Chapter 21

INSECT AND MITE PEST MANAGEMENT IN THE MID-SOUTH

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INTRODUCTION

The success of cotton insect management in the Mid-South region (Arkansas, Louisiana, Mississippi, Missouri and Tennessee) is easily seen by the presence of the multitude of cotton scouts, consultants and advertisements by commercial companies on the role of products in pest management. However, the development of insect pest management has not been easy and has often been wrought with controversy when new management practices were implemented. The broad based insect management system has resulted from years of research, experience, observation, and often trial and error on controlling cotton insects. The insect management system has evolved into a successful strategy that considers several biological factors in insect control with the ultimate objective of achieving optimum profits for the cotton producer. The overall management system will be discussed in detail in this chapter with special emphasis on each insect that occurs in this region.

HISTORICAL ASPECTS OF INSECT AND MITE MANAGEMENT IN THE MID-SOUTH

The cotton plant seems to have been designed by nature to attract insects. It has large succulent leaves, many large, open flowers, nectaries on every leaf and flower and abundant fruit. It is a ready-made haven for insects, some beneficial to man and some — the cotton leafworm, bollworm, tobacco budworm, boll weevil, cotton aphid, pink bollworm, cotton fleahoppers, tarnished plant bug, rapid plant bug, thrips, southern green and green stink bug, spider mites, and grasshoppers — very destructive.

Records from the eighteenth century show that the cotton leafworm was the first insect of major importance to the early cotton grower. In some years it destroyed 25 to 90 percent of the cotton.

In the early nineteenth century, the bollworm entered the picture. The biological differences between the bollworm and the tobacco budworm were not yet recognized, thus damage estimates attributable to either of these species are imprecise.

The chief source of cotton-insect research information was the individual cotton grower during the first half of the nineteenth century. In fact, it was a grower who first reported that the bollworm and the corn earworm were the same insect. This type of information was disseminated by letters, newspapers, and word of mouth.

Growers often found it unprofitable to grow cotton because of insects. As the country grew and cotton production increased, other insect pests made their presence known. In 1855, stink bugs and aphids were serious pests of cotton. It soon became evident that the federal government must aid cotton growers, so the Congress directed an investigation of cotton insects in 1878. These studies were directed at life histories, habits of destructive species, effects of natural enemies and cultural control methods. These studies provided much of the background information for later control efforts.

In 1892, the boll weevil crossed the Rio Grande River near Brownsville, Texas, and by 1894 had spread to six counties in southern Texas. It continued to advance at a rate of 40 to 160 miles a year and by 1922 had infested 85 percent of the Cotton Belt. Damage by the boll weevil varied greatly. Most farmers continued to grow cotton because about 95 percent of the hibernating boll weevils died and many that survived the winter died before cotton produced squares. Hot, dry weather, insect parasites and predators and birds also helped reduce populations.

The use of cultural control methods was recognized as a valuable aid in the control of insects and is still used even today. The use of early fruiting cotton varieties, early planting, frequent cultivation, clean culture, cleaning up debris in fence rows around fields and fall and winter plowing were utilized to lessen the damage caused by insects.

Artificial methods of control were attempted with varying degrees of success. Some of the methods used by both professional and lay research workers were attractants and repellents, poisoned baits, fires in fields at night to attract insects, mechanical devices for dislodging and collecting insects and hand-picking insects off of cotton.

Plant breeders played a vital role in the control of cotton insects during the early 1900s. They developed fast growing and early maturing varieties so that the cotton could be produced and matured before insects had time to build up to maximum numbers. They undertook studies to develop varieties that could better withstand insect attack and could produce additional fruit after insect damage had occurred.

Research on controlling cotton insects using various chemicals applied as sprays began in the early 1900s. As early as 1905, Paris Green was recommended as a spray to combat some insects. London Purple and arsenate of lead also came into general use. However, methods of application were crude and probably accounted for much of the ineffective control.

In 1908, lead arsenate was first used in dust form for insect control. From 1908-1916, dusts of lead arsenate, Paris Green, and London Purple were used against cotton leafworm. In 1916, calcium arsenate dust was found to be highly effective against some cotton insects. For the next three decades, research on control of cotton insects was largely devoted to developing dusts, dust mixtures and methods of application.

In 1917, the pink bollworm was discovered in Texas. Research efforts to control this pest were doubled in the areas of biology, ecology and control. This research provided the basis for the successful prevention of its spread to the Mid-South cotton producing areas through quarantine regulations and control efforts.

By 1920, calcium arsenate was a proven effective insecticide against the boll weevil, bollworm and cotton leafworm. Ground machines and airplanes were used to apply millions of pounds of calcium arsenate annually. Nicotine sulfate was used to control the aphid. Sulfur was proven effective against the cotton fleahopper, other plant bugs and spider mites.

In response to a shortage of cotton after World War I, acreage expanded. Intensive cultivation created new insect problems. Insects that previously were thought to be confined to other hosts were found in cotton. During this time, the cotton fleahopper, plant bugs, aphids, thrips, spider mites and stink bugs were all recognized as serious pests.

After World War II, new and more active organic insecticides entered the scene. DDT was the first to be tested extensively, followed by benzene hexachloride, toxaphene and chlordane. Although many of these were effective against certain insect pests of cotton, none individually controlled all the major pests. In the late 1940s and early 1950s, aldrin, dieldrin, parathion, methyl parathion, heptachlor and EPN became vital parts of the arsenal of available pesticides.

Following widespread use of the chlorinated hydrocarbon insecticides (DDT, benzene hexachloride, aldrin, dieldrin, heptachlor, toxaphene, chlordane and endrin), resistance of cotton pests to insecticides developed quickly. Since 1947, more than 25 species of cotton insects and mites are known to have developed resistance. Each new class of insecticide gave way to resistant insects in only a few years. These include (in chronological order of their appearance) chlorinated hydrocarbons, organic phosphorus compounds, carbamates and the most recent pyrethroid compounds.

BOLLWORM AND TOBACCO BUDWORM RESISTANCE

The two species of "Heliothis", *Helicoverpa zea* (Boddie) and *Heliothis virescens* (Fabricius), the bollworm and the tobacco budworm, respectively, are the most widely distributed major pests of cotton. Before the 1940s, management of bollworm/tobacco budworm populations consisted largely of avoiding problems when possible and living with them when necessary. Crops were planted at times and in areas where bollworm/tobacco budworm damage would be less and a certain amount of damage was tolerated. Control of cotton insects with insecticides was moderately successful prior to World War II using natural or elemental compounds such as rotenone, pyrethrin, and the arsenic and fluorine containing insecticides.

