Pest Management Strategic Plan for Cotton in the Midsouth

Table of Contents

PEST MANAGEMENT STRATEGIC PLAN FOR
COTTON IN THE MIDSOUTH (ARKANSAS, LOUISIANA, MISSISSIPPI)

Production Facts

- The cotton acreage of Arkansas, Louisiana, and Mississippi accounted for approximately 21% of the total of U.S. cotton acreage in 2001 and 2002 (National Agricultural Statistics Service [NASS]).
- The estimated value of cotton production in 2001 for the three states was approximately $705,853,000 (NASS).
- One hundred percent of the harvested cotton is processed into various textile products. A high percentage of the harvested cottonseed is processed, primarily into cottonseed oil.

Production Regions

Cotton is grown primarily in the delta regions of the three states (eastern Arkansas and Louisiana, and western Mississippi), but significant acreage is also grown in other areas of each state. Different production practices and pest problems occur with the region and are often associated with region specific management practices, but the entire region has similar pest problems (Johnson et al. 1996).

Research, Regulatory, and Educational Priorities for Cotton Pest Management in the Midsouth

The meeting of the multi-state Advisory Committee for the Cotton Pest Management Strategic Plan was held on April 24-25, 2003 in Vicksburg, Mississippi. A large portion of the meeting was dedicated to the development of "priority lists" for cotton pest management. The attendees, representing the various stakeholders in cotton production for the Midsouth region (participant list, page 73), were asked to identify research, regulatory, and educational priorities for cotton pest management in the Midsouth. Priorities for individual pests as well as for overall pest management in cotton were addressed.

A recurrent theme in the priority lists is the need to address the impact of transgenic cotton varieties, especially as it pertains to pest threshold determinations, cost-benefit analyses, and pest resistance management. It should be noted that these issues are also addressed annually at numerous professional meetings and conferences conducted and attended by Midsouth pest management specialists.

A major concern of the group was the intended use of the priority lists included in the management plan. While this document reflects the collective thinking of the group attending the Vicksburg meeting and paints an overall assessment of pest management practices for Midsouth cotton, it does not provide a detailed examination of the research base supporting current recommendations and practices. That would understandably be an exercise beyond the resources of this strategic plan project, but one that would be critical to some policy decisions. It is very important that policy makers utilizing this document recognize the limitations of current recommendations, the dynamic nature of pest management research, and the potential problems associated with over-simplification of a very complex and dynamic production system in a summative document. Thus, this strategic plan is basically a point in time snapshot of subjective opinions voiced in a single, collective meeting of cotton pest management specialists and other stakeholders in cotton production.

Those interested in specific pest management practices and more detailed assessments of cotton pest management should review the abundant literature associated with the subject. The Beltwide Cotton Conference Proceedings (http://www.cotton.org/beltwide/proceedings.cfm), the Southern Weed Science Society Proceedings (http://www.weedscience.msstate.edu/swss), the Cooperative Extension and Agricultural Research groups in each state (Arkansas' Division of Agriculture http://division.uaex.edu/home.htm, Cooperative Extension Service http://www.uaex.edu/, and Agricultural Experiment Station http://www.uark.edu/admin/aes/ , ;Louisiana's LSU Ag Center http://www.lsuagcenter.com/nav/extension/extension.asp; and Mississippi's Cooperative Extension Service and Agricultural Experiment Station http://msucares.com/) provide links to current management recommendations and supporting research information. Cotton production has a long history in the Midsouth and the scientific literature contains many published works of management approaches with the region. Some of the Southern Regional Research Bulletins (http://www.msstate.edu/org/saaesd/scsb/scsb.htm) and Experiment Station Bulletins (referenced at url addresses above) contain elaborate information about pest and pest management systems for cotton in the Midsouth. In addition, numerous private press groups annually compile crop production and management information for the agricultural community. The *Delta Agricultural Digest* (Primedia Business Magazines and Media, Clarksdale, MS) and the *Delta Farm Press* (www.deltafarmpress.com) are examples of information sources that routinely summarize total crop production practices and highlight contemporary issues for the cotton production environment. The National Cotton Council maintains links to a wide range of cotton production information sources (http://www.cotton.org/).

The priorities identified at the meeting are listed below in the sections for the individual pests. In addition, there is a separate priority list at the end of each of the insect, weed, and disease sections that addresses overall concerns for these pest groups. Listed immediately below are the overall priorities identified for crop and pest management in cotton produced in the Midsouth.

Overall Crop Management Concerns and Priorities for Cotton Grown in the Midsouth

- Pest thresholds need to be reevaluated in light of the increased use of transgenic cotton varieties.
- Economic issues related to pest management (ex. cost-benefits analysis) and resistance management in transgenics versus non-transgenic cotton varieties need to be evaluated.
- Growers need to be educated on the scouting procedures for transgenic versus non-transgenic cotton.
- It is extremely important to maintain aerial applications on labels for cotton pesticides.
- Plant development indices are needed for integrating crop management practices. Need all disciplines to agree on these indices.
- Address Worker Protection Standard occupational exposure issues for chemicals used in cotton production.
- Examine drift issues, including non-target effects.
- Address environmental issues related to pest management in cotton.
- Increased educational efforts are needed to help growers with pest identification.
- The efficiency of the current Section 18 registration process needs to be evaluated.

- What are the conditions that favor outbreaks of cotton pests?
- Improve the development and delivery of application technology.
- More training tools (web-based, fact sheets, training modules, etc.) need to be developed for stakeholders.
- Improve information management system to better use farm records for making decisions – 21^{st} century recordkeeping system integrated with crop, pests, costs, history, etc.
- Utilize strategies to take advantage of normal weather patterns.

Integrated Pest Management

Virtually all of the cotton in the three states is produced using integrated pest management (IPM) programs. Integrated Pest Management is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks. IPM centers on the organization of a systems type approach to the crop production plan. It is a management approach that relies, to the maximum extent possible and economically practical, on prevention or avoidance of the pest problems that are commonly encountered. Pest management practices include cultural control (includes transgenic cotton varieties), field monitoring/scouting, mechanical controls, and use of naturally occurring, or in some cases, applied biological control agents. When satisfactory non-chemical controls are not available or fail to provide adequate control, chemical controls are applied as needed based on established economic thresholds for the pest(s).

Table 1. Some Non-Insecticidal Components of Cotton IPM

1.	Scout fields twice per week to monitor pest populations
2.	Use economic thresholds to determine need for treatment
3.	Follow recommended guidelines for resistance management
4.	Preserve beneficial insects by using target-specific insecticides
5.	Monitor beneficial insect populations and utilize when possible
6.	Plant early maturing varieties to escape late season pests
7.	Plant varieties with insect resistance traits, smoothleaf, etc
8.	Plant varieties with transgenic insect resistance (ex., Bt-cotton)
9.	Destroy stalks promptly after harvest to reduce overwintering insect populations
10.	Practice fall or early spring tillage to reduce overwintering insect populations
11.	Avoid excessively dense or sparse plant stand densities
12.	Manage the crop agronomically to promote vigorous growth and early maturity
13.	Terminate insecticide treatments as soon as crop maturity allows
14.	Practice border vegetation management to minimize alternate hosts
15.	Be aware of naturally occurring insect diseases and utilize when possible
16.	State and Federal quarantines to prevent entry of new pests

INSECT/MITE CONTROL

Cotton in the Midsouth is attacked by more than a dozen different species of insect pests. Each of these pests is capable of causing economic yield loss, and some, such as the tobacco budworm, are capable of totally destroying a crop. Historically the boll weevil has ranked as one of the most damaging pests of Midsouth cotton, but the bollworm/tobacco budworm complex, tarnished plant bugs, beet armyworms, fall armyworms, cotton aphids, stink bugs and thrips have also caused high levels of damage in some years.

Several insects attack cotton at various stages of growth. The major insect pests of cotton grown in the Midsouth are the boll weevil (*Anthonomus grandis grandis*), bollworm (*Helicoverpa zea*), tobacco budworm (*Heliothis virescens*), thrips (*Frankliniella* spp.), plant bugs *(Lygus* spp.), and aphid *(Aphis gossypii).* Other arthropod pests of cotton, include the beet armyworm (*Spodoptera exigua),* fall armyworm (*Spodoptera frugiperda*), cutworm (*Agrotis ipsilon* and *Feltia subterranea* are the most common), stink bug (various species, including *Nezara viridula, Euschistus servus, Acrosternum hilare*), cotton fleahopper (*Psallus seriatus*), western flower thrips (*Frankliniella occidentalis*), loopers (*Pseudoplusia includens, Trichoplusia ni),* whiteflies (*Trialeurodes abutilonea* and *Bemisia* spp*.),* and spider mite (*Tetranychus urticae*). The insecticides used to control the major arthropod pests and the percentage of acres treated with each insecticide, by state, are found in Table 10.

Cotton growers may invest more than $500 to produce an acre of cotton, and all of this investment is potentially at risk to insect damage. The cost of controlling insects is one of the larger items of the crop production budget, annually averaging from $70 to over $100 per acre.

Cotton producers utilize a variety of non-insecticidal management tools (Table 1) to limit the number of times that pests exceed economic thresholds and consequently require treatment with insecticides. However, timely, judicious use of insecticides is an important component of cotton IPM. Recommendations for cotton insect management are published in the various insecticide recommendations revised yearly by the states' Extension Service.

Because pest populations can change quickly, cotton insect management is both information intensive and time sensitive. During the growing season, fields must be scouted every three to four days, and accurate estimates of pest populations must be determined by time consuming sampling procedures. Because of the time involved in making these counts most producers use private consultants, independent part-time scouts, and agricultural industry representatives, to provide most of the monitoring or scouting.

During recent years there have been significant changes in the Midsouth cotton IPM system, and this system continues to evolve rapidly. These changes are occurring because of three major factors: transgenic Bt-cotton, boll weevil eradication, and new, more target-specific insecticides.

In recent years from 70 to 80% of the Midsouth cotton acreage has been planted to Bt transgenic cotton varieties. Because Bt cotton is highly effective against tobacco budworm, fields planted to Bt varieties do not require treatment for this pest. Bt cotton is also effective against bollworms, but to a lesser degree, occasionally requiring treatment for control of bollworms. However, since Bt cotton was first introduced in 1996, Bt fields have consistently required fewer treatments than non-Bt fields for caterpillar pests, while also sustaining less boll damage.

During the past several years a number of new insecticides, belonging to novel classes of chemistry, have been developed, or are being developed, for use in cotton. These include products such as spinosad (Tracer), indoxacarb (Steward), and thiamethoxam (Centric). While these products are quite effective against their primary target pests, they tend to control a narrower spectrum of pests than most of the older products. This can be advantageous, when there is a need to control only one pest, because the increased selectivity fosters conservation of beneficial insects. However, when there is a need to control multiple pest species, tank mixing multiple insecticides can offer distinct economic and ecological disadvantages.

Together, the broad adoption of transgenic Bt cotton, combined with the progress of the boll weevil eradication effort has resulted in significant reductions in the number of foliar sprays applied by Midsouth cotton producers. Unfortunately, this reduction in the number of foliar insecticide treatments has not provided a corresponding decrease in the per acre cost of cotton insect control. This is because of offsetting costs associated with “technology-use fees” for Bt cotton, assessment fees to fund boll weevil eradication efforts, and increased costs of newer insecticides. Still, boll weevil eradication and Bt cotton have had the very positive impacts of reducing the risks of insect induced yield losses, reducing overall use of insecticides, and reducing the physical and logistical effort that growers must devote to insect management.

