Chapter 23

INSECT AND MITE MANAGEMENT IN THE WEST[1]

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INTRODUCTION

Insect and mite pests of western cotton were reported from the earliest cotton production. Insect pressure was relatively light compared to current pest problems and control was limited to use of the few chemicals available and to cultural practices detrimental to the pests.

Pest problems have increased over the years and change has occurred in the methods and materials used to control them. Chemical control became dominant in the late 1940s and is still an important part of integrated pest management systems currently used. Emphasis in current pest management is placed on utilizing a broad base of control components implemented on a community-wide basis.

Research and extension programs have been very important in developing new technology and in information dissemination to growers and others involved in western cotton production.

[1]USDA's Crop Reporting Service, the United States cotton industry and other groups generally include New Mexico in the West region along with Arizona and California. Because of similarities in insect and mite problems and management practices to those in Texas, the authors of the previous chapter chose to include New Mexico in the Southwest region along with Texas and Oklahoma.

HISTORY AND EVOLUTION OF INSECT AND MITE MANAGEMENT

THE MAJOR PESTS

Cotton became an important crop in the desert areas of Arizona and southern California in the early 1900s. Numerous insects were recorded as pests, but prior to the occurrence of the pink bollworm, *Pectinophora gossypiella* (Saunders), damage was primarily from plant bugs, particularly the western lygus bug, *Lygus hesperus* Knight (Morrill, 1918; McGregor, 1961). McGregor (1961) reported that *Lygus* caused an estimated $1,280,000 damage to California's Imperial Valley cotton in 1918. Morrill (1918) recorded *Lygus* as the major pest in Arizona cotton but noted that occasional problems from the bollworm, *Helicoverpa zea* (Boddie); stink bug; cotton leafworm, *Alabama argillacea* (Hübner); cotton leafperforator, *Bucculatrix thurberiella* Busck and other pests occurred. He also reported that lead arsenate, calcium arsenate, Paris green and nicotine sulfate were used to control pest infestations in localized areas. Growers were encouraged to use indirect control strategies such as winter plowing and trap crops.

In the San Joaquin Valley of California, *Lygus* have been the dominant insect pest of cotton since its earliest production in the region. Early management was through cultural practices, particularly weed management and early harvest of alfalfa grown for hay. These practices were of only limited value. While arsenical insecticides were recommended in the early 1940s, they were not highly effective and presented a direct threat to honey bees and dairy cattle. Introduction of the synthetic organic insecticides in the late 1940s revolutionized *Lygus* management on cotton for a time, providing levels of control not previously possible.

Spider mites, particularly the strawberry spider mite, *Tetranychus turkestani* Ugarov and Nikolski, have been pests of cotton since the earliest production in the San Joaquin Valley. Only outbreaks of the strawberry spider mite were common prior to use of the synthetic insecticides. As a result of crop and pest management changes, the twospotted spider mite, *Tetranychus urticae* Koch, and Pacific spider mite, *Tetranychus pacificus* McGregor have assumed major significance as pests of cotton. Major infestations of all species develop on nearby crops, particularly crops under intensive insecticide use, and invade cotton when infestation levels on these alternate hosts are high.

Bollworms have been recognized as pests of San Joaquin Valley cotton since the late 1930s. Outbreaks have been periodic and appear to relate largely to destruction of their natural enemies through use of insecticides against other arthropod pests. Severe outbreaks followed use of DDT and other synthetic insecticides, particularly in the early to mid-1960s.

Whiteflies, particularly the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), have been pests of San Joaquin Valley cotton since the mid-1930s. Associated with the introduction of the synthetic insecticides was a general decline in the occurrence of this pest until the early 1970s. Thereafter, occasional outbreaks appeared associated with excessive pesticide use. Silverleaf whitefly, *Bemisia argen-*

tifolii (Bellows and Perring), although found in greenhouses, was not a pest in the field until 1992, when it was collected from numerous locations in the San Joaquin Valley. Economic infestations occurred in limited cotton acreages in 1993.