By the mid-forties, these compounds were largely replaced by organochlorine (chlorinated hydrocarbons) insecticides. DDT was the most widely used compound; other insecticides used were endrin, toxaphene and aldrin. These insecticides, especially DDT, were cheap and highly effective in controlling bollworms/tobacco budworms. This led to the widespread and heavy use of organochlorines. By the late 1950s, control failures were reported by growers using DDT. This decrease in susceptibility was well documented in the early 1960s. Resistance in bollworms was reported in Mississippi (Pate and Brazzel, 1964), Arkansas (Lincoln *et al.*, 1967) and Louisiana (Bradley *et al.*, 1966).

Widespread resistance in tobacco budworm to organochlorines was reported in Mississippi (Snow and Brazzel, 1965) and Louisiana (Graves *et al.*, 1967). By 1970, DDT resistance had been documented in twelve states for bollworm and eight states for tobacco budworm (Sparks, 1981); five states had reported bollworm resistance to endrin and three states to carbaryl (Sevin®). By 1980, tobacco budworm resistance to endrin was reported in twelve states, to carbaryl in eleven states and to toxaphene in four states (Sparks, 1981).

Organophosphate insecticides were used extensively during the 1950s, in part due to the widespread resistance to organochlorine and carbamate insecticides. The organophosphate methyl parathion was the most commonly used insecticide to control bollworms; it was cheap, plentiful and highly efficacious. However, by 1967, bollworms had developed resistance to methyl parathion after ten generations of selection in the laboratory (Carter and Phillips, 1968). Resistance to methyl parathion was reported in Louisiana (Graves and Clower, 1971; Graves *et al.*, 1973), and Mississippi (Harris, 1972). Other organophosphate insecticides to which resistance was reported were monocrotophos (Azodrin®), EPN and parathion; resistance to carbamate insecticides was also reported. Bollworm and tobacco budworm had developed resistance to all three of the major classes of insecticides before 1970 (Mullins and Pieters, 1981). By the late 1970s these two species had developed resistance to most organophosphate insecticides in all cotton producing states (Sparks, 1981).

During the late 1970s, pyrethroids were brought into full scale use, in part due to the widespread occurrence of resistance in the bollworm/tobacco budworm complex. Pyrethroids quickly became the most widely used group of insecticides in the United

States. By 1984, laboratory tests showed increasing tolerances to pyrethroids (Crowder *et al.*, 1984). Field control failures were reported in 1985 and increased reports of failures occurred through 1993. Extensive monitoring of pyrethroid resistance using an adult moth vial-testing technique was carried out in most cotton producing states and resistance was shown to be increasing (Graves *et al.*, 1988).

Pyrethroid resistance monitoring in Louisiana from 1987 through 1992 indicated a gradual increase in the survival of tobacco budworm moths at the ten microgram discriminating dose (Graves *et al.*, 1993). The tests showed overall survival increasing from 15 percent in 1987 to 40 percent in 1992. Similar trends were observed in Arkansas and Mississippi during the same time period. The overall field performance of pyrethroid insecticides for control of tobacco budworm has declined with increased reports of failures throughout the Mid-South cotton producing region.

BOLL WEEVIL RESISTANCE

Boll weevils require frequent application of insecticides to maintain control. DDT was the first effective organic insecticide used to control boll weevils and, as in the case of bollworm control, was widely used in large quantities. Organochlorine (DDT, others) resistance in the boll weevil developed first in Louisiana and Mississippi in 1954 (Roussel and Clower, 1955), but the problem soon spread to other states. By 1960, all areas of the Mid-South and Southeast infested by boll weevil had reported the development of organochlorine resistant weevils (Brazzel, 1961).

The organophosphate insecticides replaced organochlorines after the occurrence of widespread resistance. Methyl parathion, one of the more widely used insecticides, is still a very effective insecticide when used for boll weevil control. In addition, another organophosphate insecticide, azinphosmethyl (Guthion®) still provides good control.

BEGINNING OF COTTON PEST MANAGEMENT IN THE MID-SOUTH

Cotton grower's limited knowledge concerning insect pest problems and lack of expert personnel to advise on the proper use of insecticides resulted in growers using insecticides excessively when first introduced. Broad spectrum insecticides and insecticide mixtures were applied as many as 16 to 18 times during the growing season. By 1955, excessive use of insecticide had selected populations of boll weevils that were resistant to several insecticides and secondary pest problems had increased.

The need to determine when and how to use the synthetic organic insecticides was recognized almost as soon as they became available. Entomologists such as Dr. Dwight Isely and Dr. Charles Lincoln in Arkansas, Dr. Leo Dale Newsom, Dr. John S. Roussel and Dr. Dan Clower in Louisiana, and Dr. Ted Pfrimmer and Dr. James R. Brazzel in Mississippi were instrumental in researching insect scouting techniques and economic thresholds.

Pioneers in the area of private insect consulting emerged in 1947 and 1948. In Louisiana they were Ralph Penneull and Ray Young, who did so with the encouragement of Dan Logan, a cotton grower near Shreveport. In Mississippi, insect consulting services were being offered to growers in the early 1950s by Tom Edwards, Douglas Simms and others.

Scouting, as a basis for control has been the foundation of cotton insect control in Arkansas since the first scouting was done in connection with early research programs (Boyer *et al.*, 1962; Isely, 1926). A University of Arkansas sponsored program was initiated in 1949 with two scouts employed in Little River and Lafayette Counties. The scouting program was expanded to seven scouts in 1950 and 25 scouts in 1951. A similar program was started in Missouri in 1955 with Extension hiring scouts for growers. From 1962 to 1967, between 94 and 132 scouts were employed in the Arkansas program each year, with 130 to 180 thousand acres of cotton involved (Lincoln, 1978; Lincoln *et al.*, 1970). Since that time, cotton scouting in Arkansas has become a basic part of the production program and virtually all of the cotton is scouted by extension scouts, consultants, or individual growers.

In memorandum number 1666 (October 23, 1969), the Secretary of Agriculture outlined the USDA policy regarding pesticides. The policy memorandum encouraged the use of those means of effective pest control least hazardous to man, animals, wildlife and the environment, and encouraged restriction on the use of persistent pesticides. Most notable was a statement that nonchemical methods of pest control, biological or cultural, should be used and recommended whenever such methods are available for effective control of target pests. Integrated control systems were to be used and recommended in the interest of maximum effectiveness and safety.