One consequence of this new pest management system under which cotton is grown in the Midsouth has been a shift in the overall pest complex. Pests such as boll weevils and tobacco budworms are of much less concern than they were in past years, because of the direct effects of boll weevil eradication and Bt-cotton. The reduction in foliar sprays has also had an indirect effect in reducing outbreaks of secondary pests, such as cotton aphids and beet armyworms. However, pests such as tarnished plant bugs and stink bugs have thrived in this reduced spray environment and the number of treatments applied specifically to control these pests has increased.

Insect populations vary depending on the area of the Midsouth region where cotton is produced. The southern cotton producing areas tend to have greater insect problems than northern cotton growing areas. In the northern part of the region the slightly shorter growing season combined with much cooler winters, keep insect pest populations lower than the rest of the Midsouth region.

BOLL WEEVIL (*Anthonomus grandis grandis*)

Research Priorities

- Develop an overall economic model of the cost of maintaining weevil free cotton in the Midsouth.
- Project the impact of post eradication on outbreaks of other insects and overall need for insecticides in cotton.
- Reevaluate thresholds since the implementation of the Boll Weevil Eradication Program (BWEP).
- Continue and/or increase surveillance for boll weevil.
- Explore options for area-wide barriers for containment and further reduction of weevil-infested cotton (i.e., push sources of re-infestation further south).
- Develop long term new technologies, or refinement, for preventing boll weevil, specifically transgenic cotton for boll weevil.
- Develop trapping procedures for mapping boll weevil (i.e., levels of trapping, pheromone usage or enhancement, etc.)
- National issue: how to manage states or regions without BWEP.
- Research needed on the wild hosts of boll weevil.

- Control of volunteer cotton, ornamental, regrowth, etc. as they relate to boll weevil management.
- What are the conditions that favor outbreaks?

Regulatory Priorities

- Research on importance of maintaining registration of malathion on cotton (**High Priority**). There is no other option, economically speaking, than malathion for boll weevil management.
- Understand the impact of malathion sprays for boll weevil eradication on potential use patterns for other pests (i.e., mosquitoes, plant bugs, etc.).
- What is the basis for different boll weevil control recommendations in the different states?
- How do we maintain insecticides for use against the boll weevil in emergency situations?
- Federal (USDA) activities needed to supplement university and extension efforts as far as mapping, trapping, etc.
- Identify chemicals efficacious on boll weevil and emphasize the need to maintain the registrations. Also, the specifics of how stocks of these materials will be maintained.
- Should we continue to regulate seed for boll weevil management purposes? Will quarantines be needed?
- The impacts of moving equipment (primarily harvesting) from non-eradicated zones to eradicated zones.
- Rearing facilities for boll weevil should be moved out of eradicated zones, or more specifically, out of cotton growing regions.

Educational Priorities

- How do farmers maximize profits during and after eradication?
- What are the impacts of boll weevil eradication on the overall cotton IPM programs? This is an area where the verification programs may be helpful.
- Continue boll weevil identification training for growers.
- Ensure that Agricultural Research Service (ARS) or other federal agencies maintain boll weevil identification expertise.
- In northeast Arkansas and surrounding areas, how can farmers minimize potential problems with tobacco budworm and beet armyworm when eradication programs are introduced? How can they plan for these possibilities?
- The impacts of moving equipment (primarily harvesting) from non-eradicated zones to eradicated zones.

Of the primary insect pests of cotton, the boll weevil has historically proven to be one of the toughest to control. The boll weevil's high reproductive capability and the location of the developmental stages of the weevil inside the cotton fruiting structures allow this insect to build up to large populations quickly The boll weevil is a greater problem in the southern part of the region where winter temperatures are warmer and overwintering habitats are favorable. Forested areas around rivers, drainage ditches and bayous provide favorable overwintering sites in southern cotton growing areas. Cooler winter temperatures and less favorable overwintering habitats in the northern cotton growing areas region cause high mortality of overwintering boll weevil. Control for the boll weevil is similar throughout the Midsouth. When boll weevil populations reach economic damaging levels, insecticides are the primary control measure.

Insecticide applications, especially those made during the early part of the growing season, often reduce beneficial arthropod populations and tend to increase occurrence of secondary pest outbreaks.

All three states have implemented Boll Weevil Eradication Programs (BWEP). These programs utilize pheromone traps to identify fields that are infested with boll weevils, coupled with applications of insecticides on infested fields.

Mississippi began boll weevil eradication efforts in 1997 in the Eastern portion of the state. In 2003, the Hill Region of Mississippi was in the 7th year of BWEP and the South Delta and North Delta were in the 6th and 5th year, respectively. Although Mississippi has not yet achieved the goal of eradicating this pest, overall boll weevil numbers were extremely low in 2002, and no yield loss was attributed to boll weevils. Only 32% of the acres in the state required treatment for boll weevils and most of these treatments were applied late in the season, when they would be less likely to flare secondary pests. Progress of the boll weevil eradication effort has had a tremendous positive impact on Mississippi’s cotton IPM program, and has resulted in a sharp decrease in the number of insecticide applications applied by growers.

In Louisiana an eradication effort for the boll weevil began in 1997. Boll weevils have been eradicated from several areas of the state. They are controlled by the BWEP in the other areas of the state. The boll weevil’s high reproductive capability and resistance to several insecticides allow this insect to build up large populations quickly. Forested areas around rivers, drainage ditches, and bayous provide favorable overwintering sites in southern cotton growing areas. Cooler winter temperatures and less favorable over-wintering habitats in the northern cotton growing areas cause higher mortality of overwintering boll weevil.

In Arkansas the BWEP started when the Legislation for the boll weevil eradication program was passed in 1991. The law authorized the formation of the Arkansas Boll Weevil Eradication Foundation. The Foundation has a governing board consisting of 9 members of which 8 are cotton producers or landowners and one from the Arkansas State Plant Board.

The BWEP started in southwest Arkansas in 1997 in cooperation with the Louisiana Boll Weevil Eradication program. The Arkansas Southeast Zone started in 1999, Central Zone 2000, Ridge Zone in 2001 and East Poinsett County during 2002. The remainder of the cotton producing area in Arkansas, East Craighead and Mississippi began participating in the eradication program in 2003.

The damage done by the pest: Weevils feed on squares and bolls, and females deposit eggs in these fruiting structures. If a weevil puncture is topped with a whitish or brown bump or "wart", it is an indication that the female has laid an egg in the hole and sealed the puncture to protect the egg. This gluey substance is white on newly sealed egg punctures, but turns brown~~s~~ with age. Some weevil punctures will not have this sealer, particularly if the insect merely feeds. Normally, the weevil, which prefers squares, makes only one egg puncture per square, but it will select young bolls in many cases. One egg hole also is normal. Weevil damage will range from one or two locks per boll to complete boll loss since many punctured squares or young bolls will drop off after the pest makes the feeding wound.

Life cycle: Total time from egg to adult ranges from 16 to 25 days (average of 19-21 days); egg - two to three days; larva - five to eight days; pupa - three to five days; newly emerged adult ("callow" adult) - one day; feeding adult – three to five days before egg laying. Adult females lay an average of 30 eggs each day for approximately 10 days. Each generation normally multiplies tenfold. The pests in a typical field can multiply about 2.5 times each week - about the same rate of increase as the squares in the field.

Boll weevils spend the winter in a semi-dormant state (diapause) in hardwood ground cover, such as patches of woods. During mild winters, they also can survive in grass or other cover. Usually four generations of weevils occur during the season. When daytime temperatures begin to rise above 70 degrees weevils begin emerging. Emergence may continue from before cotton is big enough to support the pests until July, peaking normally in May and June.

While there are not always clear-cut steps in the emergence of over-wintered weevils, the first adult generation can begin emerging about a week after the first white bloom, with others following at about three-week intervals. Climate and weevil food supply can greatly influence peaks in weevil populations.

Critical timing of control measures: The applications of insecticides to control the boll weevil will normally be applied when square damage levels reach one damaged square per row foot or 10% damaged squares. Once boll weevils reach this level and treatment is initiated, 4 - 5 treatments must be applied on a 4-5 day interval in order to obtain effective control. The key is to kill adult boll weevils before they can lay eggs. Treatment for suppression of overwintering boll weevils is determined using pheromone traps. If trap captures the week prior to squaring exceeds four weevils per trap per week, a suppression spray may be needed.

Yield losses attributed to pest: In the absence of effective control efforts, boll weevils have the ability to completely destroy a cotton crop. However, because of the Boll Weevil Eradication Program and growers efforts to control the pest, the average yield loss due to boll weevils for the southern region was 0.175% in 2002 (48).

Percentage of infested acres: The average percentage of boll weevil infested cotton acres in the southern region was 51.9% from 1999-2001 (48). Although the three-year average was 51.9%, the percentage of infested acres has dropped from 82% in 1999 to less than 17% in 2002 (48). This reduction in the percentage of infested acres is primarily due to the implementation of the Boll Weevil Eradication Program.

Chemical Control of Boll Weevil

The percentage of acres treated by state and the average number of applications for the insecticides used to control boll weevils is found in Table 10.

Organophosphates

Azinphosmethyl

Trade names are Guthion 2L, and Azinphosmethyl 2E. Applications are made by ground and air with a slightly larger percentage being made by ground equipment. Application rates average 0.25 pounds a.i. per acre. There is no preharvest interval for mechanically picked cotton. The restricted-entry interval is 48 hours.

Methyl Parathion

Trade names are Methyl Parathion 4E and Penncap M. Applications are made by ground and air with a larger percentage being applied aerially. Application rates average 0.42 pounds a.i. per acre. The preharvest interval is 7 days. The restricted-entry interval is 48 hours.

Malathion ULV

Trade names are Malathion, Fyfanon and various others. ULV Applications are made by ground and air with most going out aerially. Application rates average 10 ounces per acre by air and 16 ounces per acre by ground equipment. The preharvest interval is 0 days. The restricted-entry interval is 12 hours.

Other OP's for boll weevil control: None.

Resistance Problems with Organophosphates: None documented

IPM Issues: Methyl parathion can delay cotton maturity, specifically applications made before first flower will delay maturity. The use of organophosphates can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these organophosphates used: Limited malathion ULV use is due to the fact that most growers do not have the proper equipment for ultra low volume applications and because malathion is easily "rained off".

Synthetic Pyrethroids

Cyhalothrin

Trade name is Karate 2.08 CS and Warrior. Applications are made by ground and air with a larger percentage being applied by air. Application rates average 0.03 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 24 hours.

Cyfluthrin

Trade name is Baythroid 2 EC. Applications are made by ground and air with a larger percentage being applied by air. Application rates average 0.04 pounds a.i. per acre. There is no preharvest interval specified on the label. The restricted-entry interval is 12 hours.

Esfenvalerate

Trade name is Asana XL 0.66 EC. The type of application is evenly divided between ground and air. Application rates average 0.03 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 12 hours.

Zeta-Cypermethrin

The trade names are Fury 1.5 EC and Mustang Max 0.8 EC (Fury only remains in the market until inventories run out). Applications are made by ground and air with a larger percentage applied by air. Application rates average 0.04 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 12 hours.

