworm and boll weevil, as well as improves the efficiency of terminating the crop (Newsom, 1975, 1980; Reynolds *et al.,* 1982; Graves, 1994).

Late Season Crop Management—Irrigation and fertilization must be properly managed to mature the crop in a timely manner. Producers often lose many of the early bolls (which are heavier and higher in quality) while trying to mature and harvest late-season bolls. Additionally, early crop maturity reduces overwintering arthropod pest populations and pesticide use. The final phase of late season crop management involves prompt crop residue destruction, which further reduces pest populations by depriving them food and overwintering sites (Bagwell and Tugwell, 1992; Graves, 1994).

4. CROP RATIOS AND SEQUENCES. As far back as the late 1800s, crop ratios and sequences have been implicated in promoting as well as attenuating pest population densities (Gould and Stinner, 1984, Rabb *et al.,* 1984). Obviously, some arthropods are more manageable using this concept than others. For example, the boll weevil, bollworm/ tobacco budworm complex, pink bollworm, and the sweetpotato whitefly have life and seasonal histories responding favorable to large area management of crop ratios/sequences (Butler and Henneberry, 1994; Ingram, 1994; King, 1994; Smith and Harris, 1994).

If research proves that a certain crop sequence or ratio may be utilized to lessen the hazard of infestation by a major pest species, then we believe it would be a sound IPM tactic to do so. Convincing farmers to adopt this approach would be difficult because the profits from producing various commodities vary widely. Perhaps subsidies or other forms of inducement could be used to promote this pest management approach.

5. MIGRATION AND DISPERSAL. Many aspects of the biology and ecology of arthropod pests of cotton insects remain to be elucidated. In terms of information needed to design effective IPM programs, one of the greatest needs is a better understanding of their movement. Local and long range movement of both pest and beneficial species affects almost every facet of arthropod pest management. For example, pesticide resistance management plans, eradication programs, areawide control programs, and quarantine programs must be based on a clear understanding of migration and dispersal of pest species. Management of pests migrating long distances may require international cooperation. On the other hand, chemical control of pests that are stationary or move very little on the host plant can be obtained by complete coverage of the host plant or the use of systemic pesticides (Rabb, 1985; Butler and Henneberry, 1994; Ingram, 1994; King, 1994; Smith and Harris, 1994).

6. HOST PLANT RESISTANCE. Considerable research has been conducted in cotton to develop plants that are resistant to damage by insect and mite pests. This research has been fruitful. Resistance traits to the major pests have been identified and incorporated into high-yielding cotton varieties (Bird, 1985; Gannaway, 1994). In our opinion, if the available insect plant host resistance technology for several pests, such as tobacco budworm, bollworm, and tarnished plant bug, were implemented on an areawide basis, it would serve to reduce greatly overall population pressure by these pests. This in turn would decrease the need for insecticides ultimately resulting in reduction of risks of insecticide resistance development, environmental damage, destruction of beneficial organisms, and the threat of elevating secondary pests or innocuous organisms to primary pest status.

Several constraints have slowed the adoption and use of arthropod plant host resistance. First, research and extension personnel have not focused enough on plant host resistance to insect and mite pests as an answer to pest management. To the contrary, we have generally "gone with the flow" to rely too heavily on the use of insecticides and miticides. Next, the major seed companies that supply virtually all seed used by cotton producers strive for increased yield first and foremost in their variety development programs (Bridge, 1990). This emphasis on yield as the "bottom line" is fueled by the maximum yield mind set of producers and is based on the assumption that cheap and effective insecticides and miticides will always be available. In our opinion, synthetic chemical insecticides and miticides are a declining resource that are likely to be fewer in number and more expensive in the future (Phillips *et al.*, 1989; Graves, 1994). To add to the problem, most of the current commercial varieties of cotton have been developed under a complete canopy of insecticides. Thus, many of today's varieties are not as resistant to most pests as were varieties a decade or two ago. Recent emphasis in commercial cotton breeding has been on earliness (Bridge, 1990). This has indirectly benefitted IPM systems by markedly reducing the time period of risks to insect and mite damage. As the availability of effective insecticides and miticides decline, we are confident that host plant resistance will play a major role in the future in IPM programs.

7. APPLICATION TECHNOLOGY. One area of technology greatly limiting IPM programs and resulting in considerable environmental damage is the process of applying insecticides and miticides (Hall, 1991). When one considers that approximately 7.5 milligrams of cypermethrin (AMMO®, CYMBUSH®) is all that is required to kill 95 percent of a population of tobacco budworms, even up to 50,000 per acre, if it were applied directly on the pest, it seems incomprehensible that we must apply over 3,500 times this much to achieve approximately 95 percent field control. In fact, it is not unusual for 50 percent of a pesticide applied with an airplane to fail to reach the intended target, the cotton plant (Willis and McDowell, 1987). In addition to the actual application process, the effectiveness of insecticides is often negatively affected by the practice of adding other pesticides, adjuvants, fertilizers and minor elements (Long *et al.*, 1992). Conversely, synergism and other interactions among pesticides occasionally result in phytotoxicity. We are greatly encouraged by the formation of an application systems research group at the USDA, ARS Jamie Whitten Delta States Research Center at Stoneville, Mississippi. This group should advance the science of application technology, which has remained almost unchanged in the United States over the past several decades.