Recognition of the need for more sensible use of insecticides resulted in the launching of an expanded pesticide safety program by the Extension Service, USDA in 1964. This funding provided support for additional professionals in state extension services to conduct educational programs for various audiences who used, sold, recommended or applied pesticides.

Through the efforts of Dr. James R. Brazzel of USDA's Animal and Plant Health Inspection Service (APHIS) and Dr. Roy Ledbetter of Extension Service, USDA, pilot pest management programs in cotton were funded by federal grants in 1972 at the state level. By 1973, pilot cotton pest management programs had been initiated in fourteen cotton producing states. Through efforts of the National Cotton Council of America, funding was approved by Congress in 1975 and made available through the state extension services to continue the development of pest management programs in cotton.

INSECT MANAGEMENT PRACTICES IN THE MID-SOUTH

The major insect pests of the Mid-South include thrips, tarnished plant bug, clouded plant bug, cotton fleahopper, boll weevil, bollworm and tobacco budworm (Reynolds *et al.*, 1982; Young, 1969b). Other insects that occasionally attack cotton include several species of cutworms, aphids, spider mites, whiteflies, fall armyworm, beet armyworm and cabbage looper. The management practices for these insects vary depending on the species and the management recommendations made by the individual states. In general, the state-to-state philosophies on individual species management are similar but vary because of local needs and research interpretation differences.

THRIPS

Thrips injure cotton plants shortly after plant emergence by attacking the terminal bud and the first two-to-four true leaves. Thrips cause economic injury to cotton by reducing stands, retarding growth, adversely affecting post-directed herbicide applications that may result in stunted plant growth (Lambert, 1984), and delayed optimal fruiting (Lambert, 1985). High infestations may kill terminal buds and cause severe plant abnormalities (Carter *et al.*, 1982; Young, 1969b). Clower (1984) cited four reasons for growing concern about thrips damage: (a) increased numbers of soybean thrips in cotton; (b) increased wheat acreage from which thrips may move to cotton; (c) recent cool springs detrimental to cotton vigor; and (d) less concern about bollworm/tobacco budworm outbreaks (following thrips control practices) since effective bollworm/tobacco budworm insecticides were available.

Experimental evidence of direct cotton yield loss due to thrips damage often has been controversial among scientists. Beckham (1970) and Watson (1965) reported no significant yield loss due to thrips damage although yields were lower in untreated checks. However, Watts (1938) reported a 41 percent yield reduction due to thrips injury. More recently, Johnson *et al.* (1988) reported a significant yield increase in a three-year study on irrigated and dryland cotton when thrips were controlled with foliar and in-furrow insecticides. The yield increase ranged from 14 percent using foliar sprays to 26 percent using aldicarb (Temik®) in-furrow on irrigated cotton compared to an 8 percent increase using foliar sprays and 17 percent using aldicarb on dryland cotton.

Systemic insecticides applied as in-furrow granules and sprays, seed treatments (e.g., acephate [Orthene®]) and foliar sprays are recommended in the Mid-South region for thrips control. Systemic granular insecticides (e.g., aldicarb [Temik®], acephate [Payload®], disulfoton [Di-Syston®], carbofuran [Furadan®], and phorate [Thimet®]) are applied in the seed furrow with a gravity-flow, granular applicator or applied as directed in-furrow sprays (primarily acephate) mounted on planters. Systemic granular insecticides are considered to give longer lasting control for thrips than insecticides applied as seed treatments. In-furrow insecticides usually are used in conjunction with a fungicide formulation for seedling disease control and to lessen the phytotoxic nature of the insecticides under cold, wet conditions. Granular fungicides are available in combination with systemic granular insecticides or may be applied concurrently using split-box granule applicators. In addition to thrips, systemic insecticides used at planting will suppress aphids and spider mites.

Foliar sprays for thrips control include several contact or contact-systemic organophosphate insecticides. Thrips control with foliar insecticide applications is recommended generally at the time of seedling emergence based on injury or population levels. Population levels requiring control measures recommended by various states are one or more thrips per plant in Mississippi and Tennessee. In Arkansas and Missouri, it is one or more thrips per plant at the cotyledonary stage and two or more thrips per plant from the cotyledonary stage to four-leaf stage.

TARNISHED PLANT BUG, COTTON FLEAHOPPER, AND CLOUDED PLANT BUG

The tarnished plant bug injures cotton primarily by feeding on pinhead squares and terminal buds. Tarnished plant bug feeding causes young squares to shed (Cherry, 1974; Tugwell *et al.*, 1976), while terminal bud injury results in multiple branched plants or "crazy cotton" (Tugwell *et al.*, 1976; Young, 1969b). The clouded plant bug causes injury to cotton similar to the tarnished plant bug (Tugwell *et al.*, 1976). Cotton fleahopper occurrence is well synchronized with the early fruiting stage of cotton growth (Young, 1969b). Cotton fleahopper feeding on young squares also results in square shedding and cotton plants may grow abnormally due to fleahopper injury to terminals (Pfadt, 1971).

The tarnished plant bug is more important in the Mid-South than the cotton fleahopper (Luttrell, 1985). Yield loss due to tarnished plant bug may be observed when extremely high and season-long infestations occur (Schuster, 1977). Scott *et al.* (1985) demonstrated that the tarnished plant bug can be a key pest in the Mississippi Delta based upon yield reductions.

Responses to a survey indicated that the importance of tarnished plant bug in cotton remains controversial (Luttrell, 1985). The importance of tarnished plant bug in cotton production is related to variations in annual populations (Gilliland, 1981; Oakman, 1981). However, severity of damage often extends beyond pure population estimates. Oakman (1981) cited cultivated and weed hosts, cotton variety, stage of cotton development, soil type, seedling disease, predators, other early-season pest insects and other factors that influence control decisions in the field. Delays in the fruiting of the cotton plant have been shown to increase the probability of tarnished plant bug attacks (Gilliland, 1981). Such delays may be caused by late planting or replanting, use of overtop arsenical herbicides, excessively high cotton plant populations and excessive nitrogen fertilizations.

Using a recently developed square slicing technique, Williams *et al.* (1987) were able to distinguish between plant bug, bollworm/tobacco budworm, and physiologically induced pinhead square shed. They demonstrated that their technique would be valuable in identifying cotton fields damaged primarily by plant bugs and/or bollworms/tobacco budworms and in making subsequent control decisions. Pack and Tugwell (1976) reported that small squares less than three millimeter in diameter frequently were shed when fed upon by either the clouded plant bug or the tarnished plant bug.