Other Synthetic Pyrethroids for boll weevil control: Each of the following pyrethroids are used on less than 2 percent of the cotton acres: Deltamethrin (trade name: Decis), bifenthrin (trade name: Capture).

Resistance Problems with Synthetic Pyrethroids: None documented.

IPM Issues: The use of synthetic pyrethroids can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these synthetic pyrethroids used: They are used because they are effective and relatively cheap.

Carbamates

Oxamyl

Trade names are Vydate L and Vydate C-LV. Applications are made primarily by air. Applications rates average 0.24 pounds a.i. per acre. The preharvest interval for Vydate C-LV is 14 days. The preharvest interval for Vydate L is 21 days. The restricted-entry interval for both products is 48 hours.

Other Carbamates for boll weevil control: None

Resistance Problems with Carbamates: None documented.

IPM Issues: Carbamates are harsh on beneficial arthropods. Using different groups of chemicals with different modes of action for boll weevil control helps prevent development of resistance.

Why or why not are these carbamates used: Oxamyl gives added nematode and plant bug control (primarily plant bug control). The carbamates, aldicarb (trade name: Temik), when applied at planting in-furrow, primarily to control thrips, can help suppress boll weevil numbers.

Alternatives for Boll Weevil Control

The Boll Weevil Eradication program is the primary alternative for controlling the boll weevil.

Other alternatives: None.

Pipeline materials: None

COTTON BOLLWORM (*Helicoverpa zea*) **and TOBACCO BUDWORM** (*Heliothis virescens*)

Research Priorities for cotton bollworm and tobacco budworm

- What is the population structure of bollworm and tobacco budworm in the mid-south? How does this relate to resistance evolution and the need for structured refugia?
- What can we do to limit early season sprays for thrips, plant bugs and stink bugs and optimize on the opportunities created by boll weevil eradication?
- What is the distribution of the heliothines across the agricultural landscape? What are the most appropriate management units? Can we biologically define these management units?
- What are the conditions that favor outbreaks?
- Continue development of insecticidal transgenes and maintain resistance monitoring programs.
- Cost-benefit analysis of transgenic versus non-transgenic cotton are needed.
- Continue to evaluate conventional insecticides and conventional varieties.
- What effect do other transgenic crops (Bt corn, etc.) have on the total heliothine population?

Additional Research Priorities as listed in the "Recommended Research Thrusts" document developed at the *Heliothis*/*Helicoverpa* Workshop in Dallas, Texas on March 25-28, 2003 (see Attachment).

- Effect of landscape cropping systems, new varieties, soil type, cover crops, crop rotation, conservation and other tillage systems, crop host termination, sequence of host plants, influence of temperature, moisture, etc., and Roundup-Ready systems on population dynamics of all lepidopterans in cotton, especially the boll weevil (BW) and tobacco budworm (TBW), including overwintering, localized movement, and ovipositional behavior.
- Continue efforts on local and long-range movement of moths including use of isotope ratios and pollen grains as measures of influence of host plants, meteorological events, new cultivars, and development of meteorological models for prediction.
- In concert with the above statement, determine proportion of emigrants/non-migrants among local populations and determine cues for starting/stopping migration (including multiple flights).

- Use of caloric analysis to evaluate fat body reserves to aid in determining long or short-range movement.
- Conduct in-depth genetic studies and life-table analyses of BW/TBW.
- Search for female antagonists, ovipositional attractants, and improved delivery systems for BW/TBW, study pheromone production in relation to "attract 'n' kill" systems and mating disruption, and finalize potential value of "attract 'n' kill" systems, including use of food attractants, pheromones and insecticides.
- Continue studies on natural enemies of BW/TBW, including a search for their thresholds, influence of conservation tillage on their numbers, and influence of trap crops as a combined means of aggregating beneficial insects and serving as a refuge.
- Initiate studies to integrate multiple IPM tactics with insecticides in suppression and area-wide management of BW/TBW.
- Continue to study efficacy of pesticides against all pests, esp. BW and TBW, including monitoring for pesticide resistance.
- Continue to cooperate, through Cooperative Research and Development Agreements, (CRADA) when necessary, with industry in development and evaluation of new lines and improved varieties.
- Combine conventional host-plant resistance (HPR) factors (e.g. low/high gossypol) in conjunction with transgenic varieties to improve insect resistance management in transgenics.
- Identify and characterize traits for incorporation into future lines.
- Study insect transmission of diseases (e.g. aflatoxin) in relation to conventional and transgenic HPR.
- Develop molecular markers to incorporate into HPR research which is vital for improving the stacking of traits.

Regulatory Priorities for cotton bollworm and tobacco budworm

- Are structured refuges for Bt cotton important and how do they differ from regulatory requirements for other transgenics, i.e., Roundup Ready crops?
- Is the process of continually submitting Section 18s efficient?
- How do you effectively eliminate the most toxic and environmentally dangerous insecticides without increasing grower risks?
- Implementation and monitoring of insect resistance management.

Educational Priorities for cotton bollworm and tobacco budworm

- When is it necessary to treat conventional cotton for heliothines? Bt cotton?
- What is the probability of damage under a wide list of management influences (i.e., comprehensive thresholds)? What do we really know?
- When and how much Bt cotton should a grower plant? How much should a grower be willing to pay for Bt cotton?
- How about resistance management? Is it really important? How will it impact the grower economically?
- Labeling differences between conventional pesticides and that which is used for a plant incorporated pesticide (PIP).
- Scouting procedures (changes depending on type of cotton).
- Need to evaluate alternative methods of population evaluation and determination.

- Keep identification of bollworm at the forefront of educational activities.
- Information dissemination of cost-benefit analysis of transgenic versus non-transgenic cotton.

The bollworm and tobacco budworm species comprise what is commonly referred to as the Heliothine complex. Both species belong to the Noctuidae family of Lepidoptera and attack cotton in a similar fashion. Yield losses associated with this complex have been documented as high as 90% in individual fields. Bollworm and tobacco budworm populations vary greatly from south to north in the Midsouth production region. The overall population levels of the Heliothine complex are generally higher in the southern parts of the region. Both species occur as pests of cotton each year. Of the two species, the bollworm is a more frequent problem whereas the tobacco budworm is more difficult for producers to control. Tobacco budworms are resistant to two of the major classes of insecticides specifically the organophosphates and pyrethroids. However, with the development of transgenic Bt cotton and several new classes of insecticides, tobacco budworm has become much easier to control in recent years. Bollworm, on the other hand, is more tolerant of the Cry 1AC toxin produced in Bollgard cotton, and Bt cotton frequently requires supplemental treatment for bollworms.

The damage done by the pests: The most obvious damage is feeding on squares and bolls, but bollworms and budworms can also reduce yields through secondary damage. Feeding damage often provides entry for disease organisms, which can lead to boll rot. This usually occurs in irrigated cotton, but it can occur in wet periods after rainfall.

Percentage of infested acres: The average percentage of bollworm and tobacco budworm infested cotton acres for the three states was 98.5% from 1999-2001 (48).

Life cycle: Egg - three to five days; larva - 12 to 15 days spent feeding on cotton; pupa - 12 to 15 days, resting in top two to four inches of the soil; adult - moths emerge from pupae and begin laying eggs in 3 to 12 days. The development of one complete generation thus may require from 27 to 35 days. Female bollworm moths can lay from 250 to 1,500 eggs. In a normal season, there usually are about five generations, but some of these are spent on plants other than cotton. Normally, only two or three generations inflict important damage on cotton.

These insects overwinter in the soil, in the pupa stage, after going through a preparation phase. Moth migration is common and moths may move many miles. In early spring, the first generation develops on legume crops, such as crimson clover of alfalfa. The second generation apparently prefers corn, where bollworms are known as corn earworms. Third generation caterpillars generally are the first infestation for cotton, also infesting corn or grain sorghum if these crops are present. Also, roadside plants such as evening primrose attract bollworms.

Critical timing of control measures: Treatment thresholds vary depending on the type of crop (Bt or non-Bt), stage of crop, and among states. Generally, insecticide applications should be timed to egg hatch.

Yield losses attributed to pest: Despite control measures, the average yield loss due to bollworms and tobacco budworms for the three states was 1.9% from 1999-2001 (48).

Chemical Control of Cotton Bollworm and Tobacco Budworm - Ovicides

The percentage of acres treated by state and the average number of applications for the insecticides used to control bollworms and tobacco budworms is found in Table 10.

Organophosphates

Profenofos

Trade name is Curacron 8E. Applications are made by ground and air with the majority being applied by air. The application rate averages 0.43 pounds a.i. per acre. The preharvest interval is 30 days. The restricted-entry interval is 48 hours. Profenofos is rarely used today because of widespread planting of Bt cotton and the availability of more effective caterpillar treatments.

Acephate

Trade name is Orthene 90S, Orthene 75S, and Orthene 97S. Applications are made primarily by air. The application rate averages 0.45 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 24 hours. Most growers are not using acephate as an ovicide because of widespread planting of Bt cotton and the availability of more effective caterpillar treatments. It is not listed as an ovicide in the 2003 recommendations for Arkansas.

Other ovicidal OP's for cotton bollworm and tobacco budworm control: None

Resistance Problems with Organophosphates: There are resistance problems with all organophosphates used as larvacides.

IPM Issues: The use of organophosphates can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these ovicidal organophosphates used for cotton bollworm and tobacco budworm control? They are used primarily because of efficacy and cost.

Carbamates

Methomyl

Trade name is Lannate LV and Lannate SP. Applications are made by ground and air with the majority being applied by air. The application rate ranges from 0.22 to 0.45 pounds a.i. per acre. The preharvest interval is 15 days. The restricted-entry interval is 72 hours.

Methomyl is rarely used today because of widespread planting of Bt cotton and the availability of more effective caterpillar treatments. When applied at the higher rate, methomyl has a tendency to cause mild phytotoxicity (reddening of leaves), and this is another factor that limits its use.

Thiodicarb

Trade name is Larvin 3.2. Applications are made by ground and air with the majority being applied by air. The application rate averages 0.18 pounds a.i. per acre. The preharvest interval is 28 days. The restricted-entry interval is 12 hours.

Thiodicarb is rarely used today because of widespread planting of Bt cotton and availability of newer caterpillar treatments. Currently thiodicarb is recommended as an ovicide to control bollworm/budworm eggs in non-Bt cotton. It is also recommended for control of bollworm/budworm larvae and for control of loopers and armyworms. Thiodicarb continues to be one of the most effective treatments for use against larger, 'escaped', bollworm/budworm larvae. Thiodicarb is not 'rain fast' and requires several rain free/irrigation free days for maximum efficacy. This lack of rain fastness is another factor that limits its use.

Other ovicidal carbamates for cotton bollworm and tobacco budworm control: None

Resistance Problems with Carbamates: None documented.

IPM Issues: The use of carbamates can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods. Higher rates of methomyl can cause “reddening” of the cotton plant.

Why or why not are these carbamates used: They are used primarily because of efficacy and cost.

Chemical Control of Cotton Bollworm and Tobacco Budworm - Larvae and Adults

Organophosphates

Profenofos

Trade name is Curacron 8E. The majority of applications are made by air. Application rates as low as 0.5 lbs a.i per acre are used in tank mixtures but 1.0 lbs a.i per acre is required in stand-alone applications. The preharvest interval is 30 days. The restricted-entry interval is 48 hours.