CONTROL RECOMMENDATIONS

Early cotton growers in Arizona and California apparently relied heavily upon university bulletins and reports, information from U.S. Department of Agriculture and state agriculture employees, and dealers who sold insecticides for information regarding insect control. This pattern of cotton insects, their control, and assistance provided to growers continued through the 1920s, 1930s and into the 1940s.

University of Arizona and University of California Extension Services began to issue cotton insect control publications in the 1940s that were revised annually. They also provided information to growers through other means such as newsletters, meetings and field clinics. J. N. Roney, Extension Entomologist, began providing recommendations to Arizona growers in 1943.

The earliest records of insect control recommendations for California are contained in letters (1941-45), from Gordon L. Smith, Associate Entomologist, University of California to farm advisors and agricultural commissioners. These letters suggested weed control to eliminate spider mite sources, and early harvest of alfalfa to reduce the threat of *Lygus*; cotton aphid, *Aphis gossypii* Glover, and strawberry spider mite. They also indicated control of *Lygus* and migrating western yellowstriped armyworm, *Spodoptera praefica* (Grote), and hornworm, *Celerio lineata* F., with arsenical insecticides and cautioned regarding the hazards of these chemicals to honey bees and dairy cattle. The use of DDT was included in the letters of Smith after 1945.

Newsletters by Smith (1947), Smith and Bryan (1949) and subsequent authors, to growers and the cotton industry reported the efficacy of several synthetic insecticides, and recommended several organochlorine, organophosphate and other classes of insecticides and miticides. These earliest recommendations contained admonitions concerning the effect of the insecticides on parasitic and predaceous insects and on honey bees.

CHEMICAL CONTROL ERA

The availability of DDT and other synthetic organic insecticides that followed, beginning in the mid-1940s, revolutionized cotton insect control in desert areas of the West. Growers began to rely more and more on chemical control to solve insect problems. A large chemical industry developed that provided not only materials for sale but also fieldmen who sampled fields and recommended insecticides. Often these fieldmen were authorized to take care of the details of application, leaving the grower with little or no involvement in pest control on his farm. An aerial application industry also developed, and in 1958, the Agricultural Aircraft Association Inc., along with a few University of California entomologists, promoted the idea of licensing chemical sales persons (personal letters of Robert van den Bosch and Vern Stern). It was not until 1968, however, that California legislation dealing with the matter was introduced. In

1970, Claude Finnell, California's Imperial County Agricultural Commissioner and local pest control advisors (PCAs) conceived a county ordinance that required licensing and testing. That beginning saw the first chapter of what is now the California Agricultural Production Consultants Association, Inc. (CAPCA). The law requiring licensing and testing was passed and examinations were begun in 1972. Requirements for continuing education were promulgated and CAPCA was fully organized and incorporated in 1975. In Arizona, licensing of commercial applicators and pest control advisors (PCAs) began in 1972, and a continuing education requirement was begun in 1987, involving PCAs and both commercial and private applicators.

Heavy reliance on chemical control of western cotton pests that began in the 1940s continued through the 1950s and 1960s, evolving through an era of organochlorine insecticide use into a period utilizing organophosphates and carbamates. Resistance and residue problems were the primary causes of reduced organochlorine use. Residue levels were especially critical in Arizona and southern California where cotton and forage crops, such as alfalfa, are grown in close proximity. These problems were increased by a shift in the early- and mid-1960s toward automatic treatment programs for cotton that called for applications from planting until harvest. Carter (1966) stated that slowly but surely research was pointing the way to automatic treatment and season-long plant protection. His suggested program to Arizona cotton growers called for three segments of treatments beginning at planting and ending in September. DDT was the first casualty of this period of insecticide over-use as it was removed from university recommendations in 1968 and banned from use in Arizona in 1969 due to residues in forage crops and the resultant adverse impact on the dairy industry. This began an era of increasing restrictions on pesticides use in the West and nationally.

PRODUCTION PRACTICES AND PEST PROBLEMS

A factor that contributed to the evolution of pest problems in the West, particularly in Arizona, was the practice of stub (perennial) cotton production. Stub cotton production occurred except when prohibited by state regulations. The regulations were enacted to deal with increasing pest problems. Pest problems subsided during periods when stub cotton was not permitted, but growers would successfully petition to go back to stub production. It was during and after one of these periods in the mid-1960s that the boll weevil became established in local areas in central Arizona and the pink bollworm spread across Arizona and southern California and became an annual key pest.