The management of plant bugs is highly dependent upon timely scouting and the use of threshold treatment levels. Research in Arkansas indicates that scouting at least twice weekly is needed to provide timely detection of damaging populations of plant bugs (Johnson and Tugwell, 1988). Scouting methods for plant bugs include visual observations, using a drop cloth or using a sweep net. The treatment level for plant bugs is similar throughout the Mid-South region. Treatment levels in Mississippi and Tennessee are: (a) one plant bug per six row feet the first two weeks of squaring; (b) one per three row feet during the third week squaring until first bloom; and (c) two per three row feet after first bloom (Head, 1993; Roberts and Lentz, 1993). Louisiana recommends treatment for 25 plant bugs per 100 plant terminals or 100 sweeps (Baldwin *et al.*, 1993). Missouri's thresholds are (a) 10 bugs per 100 terminals during the first three weeks of squaring; (b) 15-20 bugs through peak squaring; and (c) 20-25 clouded plant bugs per 100 plants during late season boll set (Jones and Nabors, 1988). Arkansas controls plant bugs when populations reach one per row foot in normal fruiting fields and one per three row feet in fields that are late or having problems setting fruit (Johnson *et al.*, 1993). In addition, Arkansas recommends using percent square set as an indicator of plant bug injury or plant conditions that may cause fruit shed. The major cause of fruit shed on irrigated cotton in Arkansas during early fruit set has been shown to be the plant bug complex (Johnson and Tugwell, 1988). As a result, treatment for plant bug is recommended when square retention is 75 percent or less before approximately July 1 (date varies depending on area of state) or 85 percent after that date if the loss is due to plant bugs (Johnson *et al.*, 1993). A square slicer and color diagnostic key is used to diagnose the cause of square loss (Williams *et al.*, 1987; Johnson *et al.*, 1985) and these treatment levels are used only when losses are caused by plant bugs.

BOLLWORM AND TOBACCO BUDWORM

Bollworm/tobacco budworm population management is affected directly by production practices applied to individual fields and also on a community basis. These insect pests should be managed through the conservation of beneficial insects, utilization of economic injury levels, thorough scouting and careful selection of insecticides. Utilization of a total pest management approach will insure the best production of cotton and avoid, as much as possible, outbreaks of secondary pests.

The natural control of bollworm/tobacco budworm populations by predators is well recognized (Whitecomb and Bell, 1964; van den Bosh and Hagen, 1966; Lingren *et al.*, 1968) and conservation of beneficial insects is vital to their control and management. Insecticide treatments for the control of cotton fleahopper (Newsom and Smith, 1949) and tarnished plant bug (Johnson and Tugwell, 1988) have resulted in outbreaks of bollworm/tobacco budworm. The destruction of parasites, predators, and other beneficial arthropods by insecticides applied to cotton has been well documented by several researchers (Lingren *et al.*, 1968; Newsom and Smith, 1949; Pfrimmer, 1964). Beneficial insect populations also will be reduced and bollworm/tobacco budworm populations increased by use of systemic insecticide applied at planting (Rummel and Reeves, 1971; Ridgway *et al.*, 1967; Cowan and Davis, 1967). The lowest rate possible of systemic insecticide to achieve thrips control should be used in order to lessen the impact on the beneficial insect populations. In addition, treatments for the tarnished plant bug or other pests should be applied only when scouting reports indicates a need based on the use of economic injury levels.

Bollworm/tobacco budworm larvae infest pre-bloom cotton, other cultivated crops and various weed species in early-season (Harris and Phillips, 1986; Lincoln, 1972; Neunzig, 1969). Early-season bollworm/tobacco budworm populations on cotton are generally considered to be sub-economic as compared to mid- and late-season populations on cotton. Bollworms and tobacco budworms feed on terminal buds, tender young leaves, pinhead to large squares and blooms in early stage cotton (Hopkins *et al.*, 1982; Young, 1969b). Bollworms and tobacco budworms are capable of destroying squares, blooms (Young, 1969b) and terminal buds (Hopkins *et al.*, 1982). Cleveland *et al.*, (1981) described tobacco budworm damage to greenhouse-grown cotton terminal buds as resulting in "crazy cotton" symptoms.

Bollworm/tobacco budworm larvae are capable of delaying cotton maturity or causing yield loss as a result of early-season damage. Hopkins *et al.* (1982) found that naturally occurring terminal bud destruction by bollworm/tobacco budworm larvae resulted in yield loss when 20 to 30 percent of the terminals were damaged in seedling cotton. Bollworm/tobacco budworm larvae damage pinhead squares and induce square shedding (Williams *et al.*, 1987).

In most cases, the cotton plant is able to withstand early-season square loss by bollworm/tobacco budworm larvae through compensation (Graham *et al.*, 1972). Schneider *et al.* (1986) reported five to sixty percent yield loss and one to ten days increased delay in cotton maturity due to early-season (1/3 grown square stage) bollworm damage. In their studies the plants were artificially infested.

The relationship between bollworm/tobacco budworm populations and the damage to the cotton crop determines the economic injury level and when treatments should begin. Adkisson *et al.* (1964a,b) estimated that an average of 2,000 to 2,500 larvae per acre (approximately one and one-half to two per 10 feet of row) are required to cause significant yield losses to cotton.

The recommended treatment levels for states in the Mid-South region of the Cotton Belt vary slightly from state-to-state. Mississippi recommends treatment for four small larvae per 100 plants at first bloom to August 15 and 8 larvae per 100 plants after August 15 (Head, 1993); Tennessee for four or more small larvae per 100 terminals, or five percent square damage and bollworms present (Roberts and Lentz, 1993); and Louisiana recommends treatment when five live worms are found per 100 plants plus eggs when squares are at least one-third grown (Baldwin *et al.*, 1993). Missouri begins treatment for six to eight larvae per 100 plants on previously untreated fields and four to six larvae on subsequent treatments (Jones and Nabors, 1988). Arkansas recommends treatment based on the point sample method of scouting; bollworm treatments are made when 7,000 newly hatched larvae are found per acre or when 3,500 larvae that are one-fourth inch in size or larger are found per acre (Johnson *et al.*, 1993). The use of ovicides for control of the egg stage has been recommended in all states in this region. They usually are applied in combination with an insecticide, for the management of bollworms/tobacco budworms.