At one time profenophos was widely used for control of tobacco budworms and tarnished plant bugs, as well as other pests. However, its use has declined greatly in recent years due to resistance in tobacco budworm and plant bug populations, as well as to wide spread planting of Bt cotton and availability of new, more effective caterpillar materials.

Currently the key value of profenophos is that it is an economical choice for use against mixed populations of bollworms and plant bugs, or against mixed populations of bollworm/budworm and a building spider mite infestation.

Chlorpyrifos

Trade name is Lorsban 4E. Applications are made by ground and air with the majority applied with ground equipment. Application rates average 0.42 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 24 hours. Only a very small percentage of the cotton acres (<1%) are treated with chlorpyrifos to control bollworms or tobacco budworms. For various reasons chlorpyrifos is not labeled for use in Mississippi cotton.

Other OP's for cotton bollworm and tobacco budworm control: Acephate is used as a larvacide on a small percentage of the cotton acres in Midsouth.

Resistance Problems with Organophosphates: Only budworm resistance is documented. Researchers report there are indications that bollworms are beginning to exhibit tolerance to organophosphates.

IPM Issues: The use of organophosphates can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these organophosphates used for cotton bollworm and tobacco budworm control: The organophosphates are not being used as much in recent years because of new technology (i.e., Bollgard cotton) and new products such as spinosad (Tracer), indoxacarb (Steward), and emamectin benzoate (Denim).

Synthetic Pyrethroids

Currently the most important use of pyrethroids is for control of bollworms in Bt cotton. Pyrethroids are highly effective against bollworms and are more economical than the available alternatives. Pyrethroids are no longer recommended for control of tobacco budworms in cotton in the Midsouth, because of high levels of resistance, but they continue to be useful in non-Bt cotton, against populations that are known to be primarily bollworms. Pyrethroids are an especially cost-effective treatment for mixed infestations of bollworms and stink bugs, which can occur in Bt cotton during mid to late season.

Cyfluthrin

Trade name is Baythroid 2 EC. Applications are made by ground and air with a larger percentage being applied by air. Application rates average 0.03 pounds a.i. per acre. Approximately 0.5 to 2 applications are made each growing season on Bollgard cotton and 2 to 5 applications per growing season on non-Bollgard cotton. There is no preharvest interval specified on the label. The restricted-entry interval is 12 hours.

Lambda-Cyhalothrin

Trade name is Karate 2.08 CS. The majority of applications are made aerially. Application rates average 0.03 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 24 hours.

Esfenvalerate

Trade name is Asana XL 0.66 EC. The majority of applications are made aerially. Application rates average 0.04 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 12 hours.

Cypermethrin

Trade names are Ammo 2.5EC and Ammo WSB. Applications are made by ground and air with the majority applied by ground equipment. Application rates average 0.06 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 12 hours.

Zeta-Cypermethrin

Trade names are Fury 1.5EC and Mustang Max 0.8EC. Applications are made by ground and air with the majority applied aerially. Application rates average 0.04 pounds a.i. per acre for Fury and 0.02 pounds a.i. per acre for Mustang Max. The preharvest interval is 14 days and the restricted-entry interval is 12 hours for both formulations.

Bifenthrin

Trade name is Capture 2 EC. Bifenthrin is used on less than 5 percent of the cotton acres to control bollworm and tobacco budworm. Both ground and aerial applications are used. The recommended rate is 0.04 – 0.1 lbs a.i. per acre. The restricted-entry interval is 24 hours and the preharvest interval is 14 days.

Other Synthetic Pyrethroids for cotton bollworm and tobacco budworm control: The synthetic pyrethroid, deltamethrin (trade name: Decis), is used on less than 1 percent of the cotton acreage to control bollworm and tobacco budworm. The recommended rate is 0.019 – 0.03 lbs a.i. per acre. The restricted-entry interval is 12 hours and the preharvest interval is 21 days.

Resistance Problems with Synthetic Pyrethroids: There is documented resistance to the synthetic pyrethroids by tobacco budworm.

IPM Issues: The use of synthetic pyrethroids can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these synthetic pyrethroids used for cotton bollworm and tobacco budworm control: Pyrethroids are no longer recommended for control of tobacco budworms because of resistance. They are used primarily against bollworms because of efficacy and cost. The use of synthetic pyrethroids for bollworm control would likely increase if resistance to B.t. develops.

Carbamates

Methomyl

Trade names are Lannate SP and Lannate LV. Applications are made by ground and air with the majority applied by air. Application rates average 0.35 pounds a.i. per acre. The preharvest interval is 15 days. The restricted-entry interval is 72 hours.

Thiodicarb

The trade name is Larvin 3.2. Applications are made by ground and air with the majority applied aerially. Application rates average 0.6 pounds a.i. per acre. The preharvest interval is 28 days. The restricted-entry interval is 12 hours.

Other carbamates for cotton bollworm and tobacco budworm control: None

Resistance Problems with Carbamates: None documented.

IPM Issues: None identified.

Why or why not are these carbamates used: They are used primarily because of efficacy and cost. However, thiodicarb is easily "rained off" and this limits its use considerably.

Additional Insecticides for Cotton Bollworm and Tobacco Budworm Control:

Spinosad (trade name: Tracer) Spinosad is a relatively new insecticide that is used solely to control caterpillar pests. It is a fermentation product of the actinomycete *Saccharopolyspora spinosa*. Use rates range from 0.067 to 0.089 lbs ai/acre (the 0.045 lbs ai/acre rate is not recommended, except as a tank mix partner). Spinosad provides good control of tobacco budworms, as well as most other caterpillar pests, and this makes it an important tool in the production of non-Bt cotton. It is rarely used in Bt cotton. Tracer is relatively benign to many beneficial insects, but there are some key beneficial species that are quite susceptible to spinosad. The restricted-entry interval is 4 hours and the preharvest interval is 28 days.

Indoxacarb (trade name: Steward) Indoxacarb was first labeled for use in cotton in 2001. It belongs to the oxadiazine class of insecticides. At the recommended rate of 0.09 to 0.11 lbs ai/acre it is effective against most caterpillar pests. Because it is effective against tobacco budworms, the primary use niche for indoxacarb is in non-Bt cotton. However, overall use of this product may well increase, especially if the percentage use of Bt cotton declines following successful eradication of the boll weevil. Indoxacarb also has activity against tarnished plant bug. Although it is not recommended for use against plant bugs as a primary target pest, this is an important advantage when growers need to control mixed infestations of caterpillars and tarnished plant bugs. The restricted-entry interval is 12 hours and the preharvest interval is 14 days.

Emamectin benzoate (trade name: Denim) was used under a Section 18 label in 2002 on a small percentage of the cotton acres in the Midsouth to control tobacco budworm and beet armyworm. The label recommended rate was 0.0075 to 0.01 pounds a.i. per acre. The restricted-entry interval is 48 hours is and the preharvest interval is 21 days.

Alternative Control Practices

Transgenic Bt cotton is currently the primary method used to control the bollworm/budworm complex in the Midsouth. During recent years it has been planted on approximately 70-80% of the Midsouth cotton acreage. Bt cotton provides 100% control of tobacco budworm, but is less effective against bollworm and other caterpillars. Current varieties of the Bt cotton often require treatment for bollworm.

B.t. impacts on IPM: The impacts of B.t. are providing a test-case for resistance management (ex., success of the refugia requirements listed for growing B.t. cotton in preventing the development of resistance to B.t.)

Biological Controls

Naturally occurring beneficial organisms play an extremely important role in regulating bollworm/tobacco budworm populations. Outbreaks of tobacco budworms rarely occur unless these beneficial insect populations are disrupted. Increased utilization of no-till practices results in increased in-field populations of fire ants, which are excellent predators on caterpillar pests.

Other alternatives: None identified

Pipeline materials: Bollgard II and Bollgard III cotton, VIP cotton, and Widestrike cotton.

Other Issues

In the long term, the Boll Weevil Eradication Program has resulted in fewer applications for control of the bollworm and tobacco budworm. In the future it will be important to maintain insecticides for controlling bollworm and tobacco budworm in case B.t. resistance develops and also to control the pests in non-Bollgard cotton.

THRIPS (Tobacco Thrips - *Frankliniella fusca*, Flower Thrips - *Frankliniella tritici*, Western Flower Thrips - *Frankliniella occidentalis*, Soybean Thrips - *Neohydatothrips variabilis*)

Research Priorities

- Are long-term insecticide use patterns impacting the species complex and resistance levels in key pest species?
- How do adjacent crops, inter-planting of wheat and cotton, and cover crops impact thrips populations and damage potential on cotton?
- When is cotton safe from thrips damage (not well defined at present time)?
- Disease, environment, herbicide interactions as it relates to thrips control and injury.
- Interaction of thrips injured plants and other management practices (e.g. Roundup, internodes difficult to count)
- What are the conditions that favor outbreaks?

- Potential seed treatments and other management strategies for thrips control and their impact on resistance management.
- Is host resistance to thrips possible? Is development of tolerance more feasible?
- Need research on the precision placement and variable rate application of aldicarb.
- Determine if there is a real need for foliar insecticides.

Regulatory Priorities

- Maintain registration and emphasize safe uses of aldicarb (ex., closed handling systems) (**High Priority**)
- Insure safe handling of treated seed and "at planting" handling of insecticides.
- Determine if there is a real need for foliar insecticides for thrips control.

Educational Priorities

- When can a grower make a decision to not treat for thrips? Do cultural, non-insecticidal, practices make a difference?
- How can a grower distinguish the different species of thrips?
- What factors influence selection of different insecticides?
- Emphasize safe use practices for aldicarb.

Thrips are a perennial, early-season pest of Midsouth cotton. Several different species of thrips occur on cotton, but the tobacco thrips is by far the most common, especially on seedling cotton. The biology and damage caused by the different species is similar. However, susceptibility to insecticides varies with thrips species, so identification of species can be important when excessive injury and suspected population shifts are encountered among species. Western flower thrips are more tolerant of commonly used insecticides for thrips control, and tobacco thrips are controlled with commonly used materials. Young seedling plants are more susceptible to injury by thrips, although western flower thrips can occasionally cause significant damage to older cotton. Thrips injury to young seedling plants can stunt growth and reduce yield potential. As a result, most cotton is treated with an in-furrow insecticide or seed treatment to prevent the development of damaging populations and, consequently, serious yield losses due to thrips are uncommon.

The damage done by the pest: Larvae and adults suck plant juices from the tender terminals. The first targets of thrips moving into early cotton are the seed leaves, which become distorted or crinkled. Feeding damage can reduce stands enough to force replanting in extreme cases. Thrips feeding also can delay maturity. In most cases, the seedlings can grow out of the first stage of damage. Severe damage can destroy plant terminals resulting in plants with distorted growth.

Percentage of infested acres: The average percentage of thrips infested cotton acres for the three states was 98.2% from 1999-2001 (48).

Life cycle: Egg - four days; larva - six days, molting twice; pupa - four days; egg to adult - 14 days average. These pests overwinter in the pupa stage in plant trash. They begin reproducing in early spring in non-cotton host plants, such as grains, early blooming weeds, and legumes. Once the early host plants mature or die, thrips move quickly into cotton fields. When the pests migrate, late-planted cotton is one of their chief targets since the crop is tender and offers easy feeding.