Measurable infestations of the boll weevil were not recorded in Arizona cotton from 1966 to 1978, when the growing of stub cotton was banned and mandatory plowdown and planting dates were enforced to maintain a host-free period. During and after the next period of legal stub cotton production, from 1978 to 1982, boll weevils spread across Arizona and southern California (Bergman *et al.*, 1983). Boll weevils were found in stub cotton fields near Gila Bend, Arizona, during 1978 and the spring of 1979. Subsequently heavy boll weevil infestations spread from stub to planted cotton and continued to increase even after stub cotton was banned in 1983. The Arizona

Cooperative Extension, with assistance from experiment station and USDA entomologists, began a program in 1981, to create awareness of the boll weevil problem and to provide assistance to growers in controlling the pest. A California state and grower funded boll weevil eradication program was initiated in 1983, and continued through 1984. It was expanded in 1985 with USDA, State of Arizona and grower assistance into the southern California valleys, northern Mexico, and western Arizona. That southwestern regional program was expanded again in 1988 to include central Arizona. Since 1990 very few boll weevils have been trapped throughout the eradication area and the program is considered highly successful.

The pink bollworm was first found in Arizona in 1926, in Cochise and Graham Counties, and in 1927, in Greenlee and Pima Counties (USDA 1961, unpublished report). Infestations in Pinal and Pima Counties were first reported in 1929, and in Santa Cruz County in 1938. Infestations were sporadic in central Arizona counties until 1958, following increasing levels of infestations in Greenlee and Graham counties in 1956. Concerted eradication efforts of state and federal agencies reduced population levels from 1958 to 1963 in central Arizona. In 1959, only one pink bollworm larva was found despite intensive sampling. After terminating these efforts, stub cotton production was again allowed in 1963, and pink bollworm infestations increased rapidly, spreading across Arizona into the Imperial Valley of southern California in 1965. Infestations spread to Riverside and San Diego Counties by 1967, as well as the high desert area of Los Angeles, San Bernardino, and Kern Counties.

Increased populations of the pink bollworm in the western desert cotton agroecosystem, beginning in 1965, had a profound impact on the social, environmental and technological aspects of cotton cropping and pest management systems. Chemical control to prevent cotton losses was heavily relied upon despite the encouragement of entomologists, as early as 1968, to adopt cultural practices that had been demonstrated to effectively control the pink bollworm (Watson and Larsen, 1968; Rice and Reynolds, 1971; Watson *et al.*, 1973; Moore, 1972). Authority for the appointment of a California Cotton Pest Control Board was provided in the State's Agricultural Code of 1967. Soon to follow were provisions to strengthen the law pertaining to host-free periods and regions as well as to establish mechanisms for assessing monies on a per bale basis. These funds were to be used in control and eradication programs and for research.

INSECTICIDE RESISTANCE

Problems with the organochlorine insecticides during the 1960s caused growers to turn increasingly to the organophosphates and carbamates for cotton insect control until 1977 and 1978, when resistance to methyl parathion, especially in the tobacco budworm, *Heliothis virescens* (F.), resulted in control failure and serious yield losses (Crowder *et al.*, 1979). Thus, the problems of insecticide resistance, destruction of natural enemies and resulting secondary pests, as well as bee poisoning and environmental contamination, did occur as predicted.

Pyrethroid insecticides became generally available in 1979, and were effective against the pest complex of concern in Arizona and southern California. These new insecticides reversed the devastating losses caused by the bollworm/tobacco budworm complex during 1977-78, and have held these pests in a state of minor importance in most subsequent years. On the other hand, other pests, such as spider mites and the silverleaf whitefly that were rarely a problem in the desert areas of the West prior to introduction of the pyrethroids, have become major pests. These two pests, along with mid- to late-season thrips, *Frankliniella* spp., populations, have been noted to increase in association with use of some pyrethroids.