The termination of the use of insecticide treatments for bollworm/tobacco budworm control usually is based on the maturity of the cotton crop, but the exact time to stop applying treatments is difficult to determine. A decision process for determining when cotton is not susceptible to bollworm/tobacco budworm damage has not been developed or adopted in most cotton producing states. Insecticide treatments are usually terminated when the cotton is obviously mature and not susceptible. One method to estimate maturity and susceptibility to larval feeding is boll slicing. Bernhardt *et al.* (1986) proposed another method of estimating the maturity of the cotton crop; their method involves counting the number of nodes between the uppermost bloom and the first leaf that is not fully expanded (node above white bloom). They suggest that, when the average node count drops below five, the need for insecticide treatments will cease after 10-16 days. The number of harvestable bolls expected in the remainder of the season is relatively low and their overall contribution to yield was projected to be less than one percent of total yield. The decision to terminate insecticide treatments should be based on the crop maturity, pest densities and potential yield and profit.

Tobacco Budworm/Bollworm Resistance Management Plan—The increasing incidence of insecticide resistance problems in the Mid-South region brought scientists together in 1987 to develop a regional approach to insecticide resistance management. The plan was developed and adopted by university extension, research and USDA-ARS entomologists.

The resistance management plan and strategy was divided into three time frames, each directed toward different field generations of tobacco budworms. The overall objective of the plan was to delay the development of the resistance in the tobacco budworm and recommend practices to aid the grower in producing a cotton crop. During the initial portion of the production year, the emphasis was placed on managing the crop for earliness by variety selection, prevention of thrips injury and avoiding late planting as much as possible to decrease exposure to late season insect populations.

From planting to late June, recommendations include applying insecticides only as needed, avoiding the use of organophosphate and pyrethroid insecticides and advocating the use of *Bacillus thuringiensis* formulations plus carbamate ovicides or carbamate insecticides alone. The objective is to avoid selection for pyrethroid or organophosphate resistance in the tobacco budworm population during early season. Scouting was recommended a minimum of twice per week to detect egg populations and small larvae in fields. Control strategies for tobacco budworm are most successful when directed toward newly hatched larvae.

During the period of early July through mid August, control strategies are oriented around the use of mid-rate pyrethroids plus carbamate ovicides for the control of tobacco budworms and bollworm. The decisions should be based on information gathered by twice-per-week scouting and directing control efforts toward eggs and one to two day old larvae. Pheromone traps should be used to determine the species composition in the area and if the tobacco budworm is a threat. A minimum of two applications of insecticides will be needed to manage moderate to heavy infestations of tobacco budworm larvae. Pyrethroid insecticides are recommended during this period because they are effective against a wide spectrum of cotton insect pests including the boll weevil and the cotton aphid. The larvicidal rates of carbamate and organophosphate insecticides should not be used unless field failures are occurring in the area. A full rate of the carbamate and organophosphate insecticides alone or in mixtures should be used if resistant tobacco budworms are found.

From mid August until crop maturity, the objective is to protect the bolls until the crop is mature. Control strategies are directed toward the third field generation of tobacco budworm and when resistance is at its peak. The insecticides of choice are the organophosphates at full rates or organophosphate plus carbamate ovicides. The level of resistance appears to be lowest to these products at this point because of the non use policy during the earlier part of the year, thus conserving this class of insecticides for maturing the crop. Pyrethroid insecticides should not be used during this period of time against tobacco budworm populations. Pyrethroid resistance levels and population densities are highest during this period of time which increases the chances of unsatisfactory control with this class of insecticides.

Bollworm and Tobacco Budworm Pheromone Traps — The pheromone traps for bollworm and tobacco budworm are used primarily for detection of population shifts and species composition in insect management programs. Pheromone trap catches have been used in certain areas of the Mississippi Delta as input to a bollworm/tobacco budworm population model, MOTHZV, along with appropriate climate and crop phenology to predict the timing of future generations (Hartstack *et al.*, 1983). The population trends of bollworm/tobacco budworm are related to the quantitative number of moths caught (Johnson, 1983). Most moth traps used in the Mississippi Delta are utilized to detect population shifts. This information is important to cotton pest management programs. The bollworm management communities in Arkansas rely heavily on pheromone traps to provide information that aids in decisions to determine community bollworm control treatments (Nicholson *et al.*, 1984).

The traps used in most programs to monitor bollworm/tobacco budworm follow the construction guidelines provided by Hartstack *et al.* (1979). The bollworm pheromone is formulated as a 2.5 milligram per square inch bait. The tobacco budworm pheromone is a 16 to one ratio of Z-11 hexadecenal and Z-nine tetradecenal formulated at 80 milligrams per square inch. The laminated plastic baits have produced good results in trials comparing the baits to virgin bollworm/tobacco budworm females (Zvirgzdins and Henneberry, 1983).

BOLL WEEVIL

The boll weevil has been the most serious pest of cotton production since its introduction to the Mid-South area in the early 1900s. Isely (1933) reported that the weevil was often the most important limiting factor in Arkansas cotton production. Since those early control problems, the boll weevil has continued to be a major problem even with the development of effective insecticides.

The primary economic damage to early-season cotton by boll weevils is development of the F_1 generation during early fruit set. Reproduction by overwintered weevils results in square damage, shedding and subsequent delay in cotton maturity. In a case study, Cross (1983) reported one and one-half to three percent square infestation by overwintered weevils and seven to nine percent infestation by the F_1 generation. Lloyd and Merkl (1966) found that 0, 14, 25, 50 and 100 boll weevils per acre produced F_1 generation weevils that damaged 0, 28, 46, 66 and 83 percent of the squares, respectively, in field cage tests.

Overwintering adult boll weevils feed upon the base of leaf petioles and in plant terminals prior to initiation of squaring (Cross, 1983; Young, 1969); they also feed on, and reproduce in, squares once cotton fruiting begins (Cross, 1983). Weevil reproduction in squares results in square flaring and shedding. Weevils in the resultant F_1 generation will emerge 17-21 days later and will cause increased square loss.

Pheromone Traps and Early-Season Control of Boll Weevils — The discovery and development of the male boll weevil pheromone (Hardee *et al.*, 1967; Tumlinson *et al.*, 1969) has led to improved management in cotton. In 1968, the first attempt was made to influence developing populations of boll weevils and measure the potential of using male baited traps (Cross *et al.*, 1969) in surveys and suppression of boll weevils. Since this early study, Rummel *et al.* (1980) developed a pheromone trap index system to predict the need for overwintered boll weevil control at the pinhead square stage. This work has been further validated by Johnson and Gilreath (1982) and Benedict *et al.* (1985). The use of properly timed insecticides to suppress the development of boll weevil populations by preventing significant egg lay has proved to greatly reduce or sometimes eliminate the need for in-season control (Ewing and Parencia, 1950; Taft and Hopkins, 1963; Walker and Bottrell, 1970). The usage of the pheromone trap system to determine the need for insecticide applications at pinhead square stage has been adopted by most cotton producing states.