Critical timing of control measures: Must be treated early either with an in-furrow application at planting or foliar applications based on economic threshold which vary by state, state and environmental conditions. Cotton generally becomes safe from economic damage once it reaches the 4-5 leaf stage.

Yield losses attributed to pest: The average yield loss due to thrips for the three states was 0.44% from 1999-2001 (48).

Chemical Control of Thrips

The percentage of acres treated by state and the average number of applications for the insecticides used to control thrips is found in Table 10.

Organophosphates

Disulfoton

Trade names are Di-Syston 15G and Di-Syston 8. All applications are in-furrow treatments applied with ground equipment. Application rates average 0.83 pounds a.i. per acre. The preharvest interval is not specified on the label. The restricted-entry interval is 48 hours. For various reasons disulfoton is not recommended for thrips control in Mississippi.

Acephate

Trade names are Orthene 90S, Orthene 75S, and Payload 15G. Application methods include seed treatments and in-furrow sprays with ground equipment. Application rates range from 0.75 – 1.0 pounds a.i. per acre in furrow. The preharvest interval is not specified on the label. The restricted-entry interval is 24 hours.

In addition to being used as an at-planting seed treatment and as an in-furrow treatment for thrips control, acephate is also commonly used as a foliar treatment to control thrips on seedling cotton. Rates of 0.2 to 0.25 lbs ai/acre are effective against all species of thrips, except the western flower thrips.

Other OP's for thrips control: Dicrotophos (Bidrin) and methamidophos (Monitor) are occasionally used. Dicrotophos is widely used in Mississippi, but less so in the other two states. Methamidophos is a relatively expensive organophosphate insecticide, and because of this, it is rarely used.

Resistance Problems with Organophosphates: None

IPM Issues: The use of organophosphates can also trigger secondary pest problems and kill beneficial arthropods. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these organophosphates used for thrips control: They are used primarily because of cost.

Carbamates

Aldicarb

The trade name is Temik 15G. All applications are in-furrow treatments applied with ground equipment. Application rates average 0.45 and 1.05 pounds a.i. per acre The preharvest interval is 90 days. The restricted-entry interval is 48 hours.

Aldicarb is the most commonly used soil applied insecticide. This is because of its excellent, long-lasting activity against thrips and because, when used at adequate rates, it provides good suppression of nematodes. Aldicarb also provides early season suppression of plant bugs and cotton aphids, but it does not control cutworms.

Other carbamates for thrips control: None identified.

Resistance Problems with Carbamates: None

IPM Issues: None identified

Why or why not are these carbamates used for thrips control: The human toxicity problems associated with aldicarb have limited its use somewhat. Another benefit to using aldicarb for thrips control is that it is also a good nematicide.

Neonicotinoids

Thiamethoxam

Trade name is Cruiser. It is applied as a seed treatment. The recommended rate is 7.75 fluid ounces of product per 100 pounds of seed. The restricted-entry interval is 12 hours and the preharvest interval is not addressed on the label. This relatively new product provides effective control of thrips for two to three weeks following emergence. It will also control aphids on seedling cotton. It was used on less than 1 percent of the mid-south cotton acreage in 2002. The use of thiamethoxam is likely to increase in future years, but will be limited somewhat by the lack of nematode control.

Imidacloprid

Trade name is Gaucho. It is applied as a seed treatment at a rate of 4.8 to 8 ounces of product per 100 pounds of seed (rate depends on the formulation used). The restricted-entry interval is 12 hours and the preharvest interval is not addressed on the label.

Cultural Control Practices

Some cotton varieties are more tolerant than others to thrips injury.

Other alternatives for thrips control: None

Pipeline materials for thrips control: None

PLANT BUGS AND OTHER MIRIDS (Tarnished Plant Bug - *Lygus lineolaris*, Cotton Fleahopper - *Pseudatomoscelis seriatus*, Clouded Plant Bug - *Neurocolpus nubilus*, Western Tarnished Plant Bug - *Lygus hesperus*)

Research Priorities

- Threshold issues, state versus state (**High Priority**)
- Can spatial and temporal distribution of mirids be predicted in typical mid-south agricultural landscapes and manipulated to reduce infestations on cotton?
- When can plant bug stress be tolerated on cotton?
- If necessary to treat early season for plant bugs, how can you treat with minimum upsets in the balance of the system?
- Pheromone identification, alternative methods of detection
- Host plant resistance
- Resistance monitoring
- Alternative insecticides
- Scouting techniques. Post season surveys of plant bugs – where are they?
- Is there is potential for bio-control alternatives?
- What are the conditions that favor outbreaks?

Regulatory Priorities

- Help maintain ecologically safe and efficacious insecticides for plant bug control.
- Consider relationships between treating field borders, roadsides, etc. versus legal treatment of production fields.
- Labels with broad base of uses for mirids

Educational Priorities

- Emphasize need for quantitative scouting (**High Priority**).
- Evaluate insect/plant based thresholds
- How should a grower detect damage and plant susceptibility to plant bugs? When can a grower make a decision “not to treat”?
- How can a grower predict or minimize plant bug movement into his field(s)?
- How should a grower scout for plant bugs?
- Determine impacts of environment on plant bug management.
- Insect resistance management for producers

Several plant bug species in the family Miridae family attack cotton in the U.S. They include the tarnished plant bug (*Lygus lineolaris*), cotton fleahopper (*Pseudatomoscelis seriatus*), clouded plant bug (*Neurocolpus nubilus*), and the western tarnished plant bug (*Lygus hesperus*). The tarnished plant bug is the most common and important plant bug pest in Midsouth cotton. Plant bugs often reach numbers sufficiently high during the early season such that insecticides are applied. Often these actions result in outbreaks of secondary pests, including aphids, spider mites and tobacco budworms. Before BWEP the importance of the tarnished plant bug as a cotton pest of cotton often was overshadowed by the boll weevil. With BWEP and elimination of insecticide applications that key pest, specific control actions targeting the tarnished plant bug have increased. Coupled with the development of resistance by tarnished plant bug populations to a number of insecticides (Hollingsworth, *et al.*, 1997; Snodgrass, 1996), the importance of plant bugs has increased significantly.

The damage done by the pest: Plant bugs feed using the process of extra-oral digestion or solid-to-liquid feeding (Agusti and Cohen 2000). Their piercing mouthparts penetrate and mechanically macerate plant tissues at the same time delivering chemically macerating digestive enzymes. The targeted area is turned into a concentrated slurry which is sucked up by the bug. Their foods include nutrient rich, solid plant parts, especially fruit and floral tissues and meristematic cells. Plant bugs may also feed on insect tissues when they act as facultative predators.

In pre-squaring cotton, the terminal portions of plants are preferred feeding sites. Injury from plant bug feeding at this crop stage can cause loss of apical dominance, which can result in multiple terminals per plant, a condition sometimes referred to as "crazy cotton". Reduced growth following terminal injury of pre-squaring cotton can delay development of squares, crop maturity and reduce yield if optimal growing conditions do not allow for compensatory growth. As the cotton crop develops, squares become important feeding sites. Small squares will shed following plant bug feeding, but larger squares typically are more tolerant. The probability of square abscission following tarnished plant bug feeding is a function of anther size (Pack and Tugwell 1976). When anthers are hardly visible, the bug feeds on the totality of the floral bud. As the square grows, the anthers reach a large enough size for the bug to feed on the individual pollen sack. When tarnished plant bug feeding is localized on the anthers, shed rarely happens; however, squares with extensive anther damage may shed as bolls (Pack and Tugwell 1976). Flowers may be attacked by plant bugs, with feeding resulting in warty growths on flower petals and brown spots on stamens and pistils. Plant bugs lay their eggs inside tender and succulent cotton stems, making them very difficult to detect in the field.

Severe plant bug infestations can develop quickly because bug populations may build on other host plants and then move into cotton. Wild and cultivated plant hosts include most common roadside weeds and cultivated crops such as alfalfa, soybean, vegetables and corn. Plant bugs can move onto cotton from proximate wild host plants or crops when those plants senesce or are mowed or sprayed with herbicides. Growers may be faced with a severe plant bug infestation just days after having relatively clean fields. Infestations occur throughout crop development, but the period from the seedling stage until the second week of flower is when plant bugs are of greatest concern in most Midsouth production systems (Tugwell et al 1976). In recent years, the reduced spray environment fostered by BWEP and transgenic Bt cotton have been such that plant bug population densities build in July and August to levels that potentially could result in economic damage.

Percentage of infested acres: The average percentage of plant bug infested cotton acres for the three states was 95.4% from 1999-2001 (48).

Life cycle: Plant bugs are classified in the Order Hemiptera, a group that is referred to as "true bugs" by entomologists. They have gradual metamorphosis - they do not pass through a caterpillar stage, and they do not go into the pupa or resting stage. When true bugs hatch, they resemble the adults except for size and often the absence of wings. Generally plant bugs will hatch in 10 to 14 days; they will spend 10 to 18 days as nymphs; with five nymphal stages.

Tarnished, western and rapid plant bugs overwinter as adults in ground trash near host plants. The clouded plant bug and cotton fleahopper overwinter in the egg stage in the stems and stalks of host plants of various kinds.

Critical timing of control measures: Treatment thresholds for plant bugs differ among states and will vary according to crop developmental stage. Recommendations for insecticide applications in most states are based on information on square retention and population densities.

Yield losses attributed to pest: The average yield loss due to plant bugs for the three states was 0.94% from 1999-2001 (48).

Chemical Control of Plant Bugs

The percentage of acres treated by state and the average number of applications for the insecticides used to control plant bugs is found in Table 10.

Organophosphates

Dicrotophos

The trade name is Bidrin 8E. Applications are made by ground and air equipment (aerial application is the only method used after irrigation pipes go out in mid season or after significant rainfall). Application rates range from 0.24 to 0.5 pounds a.i. per acre. The preharvest interval is 30 days. The restricted-entry interval is 48 hours. Tarnished plant bugs and cotton flea hopper are the primary targets of many dicrotophos applications. The performance of dicrotophos can be erratic because of resistance problems, but it remains a very important insecticide for tarnished plant bug, as well as stink bug and thrips, control. Rates of 0.25 to 0.33 lbs ai/acre usually provide effective control during early season, but the 0.5 lb a.i./acre rate may be required during mid to late season. Multiple applications applied approximately 5 days apart are required to control heavy mid to late season plant bug infestations. Dicrotophos is also quite effective against stink bugs and is a good choice for control of mixed populations of plant bugs and stink bugs during mid to late season.

Dimethoate

There are numerous trade names for dimethoate products. The majority of applications are made with ground equipment. Application rates average 0.3 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 48 hours. For various reasons dimethoate is not recommended for plant bug control in Mississippi.

Acephate

Trade names are Orthene 90S, Orthene 97, Orthene 75S, Address and various others. The type of application is evenly divided between ground and air equipment. Rates range from 0.25 lbs a.i. per acres during early season to 0.9 lbs a.i. per acre during late season. However, multiple applications applied at 4 to 5 day intervals are often required to obtain control of heavy mid and late season infestations. The preharvest interval is 21 days. The restricted-entry interval is 24 hours.