Trends toward resistance to pyrethroids by the tobacco budworm in the early 1980s, and later by the pink bollworm, have brought about resistance management programs that encourage use of other insecticide classes prior to July 1 and at other times when effective. An IPM system emphasizing cultural control practices is very important in resistance management. It is recognized that government "set-aside" programs and fluctuating cotton prices cause annual shifts in planted acres; however, increasing problems just mentioned including pesticide use and cost brought about by the pink bollworm, were largely responsible for a decrease in planted cotton acres in California's Imperial Valley from a high of 143,000 in 1977 to a low of 17,169 in 1986.

EFFECT ON HONEY BEES

Reduced efficiency of honey bees in the West with regard to honey production and crop pollination has been a major problem. Because of the volume of insecticides used on cotton over an extended period, it is the number one crop implicated in bee poisoning and reduced honey production efficiency. The problem was particularly severe during the early period of chemical control where calcium arsenate was used extensively on cotton insects. It reached even higher levels of intensity with the development of certain organochlorines, organophosphates and carbamates. These pesticides vary from relatively non-hazardous to hazardous (McGregor, 1976).

Levin (1970) reported that 70,000 honey bee colonies were killed in Arizona and 76,000 in California. Swift (1969) reported losses in California of 83,000 colonies. Bee colonies in Arizona were reduced approximately 45 percent from 1965 through 1972 (Arizona Agric. Statistics, 1980). The numbers of hives in Arizona have increased from about 77,000 in 1972 to 96,000 in 1985. This improvement has been the result of nighttime pesticide applications, increased use of the less toxic pyrethroid insecticides, improved bee colony handling techniques, and pest management practices that reduced pesticide loads in the bee environment.

INTEGRATED PEST MANAGEMENT PROGRAMS

DEVELOPMENT

Pesticide resistance and development of secondary pest problems along with increased cost of control and other peripheral problems caused concern among western growers and led to development of Integrated Pest Management (IPM) programs (Carruth and Moore, 1973). IPM development followed insect pest evaluation programs known as supervised control that were initiated in California in the 1940s.

Objectives of supervised control included timely use of insecticides related to infestation development and avoidance of unnecessary applications. An extension-sponsored program in Graham County, Arizona, in 1969, led to a pilot IPM program supported by a federal grant for Pinal County, Arizona, in 1971. Following this pilot work, IPM expanded throughout the West and nationally; it remains the predominant method of cotton insect control. IPM is a complex systems approach to pest control that requires good field sampling and use of economic thresholds levels as the basis for a combination of control components. Delivery of IPM resulted in the establishment of grower cooperatives and increased numbers of private consultants capable of implementing community-wide programs as well as those for individual farms.

COMPONENTS AND IMPLEMENTATION

The development of IPM led to broad-based recommendations that promoted a more complex systems approach to cotton insect and mite control (Ellsworth *et al.*, 1993; Toscano *et al.*, 1979; Anonymous, 1984). Control components included cultural practices, host-plant resistance, biological control, microbial agents, mechanical-physical methods and chemical control.

A major consideration of IPM is conservation of and the role of naturally occurring beneficial insects in regulating pest species below economic levels. Natural enemies along with good cultural practices have long been considered by entomologists to be the most important factors in minimizing many insect problems (Graham, 1980). This fact was not fully appreciated in western cotton production systems until the extensive use of insecticides to control pink bollworms in the 1960s and 1970s led to serious yield losses from uncontrollable infestations of tobacco budworms in 1977 and 1978.

Numerous authors have emphasized the importance of indigenous parasites and predators in regulating pest insect populations of cotton, as well as the adverse effect of insecticides in reducing numbers of these natural enemies (Newsom and Smith, 1949; Wille, 1951; Gaines, 1942, 1954, 1955; Ewing and Ivy, 1943; Van Steenwyk, *et al.*, 1975; van den Bosch *et al.*, 1956).

The need to preserve the beneficial insects in western cotton, made evident through outbreaks of secondary pests following *Lygus* control, led to implementation of new alfalfa harvest practices referred to as strip-cut harvesting (Stern *et al.*, 1964) and alfalfa interplanting (Stern, 1969). While not widely adopted by growers, these cultural practices are quite effective and can greatly reduce the threat to cotton by *Lygus* and several other pests. Current grower practice is to closely monitor infestations and to treat for *Lygus* control based on *Lygus* numbers and plant fruiting condition. When therapeutic treatment is needed growers are encouraged to utilize the most selective insecticide.