The movement of overwintered boll weevil populations into cotton is closely related to plant phenology (White and Rummel, 1978). Only a small percentage of the overwintered weevil population which infests cotton enters prior to the onset of squaring. Boll weevil infestations increase as square size and density increase with major colonization occurring after the appearance of 1/3 grown squares (White and Rummel, 1978; Walker and Bottrell, 1970; Roach *et al.*, 1971; Rummel and Bottrell, 1976). To monitor this movement, boll weevil pheromone traps should be placed in the fields shortly after the emergence of cotton or at about the second or third true leaf stage. The traps should be placed around fields near overwintered sites such as woodland, old homes, barns or similar areas known to harbor overwintered weevils.

The need to apply insecticides is determined by the average number of weevils captured in traps around the field prior to square initiation. Rummel *et al.* (1980) reported using a treatment threshold called the Trap Index to determine the need for insecticide treatment. The Trap Index is the average catch of several traps placed around the field. The data indicated that Trap Index thresholds could be used as a guide in determining the need to treat for overwintered boll weevils. The treatment threshold was divided into three distinct groups based on their research: (a) do not treat if the Trap Index is less than one; (b) if the Trap Index is between 1.0 and 2.5, treatment may or may not be justified; inspect field carefully when the first one-third grown squares appear and base the control decision on the presence of damaged squares or adult weevils; (c) if the Trap Index is 2.5 or greater, treat for overwintered weevil just prior to or at the appearance of first one-third grown square.

The use of pheromone traps offers the advantage of allowing for control decisions for boll weevil to be made at a time when the overall population is at its lowest point for the year and in advance of any oviposition that may occur. However, a considerable degree of judgment based upon boll weevil ecology is needed to get the optimum usage from the pheromone trap. The Trap Index is not an absolute value; it is general in nature. For example, a very low average trap catch during the week of first match-head-size square would be suspect if the trap averages for the two prior weeks were high. In addition, if the cotton field was the earliest in the area and the emergence pattern of the boll weevil was just beginning, the use of insecticides to control this population would be less effective. The trapping system works best when the peak emergence occurs before the appearance of first square.

The boll weevil pheromone trap is recommended by all Mid-South cotton states to evaluate overwintering populations. If pheromone traps around fields catch certain levels of boll weevils prior to pinhead square stage of growth, insecticide applications are recommended to suppress overwintered populations. In Arkansas, insecticide applications are recommended if an average of three boll weevils are found per trap the two weeks prior to pinhead square stage of growth (Johnson *et al.*, 1993). Mississippi recommends treating if four boll weevils are accumulated per trap the four weeks prior to squaring (Head, 1993). Louisiana recommends treating if five weevils are captured per trap the two weeks prior to pinhead square (Baldwin, 1993).

In-Season Control of Boll Weevils — Once boll weevil reproduction begins in one-third to one-half grown squares, square damage should be assessed to determine the need for insecticide treatments. In-season control principles of the boll weevil are basically the same as that of early control programs. Isely (1933) recommended that when infestations were scattered over whole fields treatment applications should be made when 10 to 15 percent of the squares were freshly punctured. Currently, boll weevil control applications are recommended in Mississippi (Head, 1988) and Tennessee when 10 percent of the squares are punctured, and in Louisiana at 15 to 25 percent damaged squares. Missouri recommends treatment when 25 percent damage occurs under normal conditions and 10 to 15 percent when wet conditions occur or if the populations are building rapidly. Arkansas recommends treatment at one-damaged square per row foot.

The current philosophy on the selection and use of insecticides is based on the biology and life cycle data available on the boll weevil. Since the egg, larval and pupal stages are present only inside squares, either on the plant or in abscised squares on the ground, insecticide treatments must be directed to control the adults. The freshly damaged squares are considered to be the best overall indicator of the adult weevil population level. Once the treatment level is reached, three to five insecticide treatments (at three- to five-day intervals) may be necessary to break the reproduction cycle generally considered to be about 21 days. The insecticide selected should have good residual activity; it should be effective enough to attain good adult mortality during the first 24 hours after application and have continued activity for about 72 hours. This level of activity allows the producer to maintain about a five-day interval between treatments for moderate populations of boll weevils.

CUTWORMS

Several species of cutworms attack cotton. Most cutworms overwinter in the larval stage, but some overwinter as pupae. The eggs are laid on grass or soil in low spots of fields. The eggs hatch in two to five days and larval feeding time averages two to three weeks. Cutworms usually cut off plant stems at the soil surface. Stand reduction may be more visible in field margins and low lying weedy areas. Cutworm damage can be severe enough at times to require replanting.

In Arkansas, Louisiana, Missouri and Tennessee, control decisions are based on the presence or absence of cutworms and cutworm damage. In Mississippi, control is recommended if cutworms reduce the stand below 35,000 plants per acre (3 plants per row-foot) in a field or part of a field.

COTTON APHID

The cotton aphid has been recognized as a pest of cotton in the Mid-South since Isely (1946) reported that injury by the cotton aphid most frequently followed a succession of insecticide dust applications for boll weevil control. High aphid populations stunt seedling cotton growth and hinder plant development through direct feeding. Production of honeydew by late-season aphid populations can cause decreased fiber quality due to black sooty mold associated with honeydew dropped onto cotton fiber.

The cotton aphid has a high reproductive capacity and large populations may develop in cotton in a relatively short period of time. The cotton aphid has a detrimental effect on cotton plant development. The population level density where damage occurs is thought to be fairly high. The precise population level that causes damage is difficult to determine and is affected by the physiological condition and growth stage of the cotton plant.

The cotton aphid has many biological control factors that play a major role in the overall population regulation of this insect. The primary natural enemies in the Mid-South are the braconid parasite, *Lysiphlebus testaceipes* (Cresson) and a fungal pathogen, *Neozygites fresenii*. Both will significantly reduce high aphid populations in a short period of time. These natural enemies have been the major factor in control of aphids in the Mid-South since the onset of aphid resistance to many insecticides.