Acephate is categorized in a different chemical sub-class compared to most other organophosphates used on cotton, and it is one of the few 'older' insecticides to which plant bugs have not developed high levels of resistance. Acephate is used to control plant bugs, thrips, and stink bugs throughout the growing season.

Chlorpyrifos

Trade name is Lorsban 4E. Applications are made by ground and air with the majority applied with ground equipment. Application rates average 0.31 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 24 hours. For various reasons chlorpyrifos is not labeled for plant bug control in Mississippi.

Other OP's for plant bug control: Profenofos is used on less than 1 percent of the cotton acres for controlling plant bugs. The use of malathion ULV for boll weevil control provides some secondary control of plant bugs. Methamidophos is also occasionally used for controlling plant bugs on a small percentage of cotton acres.

Resistance Problems with Organophosphates: Resistance problems with organophosphates have been documented (Hollingsworth, *et al.*, 1997; Snodgrass, 1996)

IPM Issues: The use of organophosphates can reduce natural enemy populations and may also trigger secondary pest problems. In areas where BWEP is implemented malathion ULV reduces plant bug numbers and may eliminate the need for other insecticides. Timing of malathion applications for BWEP and for plant bug control do not necessarily correspond.

Why or why not are these organophosphates used for plant bug control: They are used primarily because of efficacy and cost. Studies in Arkansas have shown both dicrotophos and acephate are the most efficacious insecticides used for plant bug control.

Carbamates

Oxamyl

Trade names are Vydate C-LV and Vydate L. Applications are made by ground and air with the majority applied with ground equipment. Application rates average from 0.25 pounds to 0.33 lbs a.i. per acre. The preharvest interval is 21 days for Vydate L and 14 days for Vydate C-LV. The restricted-entry interval for both formulations is 48 hours.

Because it belongs to a different class of chemistry than other plant bug materials, oxamyl plays an important role in plant bug resistance management. It also provides secondary nematode control when both pests are in the field. Oxamyl is very efficacious and cost-effective, especially when both plant bugs and nematodes are present.

Other carbamates for plant bug control: None identified.

Resistance Problems with Carbamates: None identified.

IPM Issues: Carbamate insecticides may reduce natural enemy populations and may also trigger secondary pest problems.

Why or why not are these carbamates used for plant bug control: Oxamyl applied at the "pinhead" stage of cotton for boll weevil control will also help control plant bugs, but oxamyl is not the first choice for plant bug control unless nematodes are also present in the field.

Cultural Control Practices

Thick stands of cotton tend to have increased numbers of plant bugs. The use of Roundup Ready cotton varieties can affect the availability of alternate weed hosts for plant bugs around and in the cotton field. For example, in a reduced tillage production system where herbicide application for weeds is delayed until after crop emergence, adult plant bugs present on weed hosts may move on to pre-squaring cotton and feed and/or fly to other areas. Movement of immature plant bugs is more restricted, and plant injury from their feeding activity can be severe (Luttrell et al 2002).

Biological control of plant bugs: Increased utilization of no-till practices results in increased in-field populations of ants, which are predators of plant bugs.

Other insecticides for plant bug control:

Thiamethoxam (trade name: Centric), is a neonicotinoid. The recommended rate is 0.047 lbs a.i. per acre. The restricted-entry interval is 12 hours and the preharvest interval is 21 days.

Imidacloprid (trade names: Provado, Trimax), is a neonicotinoid. The recommended rate is 0.047 lbs a.i. per acre. The restricted-entry interval is 12 hours and the preharvest interval is 14 days.

These two neonicotinoid products were generally used when there was also an aphid problem in the cotton field. Pyrethroids can be highly effective in controlling plant bugs, but they are rarely used because of insecticide resistance problems.

Indoxacarb (trade name: Steward), is an oxadiazine, is a new insecticide that has shown activity for controlling plant bugs and lepidopteran pests, but it is not as good as the other materials especially when used alone for plant bug control. However, it is used primarily as a lepidopteran pest insecticide and its use is cost-prohibitive when used as a plant bug insecticide only.

Pipeline materials for plant bug control: Novaluron (Diamond) has been reported as having some level of efficacy for controlling plant bugs.

APHIDS

Research Priorities

- How will boll weevil eradication and Bt cotton impact the frequency of aphid problems (e.g., more beneficial arthropods?)
- Can we further manipulate the natural epizootics of fungi for biological control?
- How much stress from aphids can be tolerated?
- Alternative chemicals to nicotinoids for aphid control
- Impact on yields due to aphids? Define impacts on yield and quality.
- Thresholds for aphids
- What are the conditions that favor outbreaks?

Regulatory Priorities

- We need more than one chemistry (i.e., new modes of action) for aphid management.
- Do we have sufficient reduced risk chemistries to manage cotton aphid, including resistance management?
- Availability of carbofuran is very important in heavy aphid pressure years.
- Is Sec. 18 the only way to keep carbofuran registered? What is industry's role?
- Regulatory hurdles for selective insecticides (specifically those to control aphids)?

Educational Priorities

- How do we sample and when can we make decision "not to treat"?
- How to identify and assess the impact of the fungus and hold off on insecticide use?
- Can the numbers of beneficial insects present be used to delay aphid applications?
- Aphid threshold determinations

Aphids are a secondary pest in cotton. Aphids tend to be a greater problem in cotton when early applications of insecticides have been made to reduce the overwintering boll weevil populations, to treat early plant bug infestations, or following application of foliar insecticides for thrips.. The insecticides destroy natural enemies that normally suppress aphid populations. In some years aphids have caused severe problems for cotton growers.

Frequency of occurrence: Aphids tend to be a frequent pest of a portion of the Midsouth cotton crop each year.

The damage done by the pest: Heavy infestations cause curling or crinkling of leaves. Aphids feed on the youngest, most tender growth and, when present in large numbers, will cover terminals. During the principal blooming period, aphids may cause older leaves to turn yellow and shed. Severe infestations can cause heavy yield/quality losses.

Percentage of infested acres: The average percentage of aphid infested cotton acres for the three states was 81.8% from 1999-2001 (48).

Life cycle: Female aphids give birth to live young. Females continuously reproduce without a male. The pests can multiply rapidly under high temperatures and may develop the equivalent of a new generation every 3-5 days.

Critical timing of control measures: Treatment thresholds vary among states and may be impacted by environmental conditions. It is recommended that pyrethroid applications not be made prior to July 1. It is also recommended to use systemic in-furrow insecticides at planting to suppress early season aphids.

Yield losses attributed to pest: The average yield loss due to aphids for the three states was 0.22% from 1999-2001 (48).

Chemical Control of Aphids

The percentage of acres treated by state and the average number of applications for the insecticides used to control aphids is found in Table 10.

Organophosphates

Dicrotophos

The trade name is Bidrin 8E. Applications are made by ground and air with the majority applied with ground equipment. Application rates average from 0.4 to 0.5 lbs a.i. per acre are usually required to provide control. The preharvest interval is 30 days. The restricted-entry interval is 48 hours.

A single, properly timed application of dicrotophos will usually provide adequate control of aphid infestations, but overall efficacy is somewhat less than that of products like carbofuran, acetamiprid, or thiamethoxam. Dicrotophos is a cost-effective treatment for control of mixed infestations of plant bugs and aphids.

Other OP's for aphid control: None identified.

Resistance Problems with Organophosphates: Aphid resistance to organophosphates has been documented.

IPM Issues: The use of organophosphates can also trigger secondary pest problems and reduce beneficial populations. Timing the applications too late can also adversely affect beneficial arthropods.

Why or why not are these organophosphates used for aphid control: If aphids are present imidacloprid (Provado or Trimax), dicrotophos (Bidrin), acetamiprid (Intruder), and thiamethoxam (Centric) will be used more than other materials.

Carbamates

Why or why not are carbamates used for aphid control: Carbofuran is rarely used for aphid control because it is not labeled for that use although it is occasionally used under Section 18 exemptions.

Synthetic Pyrethroids

Bifenthrin

Trade name is Capture 2EC. The application type is evenly divided between air and ground equipment. Application rates average 0.04 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 12 hours. For various reasons bifenthrin is not recommended for aphid control in Mississippi.

Other Synthetic Pyrethroids for aphid control: None identified.

Resistance Problems with Synthetic Pyrethroids: Aphid resistance to synthetic pyrethroids is well documented. The pyrethroids can even increase aphid fecundity.

IPM Issues: If synthetic pyrethroids are used early on cotton they can actually promote aphid populations.

Why or why not are these synthetic pyrethroids used for aphid control: Lack of efficacy.

Neonicotinoids

Imidacloprid

Trade names are Provado 1.6 F, Trimax 4 SC . The applications are made with both ground and aerial equipment. Application rates average 0.036 pounds a.i. per acre. The preharvest interval is 14 days. The restricted-entry interval is 12 hours.

The relatively high price of imidacloprid products has resulted in its limited use compared to other insecticides.

Thiamethoxam

Trade name is Centric 25 WG or 40 WG. The applications are made with both ground and aerial equipment. Application rates average 0.047 pounds a.i. per acre. The preharvest interval is 21 days. The restricted-entry interval is 12 hours.

Because it provides good control of aphids and plant bugs and is reasonably priced, the relative use and importance of thiamethoxam will likely increase.

Acetamiprid

Trade name is Intruder 70 WP. The applications are made with both ground and aerial equipment. Application rates average 0.0375 pounds a.i. per acre. The preharvest interval is 28 days. The restricted-entry interval is 12 hours. Studies in Arkansas have shown that acetamiprid is the most efficiacious of the neonicotinoids for controlling aphids. It may see increased use in the future.

Biological Controls

The aphid fungus (*Neozygites fresenii*) is very effective in reducing aphid populations. The aphid fungus usually occurs in late June to mid-July. Before treatments are applied, fields should be checked for the fungus. If the fungus is present, it is recommended to not treat with insecticides for aphid control. Cotton Incorporated sponsors a free service that will diagnose aphid fungus levels in cotton fields. More information on this service can be obtained at: http://www.uark.edu/misc/aphid/

The parasitic wasp, *Lysiphlebus testaceipes*, also helps control aphid populations in cotton. It is a parasitoid used/conserved for added biological impact on aphids. It aids the aphid fungus in decimating aphid populations. The wasp is conserved/protected by not spraying broad spectrum insecticides. Arkansas has developed thresholds for aphid control, incorporating the aphid fungus and beneficial insects.

Other alternatives for aphid control: Pymetrozine (Fulfil)

Pipeline materials for aphid control: None identified.

OTHER INSECT/ARTHROPOD PESTS OF COTTON

Other secondary pests such as spider mites, cutworms, stink bugs, beet armyworms, fall armyworms, whiteflies, and loopers occur sporadically throughout the region, but do not occur in economically damaging numbers every year. However, the pest spectrum continues to change with advances in technologies concerning cotton insect pest management, and one or several of these or other arthropods not listed could quickly become much more important in the future. Because of the sporadic nature of these insect pests, the acres treated with specific insecticides are difficult to estimate. Therefore, we are listing the recommended insecticides for each pest, but we are not estimating acres treated.

Spider Mites (Two-Spotted Spider Mite - *Tetranychus urticae,* and various other species)

Research Priorities

- How much damage do spider mites cause to mid-south cotton? Is it economical to treat with mititcides (a question of thresholds)?
- Can spider mite problems be manipulated with cultural practices?
- Are biological or cultural control options available?
- How will boll weevil eradication and Bt cotton impact the frequency of spider mites problems (i.e., will there be more beneficial arthropods?)?
- More efficacious and economical chemical controls.