DISSEMINATION OF INFORMATION

Western growers and pest control advisors are encouraged to consider year-around IPM implementation. Integrated Pest Management for Cotton (1984) is a Western regional publication written by scientists from California, Arizona and New Mexico, that is a complete guide to cotton IPM in the West. Arizona Cotton Insects (Werner *et* *al.*, 1979) and Pest Management Guide for Insects and Nematodes of Cotton in California (Toscano *et al.*, 1979) provide information on identification and biology of insects and spider mites found in western cotton. These publications are supplemented by annually-revised pamphlets and reports and occasional newsletters that provide both chemical and nonchemical alternatives for cotton pest control (Ellsworth *et al.*, 1993; Burton, 1981).

University of California recommendations for use of insecticides and miticides are based on field experiments conducted by university research entomologists and farm advisor cooperators within California. University of Arizona recommendations, however, may also be based upon USDA information or other sources deemed reliable by the person(s) making the recommendations. Not all registered insecticides and acaricides (miticides) are recommended in either Arizona or California. Climatic and cultural conditions as well as length of season differ substantially between California's San Joaquin valley and the smaller, more isolated Coachella, Imperial, and Palo Verde desert valleys. These dissimilarities, along with differences in the components within the cotton insect complex, require attention to local information, situations and regulations as recommendations are being formulated and disseminated.

In both California and Arizona, concern exists within the university systems relative to liabilities associated with recommendations, or, suggestions as they are now called by the University of Arizona. The University of California has revised its "Policy Communication No. 18" (Policy for Pesticide and Related Chemicals Use and Experimentation) and issued a handbook describing the essential elements of compliance requirements for its researchers (Stimmann, 1986). Subjects included are: (a) employer responsibilities and employee training; (b) experiments on or off university property; (c) licensing and certification; (d) written recommendations; and (e) special use authorizations.

Continued urbanization in California and Arizona, and public attitude concerning pest control, will lead to increased restrictions on pesticide use. Greater reliance will be placed on recommendations that emphasize control components such as cultural practices, resistant cultivars and biological control agents to reduce the threat of cotton pests and the need for chemical control.

COMMUNITY ACTION PROGRAMS

PINK BOLLWORM AND BOLL WEEVIL

Communitywide IPM programs have become common in Arizona and southern California. Problems with yield losses and control costs from insects such as pink bollworm, boll weevil and whiteflies, were largely responsible for increased interest in community action groups. A Cotton Pest Abatement District in the Imperial Valley was promoted by growers, and established by California Department of Food and Agriculture regulation in 1982. This regulation required the mandatory application of the pink bollworm pheromone, gossyplure, for all early-season control measures against that pest. With that as a requirement, chlordimeform (Fundal®, Galecron®)

reregistration was allowed and the product was again permitted in that district for a period of five years, subject to restrictions and detailed monitoring by the Department's Division of Health and Safety. Use of chlordimeform products was also permitted in the Palo Verde Valley for the last four of the five years. Imperial Valley growers in California developed a community program within the pest abatement district to help them deal with the pink bollworm and whiteflies, including early crop production, chemical termination of the crop by September 1, followed by harvest and plowdown by November 1. Growers in the Palo Verde Valley have been reluctant to establish regulations calling for crop termination as early as September 1. For the 1993 season however, they did request and receive a variance from the host-free period of January 15 - March 15 to one of January 1 - March 1. Maintaining the 60-day host-free period, they petitioned the California Department of Food and Agriculture to grant a variance for the 1994 season which called for a plowdown date of December 15 and permits planting on February 15. Moving the plowdown to an earlier date forced, although not by regulation, earlier harvest which tends to reduce the extent of diapausing pink bollworm larvae.

In addition, many growers have adopted the practice of winter irrigations, following cotton, to reduce the extent of pink bollworm survival and spring emergence. That cultural control practice has been reemphasized by Beasley (1991). Similarly, most cotton producers in the Palo Verde Valley plant to moisture and strive to water back sufficiently early to promote maximum pink bollworm emergence prior to the hostable square stage of the crop (Beasley, 1990).