The cotton aphid was traditionally controlled with organophosphate insecticides such as dimethoate (Cygon®, Rebelate®) and dicrotophos (Bidrin®) prior to 1987. However, control became more difficult as the cotton aphid developed resistant to four classes of insecticides (O'Brian *et al.*, 1991). Kerns and Gaylor (1991) reported that cotton aphid resistance to insecticides increased rapidly within fields shortly after insecticide applications. A similar trend was observed in the Mid-South where early treatments for thrips or plant bugs tended to increase resistance of the cotton aphid to those insecticides. The only successful control was achieved using bifenthrin (Capture®) or a combination of pyrethroid plus an organophosphate (Johnson and Studebaker, 1991). In many cases, the population reached a high level as controls were being applied and the only effective control was the epizootic[1] of the fungus *Neozygites fresenii* or the braconid parasite, *Lysiphlebus testaceipes.*

As a result of these problems, several states developed recommendations to aid in overcoming aphid control problems. These recommendations were directed toward conservation of beneficial insects and insecticide usage, utilizing early maturing cotton varieties, using in-furrow insecticides and careful insecticide selection.

SPIDER MITES

Spider mites may cause damage and occur at any time during the cotton growing season. They generally move into fields from borders which serve as overwintering sites. Spider mites may build high populations in a relatively short time since they develop from an egg to adult in five to seven days during the summer. Early-season applications of pyrethroid insecticides have been shown to increase the probability of spider mite infestations. Areas in fields infested with spider mites may appear lighter in color or reddish from a distance. Treatment for spider mites is recommended when leaves become discolored and mites are numerous or when 50 percent or more of the leaves five nodes from the terminal are infested (Johnson *et al.*, 1993; Head, 1993; Baldwin *et al.*, 1993; Roberts and Lentz, 1993; Jones and Nabors, 1988).

WHITEFLIES

Populations of whiteflies usually occur in late-season. The nymph and adult of the whitefly damage cotton by sucking juices from the plant and by excreting honeydew when the cotton bolls begin to open. The accumulation of honeydew on the lint provides a substrate for the growth of black sooty mold that stains the lint and lowers cotton grades. Treatment for whiteflies is recommended when 50 percent of the plant terminals are infested.

FALL ARMYWORM AND BEET ARMYWORM

The fall armyworm and the beet armyworm may occasionally infest and cause damage to cotton fields in the Mid-South. The eggs are laid indiscriminately in masses of about fifty to several hundred. The masses are covered with a grayish fuzz and hatch in two to four days.

The beet armyworm larvae feeds on foliage, squares, blooms and bolls. The larvae tend to feed in groups and the feeding results in a general ragged appearance of the cot-

[1]Epizootic is the outbreak of a disease that affects large numbers of the same kind of organism at the same time.

ton plant. The fall armyworm does not feed in groups but disperses when the egg masses hatch. The fall armyworm tends to feed on bolls even when the larvae are small but may feed on squares and blooms.

Treatment is recommended in the Mid-South under the following conditions: (a) when three to five egg masses and live larvae are found per 100 plants, or when four or more larvae are found in 100 blooms and bolls; (b) when one small larva is found per four row-feet; or (c) when damaging populations are found.

CABBAGE LOOPER AND SOYBEAN LOOPER

The cabbage looper and soybean looper occasionally may develop into damaging populations in the Mid-South. The larvae are very susceptible to disease outbreaks especially during damp cool weather. Large numbers of the larvae may severely defoliate cotton and potentially reduce yields. Populations of cabbage and soybean looper have been relatively low since the introduction of the pyrethroid insecticides, probably due to the insects's high susceptibility to these insecticides. However, the soybean looper now has developed resistance to most pyrethroids; it is becoming an occasional problem and may cause cotton defoliation in late-season. Treatment is recommended in the Mid-South when 25 percent defoliation has occurred or when populations threaten premature defoliation.

SCOUTING TECHNIQUES IN THE MID-SOUTH

Cotton insect pest management is based on the principles of insect scouting and the use of economic thresholds. Scouting cotton fields for insects at regular intervals during the growing season is one of the most valuable cotton insect management practices available to growers. Insect scouting detects developing insect infestations and population levels; it indicates when an insecticide should be applied based on threshold levels; and, it evaluates insecticide treatments. Fields should be scouted at least weekly and twice weekly is highly recommended to enhance the early detection of damaging insect populations and timely application of insecticides.

Insects are not distributed uniformly and all areas of each field must be covered every time the field is scouted. The pattern followed may be a "Zig-Zag," or a "U" pattern that allows adequate sampling in the center, sides and corners of the field. The major sampling methods used in insect scouting are the point sample, random sample and sequential sample.

POINT SAMPLING

The point sample method involves selecting four points at random (Johnson, 1990) in the field to sample. At each point, all plants are searched on a designated length of row, usually 3.5, 7, or 14 feet. In addition, the shake or drop cloth is used to sample beneficial insects and plant bugs. Small square set is also determined by examining the presence or absence of small squares in the plant terminal. The square set data often reflects the condition of the plant and aids in decisions concerning plant growth.

Square shed may be caused by dry conditions, fertility problems, plant bug populations or newly hatched bollworms.

RANDOM SAMPLING

The random sample method involves examining terminal buds, squares and leaves and sweeping the top one-third of the plants in a random pattern throughout a field. A standard 15-inch diameter sweep net should be used. The number of samples taken should be dictated by the field size. One hundred squares and terminals should be examined in fields of 20 acres or less. The number of samples should be increased accordingly as field size increases. Square samples and leaf samples should be taken from the bottom, middle and tops of the plants to minimize bias. The insect damaged squares should be examined for boll weevil, bollworm and other insect damage. The data is recorded as a percent of the total examined. Insects caught in the sweep net should be recorded as the number per 100 sweeps.

SEQUENTIAL SAMPLING

The sequential sampling method is a modification of the random sample method. It allows decisions to be made to treat or to not treat while the sampling is underway. Background knowledge of the distribution of the insect is required for sequential sampling. Results from using sequential sampling indicate that sampling time may be reduced without loss in accuracy.

AREAWIDE PROGRAMS FOR COTTON INSECT MANAGEMENT IN THE MID-SOUTH

Areawide programs for suppression of cotton insect pests have been successful in the reduction or exclusion of several key cotton pests. These efforts are logical only for pests which infest a large area at a given point in time. Most programs in the Mid-South are targeted toward the boll weevil, bollworm and tobacco budworm and quarantine efforts against the pink bollworm.

BOLL WEEVIL PROGRAMS

Boll weevils were introduced into United States cotton in the later part of the 19th century and had infested cotton in Virginia by 1933. In recent years boll weevils have infested cotton in Arizona and California. From this distribution, it is obvious that boll weevils are truly an areawide pest. This is especially true in the Mid-South where the weevil has been well established since the 1920s.