- What are the conditions that favor outbreaks?

Regulatory Priorities

- How do we maintain cost effective materials for limited use on cotton?
- Aerial applications (precision applications e.g., border/spot treatments). It is extremely important to maintain aerial applications on labels.

Educational Priorities

- Traditional information on identification, scouting and prevention of problem.
- Economics of treating…when is it worth the cost?
- Educate growers on thresholds.
- Inform growers on impact of weed hosts on edge of fields.
- Emphasize cultural control practices.
- Insect resistance management strategies

Although several different species of spider mites can potentially occur on cotton, the two-spotted spider mite, *Tetranychus urticae,* is the most common. Sub-economic populations of spider mites are normally present in most fields, but the occurrence of economically damaging infestations is usually localized. However, when heavy populations of mites do occur they can cause significant damage. Severe infestations of spider mites are capable of reducing lint yield by several hundred pounds. Spider mites are often considered secondary pests because infestations can be flared by applications of broad-spectrum insecticides applied to control other pests, but hot, dry environmental conditions can also favor mite outbreaks.

Historically, spider mites were a more consistent problem during the late 50s and 60s than they were during the 70s through early 90s. However, although spider mites continue to be a relatively uncommon problem, there has been a notable increase in occurrence in recent years. This may possibly be associated with increased adoption of transgenic herbicide resistant plants and reduced tillage systems. Such systems often allow higher weed populations to remain in the field after planting and during early seedling development. Although these weeds are ultimately controlled by post-emergence herbicide applications, they can provide a source for early season spider mite infestations.

Control: When spider mites are a problem during dry periods, irrigation, or timely rainfall, can help increase plant vigor and tolerance and may affect mite populations. Treatment thresholds vary among states as well as due to environmental conditions. However, when populations exceed the economic threshold, treatment with a specific miticide is recommended. Depending on the material being used, successful control of heavy spider mite infestations may require two successive applications at approximately five-day intervals. This is because many treatments are not active against the egg stage and because the residual control provided by most miticides is relatively short.

Table 2: Insecticides Recommended for Control of Spider Mites

Insecticide	Class	Trade Name	Lbs ai/acre
Bifenthrin *	SyP	Capture	0.06 to 0.1
Fenpropathrin *	SyP	Danitol	0.2 to 0.3
Abamectin	Misc.	Zephyr	0.00465 – 0.0188
Dicofol	Chlor. Hydro.	Kelthane	1.00 to 1.50
Propargite	Misc.	Comite	1.23 to 1.64

* These products require two consecutive applications at 5-day intervals.

Cutworms (Black Cutworms - *Agrotis ipsilon*, Granulate Cutworms - *Feltia subterranean,* and various other species)

Research Priorities

- What species are important?
- How do current cultural management systems and conservation tillage programs impact cutworm populations (i.e., can you predict a cutworm problem) and how can pesticide applications be modified as a result?
- Is Bt cotton more tolerant of cutworms? What about Cry2Ab cotton?
- Potential of using pheromone traps to determine populations early season.
- How to assess potential damage
- What are the conditions that favor outbreaks?

Regulatory Priorities

- How do we maintain cost effective materials for limited use on cotton?
- Maintain aerial applications.
- Pyrethroids + glyphosate as preplant burndown can also provide cutworm control, but timing is critical. Needs registration changes to allow use of pyrethroids in this manner.

Educational Priorities

- Where are cutworm populations prior to planting? How to assess potential damage?
- How does a grower fine-tune the need for treatment? When can it be determined that treatment is not necessary?
- Traditional information on species identification, scouting, when to treat, etc..
- Identify practices associated with infestations that cause damage.

Cutworms attack newly emerged plants by cutting the young plant at the soil line and pests on field by field basis. Rarely are large numbers of acres affected by cutworms. Black cutworms (*Agrotis ipsilon*) and granulate cutworms (*Feltia subterranea*) are the most common species encountered in Midsouth cotton fields, but other cutworm species occasionally occur. The potential for cutworms has increased in recent years because of increased use of reduced tillage systems and herbicide tolerant varieties.

Cutworms are one of the few cotton pests that are capable of killing an entire cotton plant. Larger larvae feed by cutting the main stem of seedling plants. When plants are cut below the cotyledon node, the entire plant is killed, and this is the most common type of injury, especially in plants younger than the 3-leaf stage. Occasionally larger seedlings are cut above the cotyledon node, and plants damaged in this manner often survive, although they may be less productive. Cutworms have the potential to cause very heavy yield losses if stands are destroyed or severely reduced and fields are not re-planted. However, in practice, cutworms seldom cause heavy yield losses. This is because cotton has the ability to compensate for low to moderate level stand loss, and because fields are routinely re-planted, or "spot re-planted" in cases where stand loss is excessive. Thus, the greatest loss associated with cutworm damage is the cost of re-planting, which is substantial, and any yield reductions or increased production costs associated with later planting.

Control: Cutworms are rarely a problem in fields, or areas of fields, where all vegetation is destroyed several weeks before planting, either by tillage or by herbicides. Thus, classical conventional tillage systems provide excellent cultural control of cutworms. In conventionally tilled fields cutworm infestations are usually restricted to low, wet areas of the field and other areas where vegetation was not completely destroyed before planting. However, under reduced tillage systems vegetation is often present up to, and even after, planting. In these situations the potential for cutworm infestations is greatly increased, and at-planting insecticide treatments are routinely recommended to control cutworms that are present. Fields in which a large number of leguminous plants or other broadleaf weeds are present at planting should be considered to be at extremely high risk of cutworm infestation.

Regardless of whether or not a cutworm treatment is applied at planting, fields of seedling cotton should be scouted regularly for cutworms until plants reach the four to five leaf stage, at which point the plants become relatively safe from cutworm damage. Treatment is recommended when cutworm infestations threaten to reduce plant population below an acceptable level (approximately 35,000 plants per acre). Because cutworms are relatively susceptible to the recommended insecticides, a single application is usually sufficient. It is worth noting that most of the treatments that are applied in-furrow, or as seed treatments, for thrips control do not provide effective cutworm control. Also, note that transgenic Bt cotton does not provide effective control of cutworms. This is because cutworms are relatively more tolerant of Bt toxin than many other caterpillar pests and because large cutworm larvae will destroy several plants before they consume enough toxin to provide control.

Table 3: Insecticides Recommended for Control of Cutworms

Insecticide	Class	Trade Name	Lbs ai/acre
Acephate	OP	Orthene (generics)	0.8
Cyfluthrin	SyP	Baythroid	0.0125
Cyhalothrin	SyP	Karate	0.02 to 0.03
Cypermethrin	SyP	Ammo	0.025
Deltamethrin	SyP	Decis	0.013 to 0.019
Esfenvalerate	SyP	Asana	0.03
Tralomethrin	SyP	Scout X-tra	0.016 to 0.02
Zetamethrin	SyP	Fury, Mustang Max	0.016 to 0.024
Bifenthrin	SyP	Capture	0.04 – 0.1
Carbaryl	Car.	Sevin	1.2 – 2.4
Thiodicarb	Car.	Larvin	0.6

Stink Bugs: Southern Green Stink bug: *Nezara viridula*
Green Stink bug: *Acrosternum hilare*
Brown Stink bugs: *Euschistus servus* and other various species

Research Priorities

- Threshold issues, state versus state (**High Priority**)
- How are stink bugs distributed across the agricultural landscape? When do they move to cotton? Can we manipulate their dispersal habits?
- How do you scout for stink bugs? When is cotton safe from stink bug damage?
- How does species composition impact control options?
- Aerial application for Bidrin is gone in 2005 (need to evaluate and identify the impacts and control alternatives).
- More research needed on brown stink bug resistance management.
- What are conditions that favor outbreaks?
- Can spatial and temporal distribution of stink bugs be predicted in typical mid-south agricultural landscapes and manipulated to reduce infestations on cotton?
- When can stink bug stress be tolerated on cotton?
- If necessary to treat early season for stink bugs, how can you treat with minimum upsets in the balance of the system?
- Pheromone identification, alternative methods of detection
- Host plant resistance
- Resistance monitoring
- Alternative insecticides
- Scouting techniques. Post-season surveys of stink bugs – where are they?
- Is there potential for bio-control alternatives?

Regulatory Priorities

- Maintain effective, safe materials for producers.
- Since these bugs are polyphagous and may move across the landscape, how can management strategies targeted at population regulation in other crops be legally constructed for flexible management options.
- Maintain aerial application for Bidrin and realize that reduction in seasonal use amounts also adversely impacts stink bug control.
- Maintain registrations for Bidrin and Orthene. Loss of Bidrin would leave us without acceptable control options. Methyl parathion would require multiple applications.
- Help maintain ecologically safe and efficacious insecticides for stink bug control.
- Consider relationships between treating field borders, roadsides, etc. versus legal treatment of production fields.
- Labels with broad base of uses for stink bugs.

Educational Priorities

- Emphasize need for quantitative scouting (**High Priority**). Look at insect/plant based thresholds.

- Traditional scouting, identification, thresholds.
- What areas of the mid-south are more prone to stink bug problems, geographically and based on local habitats? Hazard ratings may be needed.
- How can a group of farmers manage stink bugs across large areas? Can they reduce risks of infestation?
- Distinguishing/diagnostic features of beneficial insects
- Need to know how to identify stink bug damage.
- How should a grower detect damage and plant susceptibility to stink bugs? When can a grower make a decision "not to treat"?
- How can a grower predict or minimize stink bug movement into his field(s)?
- How should a grower scout for stink bugs?
- Determine impacts of environment on stink bug management.
- Insect resistance management for producers

Stink bugs are generally more of a problem in cotton fields that have received few insecticide applications. Historically, stink bugs were not considered a significant pest of Midsouth cotton because they were controlled coincidentally by the large number of treatments applied to control boll weevils, bollworm/budworms and other pests. The overall reduction in insecticide use that has accompanied the success of BWEP and Bt cotton has allowed stink bugs to increase in importance as a pest of cotton in the Midsouth during recent years and insecticide applications targeting stink bugs have become more common.

Several important species of stink bugs occur in cotton. These include the southern green stink bug, *Nezara viridula*, the green stink bug, *Acrosternum hilare*, and several species of brown stink bugs belonging to the genus *Euschistus*. Of the brown stink bugs, *Euschistus servus*, is the most common species found in cotton. Several other species of stink bugs may be found occasionally in Midsouth cotton fields, but these rarely occur in large numbers.

Yield effects of stink bug injury are dependent on the percent of bolls damaged. Heavy uncontrolled infestations of stink bugs can cause severe yield loss. Because stink bugs often do not appear in cotton fields until the later part of the growing season, damage is often concentrated in the upper portion of the plant. Historically, the percent yield loss attributed to stink bugs in the Midsouth has been near zero. However, in more eastern states where boll weevil has been eradicated for a number of years, estimates of the amount of yield lost to stink bugs have ranged as high as 3.8% (48). It is anticipated that the importance of stink bugs will increase considerably in in the Midsouth in the coming years.