8. CHEMICAL CONTROL AND RESISTANCE MANAGEMENT. Insecticides and acaricides historically have been the primary means of population management for arthropod pests of cotton (Newsom and Brazzel, 1968; Matthews, 1994). The principal factors contributing to the predominance of chemical control include: (a) the large arthropod pest complex which, directly or indirectly, may lower yield and quality of cotton; (b) the lack of effective biological control agents for the boll weevil, a key pest of cotton; (c) the rapid action and efficacy of insecticides and miticides in relation to other suppression components; and (d) the relatively low cost of insecticides and miticides. Deleterious aspects of chemical control such as environmental contamination, acute and chronic toxicity to non-target organisms, pest inducement and resurgence, and insecticide resistance remain as serious constraints.

The continued availability of effective and economical insecticides and acaricides is in question because of: (a) the rapid development of resistance by arthropods to chemicals used for their control (Georghiou, 1990); (b) the increasingly stringent and costly federal and state registration and reregistration requirements; (c) the relatively short effective patent life of new chemicals; and (d) the difficulty in discovering new leads for chemicals with novel modes of action. These developments have increased the cost of developing and registering a new chemical (current estimates range from $50 to $180 million) to such an extent that some companies are no longer active in pesticide research and development (Szczepanski, 1990). In the future, it appears that only a few very large companies will be financially able to compete in the agricultural chemical arena. This trend is already underway and the expected outcome is fewer, more expensive insecticides and acaricides.

Let us reiterate that IPM is the most logical and ecologically sound approach to arthropod population management. Because insecticides and acaricides are generally used in IPM programs only when other control measures (biological, cultural, physical and regulatory) fail to keep pest populations below acceptable thresholds, the availability of effective insecticides and acaricides is necessary for most of these programs to succeed (Phillips *et al.,* 1989; Graves, 1994). Thus, the usage of the declining arsenal of chemicals registered for control of the arthropod pests of cotton must be managed to impede resistance development (Sawicki, 1989; Leonard *et al.,* 1994). Insecticide and acaricide resistance management (IRM) must become an essential part of IPM.

Very importantly, IRM is supported by the chemical industry (Riley, 1989; Hope, 1993). The Mid-South (sometimes referred to as the Tri-State Area) and Texas insecticide resistance management plans represent the first attempts at IRM in cotton in the United States; their initial success is encouraging (Anonymous, 1986; Plapp, 1987; Graves *et al.,* 1991b). Increased research concerning the best utilization of available resources is imperative. Information on how to best use available insecticides and acaricides (*i.e.,* mixtures, alternations, mosaics, rates and timing) will be necessary to ensure effective pest control.

Novel insecticides with modes of action different from presently available chemicals or novel approaches in chemical control are desperately needed because IRM only delays resistance development in most situations. Current research thrusts on insect endocrinology (especially juvenile hormones, hormone inhibitors and biologically active peptides), entomopathogens, allelochemicals, light sensitive porphyric compounds, avermectins, nitroguanidines, pyrroles, phenylpyrazoles and spinosyns offer great hope for the future (Sparks *et al.,* 1993; Graves *et al.,* 1995). Similarly, recent biotechnological breakthroughs in genetic engineering that permit incorporation of foreign genes into insects and plants present new opportunities in arthropod pest management. An excellent example is the development of cotton varieties expressing the gene for *Bacillus thuringiensis* (Bt) (Perlak *et al.,* 1990). Bt cotton has been shown to give excellent control of tobacco budworm, bollworm and pink bollworm (Jenkins *et al.,* 1993).

SUMMARY

Integrated pest management (IPM) is the most logical, ecologically and environmentally, approach for insect population management now and for the foreseeable future. IPM must be based on coordinated use of multiple tactics to keep insect and mite pest damage below economic threshold. Because insecticides are primarily used in IPM programs when other control measures (biological, cultural, physical and regulatory) fail to keep pest populations below acceptable thresholds, the availability of effective insecticides and acaricides is necessary for most of these programs to succeed. However, total dependence on insecticides and acaricides or any other single approach for long term insect management is unrealistic.

Cotton IPM of necessity will be different in the future when one considers: (a) the dynamic nature of cotton production systems; (b) the ever present threat of insecticide and acaricide resistance; (c) the slow rate of development and registration of new, efficacious insecticides and acaricides; (d) the general public expectations for an abundant supply of a variety of wholesome food and quality fiber; (e) the incredibly complex and self-serving national and international political systems dictating agricultural program development; (f) the environmental concerns such as endangered species, water quality, worker protection, and wetlands; and (g) the improvement of plants and animals by genetic engineering.

Some important ancillary issues that will shape IPM in the future are: (a) funding for IPM and agricultural production research; (b) training of IPM practitioners; (c) emphasis on interdisciplinary research; (d) advent of private agricultural consultants; and (e) the roles of the land grant university system, the cooperative extension service, and the federal research and extension programs.

Some present constraints on IPM that provide great challenges for refinement of future IPM programs are: (a) inadequate and inefficient insect and mite sampling procedures; (b) poorly defined economic injury levels; (c) lack of areawide insect population management programs; (d) insufficient information on crop productions systems; (e) lack of knowledge of insect migration and dispersal; (f) underutilization of host plant resistance; (g) antiquated application technology; (h) loss of insecticides due to resistance, regulation, cost of development and difficulty in discovering new insecticidal and acaricidal chemistry; and (i) lack of acceptance of insecticide and acaricide resistance management strategies.

The challenges facing insect and mite management in cotton in the future will be numerous and difficult to surmount. However, we remain optimistic that all challenges will serve as great opportunities to improve and refine present management systems.