Three groups, formed in central Arizona in 1986 and 1987 to combat the boll weevil and other pests, used cultural, chemical and biological control components. Specific control components included: (a) trap crops; (b) delayed uniform planting; (c) pinhead square treatments; (d) in-season control; (e) early irrigation termination; (f) use of harvest-aid chemicals; (g) early harvest; and (h) immediate stalk shredding. All of these programs center around a shortened growing season to place an additional stress on overwintering pest populations. Important to these community action programs are grower and pest control advisor committees that work closely with extension personnel in developing policy and activities. Regular meetings to keep all growers informed are important to program success. A program in the Marana-Avra Valley area uses multiple control components to effectively control all cotton insect pests in the community. The Marana-Avra Growers Task Force oversees the operation of this program in cooperation with extension and research personnel and pest control advisors. The Arizona Cotton Growers Association established a community-wide pink bollworm management program in the Parker area in 1989 in cooperation with local growers. The program was later expanded into the Gila Bend area and to include whitefly management.

Successful results by community action groups have been favorably received by growers and pest control advisors because of improved pest control and reduced adverse environmental impact. This is especially critical in areas of urban-agriculture interface where pesticide use is being increasingly challenged.

SILVERLEAF WHITEFLY

The silverleaf whitefly is a serious problem in Arizona and California primarily because of honeydew production, disease transmission, and yield loss. A complete effective management system for silverleaf whitefly is a goal for the future and at present, is in the early formative stages. However, extensive ecological, biological and fundamental research on the whitefly complex and its natural enemies is revealing many potential components for incorporation into an ecologically-based management system. Some crop management and community-oriented farm practices are being implemented in an effort to provide overall whitefly population reduction. The extensive cultivated crop host range, wild weed hosts and urban ornamental and weed hosts combine to provide a year-long spatial (relating to space) and temporal (relating to time) continuum of host biomass that provide food, shelter and reproductive substrate throughout the year. The resulting complex interrelationships of types of cultivated crops, crop growing sequences and urban community hosts have an impact and are of concern to the entire farm community in whitefly population development.

Areawide community-involved approaches to silverleaf whitefly management have the best possible chance of success. The cotton grower in a farming community must give careful consideration to the status of winter-spring cultivated crop sequences in proximity to prospective cotton planting locations. Although, low silverleaf whitefly populations occur on vegetable crops such as broccoli, lettuce and cole crops during October through February and March, populations developing in early spring melons increase dramatically in April to May and high numbers move to cotton. Thus, early harvest and melon crop residue destruction and plowdown is an essential silverleaf whitefly management component for the cotton grower.

Uniform, optimum cotton planting date scheduling may help escape high, early-season infestation levels. Planting upwind of infested or potentially infested cultivated crop hosts is a further precaution to managing early-season infestations. Smoothleaf cottons support lower silverleaf whitefly population levels than hairy-leaf cottons. Also, short-season cotton types to develop an early maturing cotton crop for early harvest and crop destruction are effective in reducing overall population densities in areawide farming community programs.

Water and fertilizer management are important factors in silverleaf whitefly management. Although the mechanisms involved in the complex interaction of the host plant condition and whitefly population dynamics are largely unknown, silverleaf whiteflies increase dramatically when cotton plants become stressed. Thus, frequent and adequate irrigation during the season delay the occurrence of high population densities.

Several insecticides alone or in combination have been found to provide adequate silverleaf whitefly control. Special attention must be given to good coverage, particularly to underleaf surfaces. Insecticide resistance is a particularly important factor in whitefly management. It is important to avoid using materials in the same chemical class for extended periods. Frequent population monitoring of the adult and immature populations on leaves is critical to assess effectiveness of control strategies. Definitive economic threshold values have not been established but high population levels cause severe defoliation and reduced yield as well as sticky cotton.