The first areawide program for boll weevil control was reported by Ewing and Parencia (1950). This program targeted overwintered boll weevils with early-season applications of insecticides. Insecticide applications were terminated early enough to preserve parasites and predators of the bollworm.

Diapause, the winter survival mechanism first reported for the boll weevil by Brazzel and Newsom (1959), insures a continued survival of some individuals which infest cotton the following season. The rate of survival is normally about 10 percent but may be lower following colder winters (Cross, 1983).

Brazzel and Newsom (1959) described a control program that involved late-season applications of insecticides to destroy overwintering boll weevils before they enter ground trash. This concept was later expanded to include the last generation of reproductive weevils. In the Mid-South, Lloyd *et al.* (1966) demonstrated the effectiveness of this program in a reproductive diapause program that reduced the overall population.

Young (1969a) reported on the results of two areawide boll weevil diapause control programs conducted in Monroe and Sharkey Counties in Mississippi. The results were a 30-50 percent cost reduction, fewer insecticide applications, preservation of beneficial insect populations and increased yields.

The Optimum Pest Management Program was conducted in Panola County, Mississippi, from 1978 to 1980. The boll weevil was the target insect but other cotton pests were monitored and controlled. The success of this program on about 30,000 acres of cotton was indicated by an increase in yield of 85 pounds of lint cotton per acre over the previous ten-year average for the county. The number of in-season applications of insecticide per acre decreased from 8.6 (ten-year average) to 3.23 (three-year average). In 1980, the cost of insect control plus scouting was only $17.40 per acre (Andrews *et al.*, 1980).

Boll Weevil Eradication — The original Boll Weevil Eradication Test was initiated in Mississippi in July, 1971, and terminated on August 10, 1973. The Technical Guidance Committee concluded "that it is technologically and operationally feasible to eliminate the boll weevil as an economic pest in the United States by the use of techniques which are ecologically acceptable" (Parencia, 1978). For further information, refer to "Cotton Insect Management with Special Reference to the Boll Weevil," Agriculture Handbook Number 589, edited by R. L. Ridgway, E. P. Lloyd, and W. H. Cross.

COMMUNITY MANAGEMENT OF BOLLWORMS/TOBACCO BUDWORMS

In many areas of the Cotton Belt, including all Mid-South states, the bollworm and tobacco budworm are the major pests of cotton. Almost 100 percent of planted acres are infested at one level or another. In some seasons, insecticide resistant tobacco budworms have caused total crop destruction.

Since bollworm/tobacco budworm frequently infest a high percentage of acreage in an area, they are candidates for areawide management. The first successful efforts to manage these pests over a large area were initiated in Arkansas in 1976 (Phillips, 1978). It was assumed that if the June population was reduced in excess of 50 percent, the overall July population would be reduced. As the research progressed, thresholds were developed to treat each generation during the summer (Nicholson *et al.*, 1984). The community bollworm management approach requires that at least 90 percent of the cotton acreage participate. The scouting results are summarized daily and bollworm/tobacco budworm pheromone traps are utilized to determine peak flights and egg deposition. When populations reach designated levels, the entire community applies a larvacide plus an ovicide within a three-day period. The success or failure of community programs is dependent on grower support and participation, accurate data collected by the point sampling method, and daily review of the community data to support decisions on control measures. Communities utilizing this approach in Arkansas have realized excellent bollworm/tobacco budworm control, increased yields reduced insecticide costs.

These programs have been expanded to several areas of Arkansas and are currently accepted as standard management practices. Cochran *et al.* (1985) reported that these programs had expanded to 80,000 acres and gave a return of $1,500,000 to cooperators. In addition, insecticide use was reduced by 92,000 pounds per year.

A similar type program was conducted on about 40,000 acres of cotton in Leflore County and 9,000 acres in Monroe County, Mississippi, during the 1980-81 growing seasons. Some reports credited these efforts with returning cooperators $45 per acre. These programs were conducted with cooperation among industry, research, and extension (Head, 1981). An areawide program for bollworm/tobacco budworm and boll weevil management was conducted on about 90,000 acres in the eastern delta of Mississippi in 1982-83 (Head, 1983). Many of these management components continue.

IMPLICATIONS FOR FUTURE AREAWIDE PROGRAMS

With the Boll Weevil Eradication Program successfully in place in North and South Carolina and recently expanded to Florida, Georgia and Alabama, Mid-South producers should expect this program to expand into Mississippi, Tennessee, Arkansas, and Louisiana.

Areawide management will be required for successful introduction of parasites and predators or for release of sterile insects such as the backcross *Heliothis virescens - H. subflexa*. This program showed promise of success in the trial on St. Croix Island (Proshold and Smith, 1982). Stadelbacher (1985) reported that cutleaf geranium, *Geranium dissectum* L., is a major early-season host of bollworm/tobacco budworm. Destruction of these hosts by use of herbicides or mowing, or spraying the hosts with insect growth regulators, shows promise in areawide suppression of bollworm/tobacco budworm.

SUMMARY

The management of cotton insects begins when the cotton seed is placed in the soil. The insect populations in cotton fields are diverse and directly or indirectly affected by production practices used during the production year. Similarly, the methods used to manage insects will affect the earliness, quality and yield of the crop. Early-season insect damage is one of the many factors affecting "earliness" of cotton. Delays in maturity in the early part of the season affect insect pest pressure later in the season (Gilliland, 1981), cotton quality (Schuster, 1977), and yields (Hoskinson *et al.*, 1974). Indirect yield loss may occur particularly in northern areas of the Mid-South where early fall harvesting is critical (Hoskinson *et al.*, 1974). Earliness has been reviewed recently within the context of the value of short-season cotton production (Smith, 1980; Herzog, 1980), insect control (Clark, 1988; Hargett, 1988; Roof, 1988), plant growth regulators (Guthrie, 1988), weed control (Bonner, 1988), and varying agronomic (Burch, 1988) points of view.

Insect control decisions are based upon the detection of insect populations by use of various scouting procedures. However, scouting must be used in conjunction with a working knowledge of insect biology, treatment levels and potential consequences of any control measures that may be applied. Decisions on insect management in mid- to late-season must be directed toward setting and protecting the boll load while considering the many factors that may affect cotton production and insect populations. The key to all successful insect management programs is proper timing of management decisions applied. If a control strategy is needed, it should be applied without delay.