Late-season cotton crop and silverleaf whitefly management must be carefully planned and carried out. Logarithmic population increase of silverleaf whitefly populations begins in late July and early August shortly after peak cotton flowering. Thus, the cotton plant is subjected to increasing stress from whitefly feeding during the period of boll maturity and boll opening with increasing numbers of open bolls exposed to accumulations of honeydew. The critical timing of irrigation termination, defoliation and harvest leaves very little margin for error, but must be accomplished as early as possible considering optimal yield.

SAN JOAQUIN VALLEY PROGRAM

The current IPM program for cotton in California's San Joaquin Valley places major emphasis on pest detection and infestation monitoring (e.g., presence/absence sampling for spider mites). This provides for avoidance of unnecessary insecticide use and for timely scheduling of management practices. Biological control provides an opportunity to suppress pest infestations. Where insecticides or miticides must be applied, use of the more selective materials is encouraged. Use of broad spectrum pesticides during July, when the threat of lepidopterous pests is high, is discouraged.

FUTURE PROGRAMS

Pesticide regulation, especially water quality legislation and the Endangered Species Act, is reducing the flexibility of chemical pest control. It is this reduced flexibility that also may be accelerating, rather than delaying, the development of resistance to some chemicals by some insects (Trumble and Parella, 1987). This places added importance on the continued development and implementation of alternative control practices packaged as IPM community action programs.

EDUCATION AND EXTENSION LEADERSHIP

A major portion of the cotton acreage in Arizona and California is monitored for arthropod pests by trained personnel. Some of the larger farms utilize a permanent employee, supplemented by additional summer assistants, to monitor fields. Many cotton growers retain the services of private consultants who advise them of pest management needs and other practices. In some cases, however, growers rely on the representatives of pesticide retailers despite efforts from some groups to allow licensing of only crop consultants and/or pest control advisors who have no vested interest in sales. Extension educational activities such as meetings, publications and demonstrations are important in meeting the training needs and continuing education requirements of field monitoring personnel.

Continued efforts to improve grower acceptance and use of new IPM strategies and technologies are underway throughout the West, as well as in other cotton producing regions. Some examples may be seen in the University of California's IPM implementation program. This program was first established in 1981, by annually appropriated money from the State General Assembly and is now an in-line part of the University of California budget. The UC IMPACT computer network has, since 1982, provided a number of programs and databases to mini-computers housed in county extension offices. These include degree-day and phenology (relationship of climate and biological phenomena) models for the pink bollworm and cotton developmental stages, a comprehensive meteorology database for over 125 reporting stations, three-day agricultural forecasts, and realtime data for over 100 stations. In addition, information on biologies, monitoring guidelines and control tactics are available by computer for most important insect, weed, pathogen and nematode pests. The system has recently been made available by phone line to microprocessors of individual growers, pest control advisors and other interested persons. A similar system, known as AZMET, is operated by the University of Arizona. In addition to on-line computer data, the Arizona system provides weekly advisories (newsletters) that include localized information on heat unit accumulations, agronomic conditions, and insect control recommendations. Cotton models, including COTSIM, are being produced for microprocessors and expert systems are being developed for assisting in decision making by owner/operators, managers and pest control advisors.

The last 15 to 20 years have seen much activity in IPM research and implementation. Refined detection and sampling methods, coupled with a better understanding of the pests, their natural enemies and the cotton plant, have resulted in highly developed management recommendations (Anonymous, 1984). Research and implementation efforts must continue and interdisciplinary information exchange must expand in order to offset increasing problems of pest resistance, production costs, reduced availability of chemical control materials, expanding urbanization, environmental contamination and human health concerns.

SUMMARY

Western insect and mite management has evolved through periods of relatively light pest conditions to increased pest problems and changes in the methods and materials used to prevent or reduce their damage.

Synthetic organic insecticides were very important in reducing pest damage and increasing yields. Problems developed however from pest resistance, secondary pests and environmental hazards. These brought about integrated pest management programs that emphasized use of multi-component systems designed to reduce insecticide input. These systems are being implemented on a community-wide basis using cultural, biological and chemical components that attack weaknesses in the biology and ecology of key pests.

Extension educational programs have played a key role in creating awareness, disseminating information, and demonstrating new technology to western growers. It is important that research and implementation efforts continue and expand as a means of helping growers meet the challenges of the future in environmentally sound, cost effective insect and mite management.