Control: Effective control of stink bugs depends on the application of foliar insecticide sprays that are applied whenever infestation levels exceed the economic threshold. Although there are some differences between the brown stink bugs and other stink bugs in susceptibility to certain insecticides, stink bugs are relatively easy to control with foliar sprays. However, fields located near plantings of alternate hosts harboring high numbers of stink bugs may require multiple insecticide treatments for adequate yield protection. Because of their clumped distribution, spot treatment or border treatments are often effective against this pest.

Table 4: Insecticides Recommended for Control of Stink Bug.

Insecticide	Class	Trade Name	Lbs ai/acre
Acephate	OP	Orthene, etc	0.75 to 1.0
Dicrotophos	OP	Bidrin	0.4 to 0.5
Methyl parathion	OP	Various	0.5
Cyfluthrin *	SyP	Baythroid	0.025 to 0.033
Cyahlothrin *	SyP	Karate	0.025 to 0.03
Deltamethrin *	SyP	Decis	0.019 to 0.03
Bifenthrin*	SyP	Capture	0.06
Zeta-cypermethrin*	SyP	Fury	0.033-0.045
Zeta-cypermethrin*	SyP	Mustang Max	0.0165-0.0225
Esfenvalerate*	SyP	Asana XL	0.03-0.05

*Pyrethroid insecticides are less effective against brown stink bug species.

Beet Armyworm (*Spodoptera exigua)*

Research Priorities

- What is the source(s) of beet armyworms in the mid-south? Are populations predictable?
- When is it necessary to treat Bt cotton?
- Research conditions that favor outbreaks, conditions of epizootics.
- What are effects of compounds obtained from other plant hosts that can impact chemical control on cotton?
- Need research on better thresholds (especially for transgenics) and sample methods.
- What are the conditions that favor outbreaks?

Regulatory Priorities

- Maintain effective, reduced risk material registrations.
- Maintain aerial application on labels.

Educational Priorities

- Traditional scouting, identification, thresholds,etc.
- Can problems with beet armyworm be detected and growers alerted on basis of trapping programs?
- What currently works? What are the resistance levels? Does Bt cotton work?

Beet armyworms and fall armyworms occur primarily during late summer in Louisiana, Mississippi and south Arkansas. Most years they are either uncommon or do not build to high numbers until late in the growing season, when there is less potential for economic damage to occur. However, beet armyworms will occasionally build to high numbers by mid-season, resulting in outbreaks that can potentially cause severe crop injury. Such outbreaks occurred in 1988, 1993, and 1995. Conditions thought to be favorable for beet armyworm outbreaks include: mild winters, heavy early season insecticide use, and hot dry growing conditions. Of these, heavy early season use of organophosphate and/or pyrethroid insecticides is most important. Beet armyworm populations are normally kept in check by predators and parasitoids, which are adversely affected by these types of insecticides. Because wide spread adoption of Bt cotton and progress of the boll weevil eradication effort have resulted in substantial reductions in the number of early season insecticide treatments, the potential for beet armyworm outbreaks has declined in recent years. Also, the availability of new, more effective insecticides has improved the potential to effectively control beet armyworm outbreaks when, and if, they do occur.

Beet armyworms are primarily leaf feeders, but defoliation is not the only type of injury caused by this pest. Under some conditions they will attack squares, blooms, and bolls. Over the past five years yield losses attributed to beet armyworms have ranged from 0 to 0.12% (48). However, these were all years of low beet armyworm infestations. During the severe outbreak of 1993 this pest caused an estimated 4.4% yield loss to Mississippi cotton and some individual fields were totally destroyed by beet armyworms. The potential for severe outbreaks of beet armyworm to cause catastrophic yield losses is evidenced by the 50% yield loss that was attributed to it in the Lower Rio Grande Valley of Texas in 1995.

Control: Until recently beet armyworms were difficult and costly to control because of resistance and/or tolerance to most available insecticides, which resulted in the need for multiple applications of costly insecticides. However, during the past few years several new insecticides have been introduced which are more efficacious against beet armyworms. Availability of these more effective insecticides greatly reduces the potential for catastrophic yield losses and/or excessive control costs due to beet armyworm outbreaks. Although the current lines of transgenic Bt cotton, which express the Cry IAc endotoxin, provide limited suppression of beet armyworms, Bt cotton can be damaged by beet armyworms and supplemental insecticide treatments may be required to control beet armyworms in Bt fields. The second generation Bt-cotton, which is currently under development and expresses both the Cry1Ac and Cry IIAb endotoxins exhibits much higher activity against beet armyworms. In addition Denim (emamectin benzoate), received a Section 18 Emergency Exemption for use against beet armyworm during 2002.

Table 5: Insecticides Recommended for Control of Beet Armyworm

Insecticide	Class	Trade Name	Lbs ai/acre
Indoxacarb	Oxadiazine	Steward	0.09 - 0.11
Methoxyfenozide	IGR	Intrepid	0.1 to 0.16
Tebufenozide	IGR	Confirm	0.125 to 0.25
Spinosad	Spinosyn	Tracer	0.067 - 0.089
Thiodicarb	Car.	Larvin	0.60 -0.90

Fall Armyworm (*Spodoptera frugiperda)*

Research Priorities

- Are infestations impacted by the local landscape?
- What is the significance of the rice-grass, corn-cotton strain issue? How does this impact management options in the mid-south?
- How does Bt cotton impact fall armyworm? Different endotoxin proteins?
- What are sources of the populations?

- What has caused the epizootics of fall armyworms in certain years?
- Why are there different strains and how does this affect management?
- What are the conditions that favor outbreaks?
- Thresholds

Regulatory Priorities

- Maintain effective, reduced risk materials registrations.
- Maintain aerial application on labels.

Educational Priorities

- Traditional scouting, identification, thresholds, etc.
- Can problems with fall armyworm be detected and growers alerted on basis of trapping programs?
- What currently works? What are the resistance levels?
- How do you incorporate the strain differences into management programs?

Fall armyworms are occasional, late-season pests of Midsouth cotton. There are many years when it is difficult to find fall armyworms in cotton fields. However, in 1977 and 1985 much of Mississippi experienced severe outbreaks of fall armyworms and many fields suffered heavy yield reductions. Less severe outbreaks have occurred more recently throughout the region. Because fall armyworm infestations are easily overlooked and because undetected infestations of fall armyworms can cause severe yield loss, scouts must remain vigilant for this pest each year.

Recent research in Louisiana has shown that there are two 'strains' of fall armyworms, a corn strain and a rice-grass strain. The corn strain is thought to be the strain most commonly found on cotton. This may explain why there can be years when cattlemen experience heavy populations of fall armyworms in bermudagrass pastures while populations in cotton remain low. The corn strain is more tolerant to insecticides than the rice-grass strain, and this may explain, at least partially (insecticide coverage is also a big issue), why fall armyworms are much more difficult to control in cotton than in pastures.

Boll damage in excess of 10% is not uncommon during years of heavy fall armyworm infestations. Large larvae are also commonly found feeding in blooms, and fall armyworms will occasionally feed on squares, but this is seldom common enough to be of economic importance.

Control: As previously mentioned, fall armyworms that occur in cotton are more tolerant to insecticides than are fall armyworms that occur in bermudagrass. Moreover, because fall armyworms are normally found feeding under the bracts of large bolls in the lower half of the cotton canopy, it is difficult to obtain adequate spray coverage when treating fall armyworms in cotton. Because of these two factors, fall armyworms can be difficult to control in cotton. Control is further complicated by the difficulty of detecting fall armyworm infestations while larvae are still small and easier to control. Increasing spray volume above what would normally be used to control pests, such as plant bugs and bollworms, will usually improve fall armyworm control, but any control over 60 to 80% should be considered "good". Because fall armyworms are tolerant to the Cry 1Ac Bt toxin, they are capable of causing significant damage to transgenic

Bt cotton, and Bt cotton must occasionally be treated specifically to control fall armyworms. The second generation Bt cotton, which is currently under development and contains both the Cry 1 Ac and Cry IIAb endotoxins, is much more effective against fall armyworms. In addition, many pyrethroids will provide control of newly hatched fall armyworms, and Denim (emamectin benzoate), which received a Section 18 Emergency Exemption for use against beet armyworm and/or tobacco budworms in 2002, is also effective against fall armyworms.

Table 6: Insecticides Recommended for Control of Fall Armyworm

Insecticide	Class	Trade Name	Lbs ai/acre
Acephate	OP	Orthene	1.00
Profenofos	OP	Curacron	1.00
Methomyl	Car.	Lannate	0.45
Thiodicarb	Car.	Larvin	0.60 -0.90
Indoxacarb	Oxadiazine	Steward	0.09 - 0.11
Methoxyfenozide	IGR	Intrepid	0.1 to 0.16
Tebufenozide	IGR	Confirm	0.12 – 0.25
Spinosad	Spinosyn	Tracer	0.067 - 0.089

Whiteflies: **Bandedwinged Whitefly** (*Trialeurodes abutilonea)*
Silverleaf/Sweet Potato Whitefly (*Bemisia* spp.*)*

Research Priorities

- Species composition and relationships to horticultural industry (from nursery stock, green house operations).
- What are the conditions that favor outbreaks?
- Impact on cotton yield and quality
- Biological control options (parasites)
- Research needed on pesticide options.

Regulatory Priorities

- How do we maintain effective controls?
- What is relationship to movement and regulation of ornamentals? Improve inspections of horticultural plants.
- Insect resistance management
- Alternatives to nicotinoids for whitefly control
- Need insect growth regulators (pyroproxifen is one possibility).

Educational Priorities

- Traditional information about identification (especially of different species), when to treat, what to treat with, etc.
- What is the probability of infestation given geographic location, local crops, etc?
- What is known about the problem in other areas (in order to understand the threat to the mid-south)?

Of the whiteflies that occur in the Midsouth, the bandedwinged whitefly is by far the most common and the most widely distributed. Low numbers of bandedwinged whiteflies can be found in most fields, most years. But, damaging infestations are relatively uncommon, and most commonly occur in fields that have received repeated insecticide treatments, which disrupt predation and parasitism.

Fortunately, the *Bemisia* whiteflies are rare through most of the Midsouth. There are two species, the sweetpotato whitefly, *Bemisia tabaci*, and the silverleaf whitefly, *Bemisia argentifolii*, which are difficult to distinguish from one another. Infestations of *Bemisia* whiteflies are most commonly found in the extreme southern part of the region in cotton fields located near commercial ornamental plant nurseries. However, *Bemisia* whitefly infestations are found occasionally in more northern regions of the region where cotton fields are located near large greenhouses.

The damage caused by both species is similar. Both immatures and adults remove sap from the plant, which otherwise would be used for growth and development. Heavy, sustained whitefly infestations can remove enough sap to cause reduced development and yield loss and severe infestations of *Bemesia* whiteflies can kill plants. However, such heavy infestations are relatively uncommon. The most important damage caused by whiteflies is the production of honeydew which, when deposited on open lint, causes "sticky cotton". Sticky cotton is subject to substantial price discounts, because it is more difficult to process. In past years western-grown cotton has suffered from such quality discounts following heavy outbreaks of *Bemesia* whiteflies. Fortunately, the potential for whiteflies to cause "sticky cotton" seems to be much less in the more humid and rainy environment of the Midsouth. The honeydew produced by whiteflies is quickly colonized by "sooty mold" fungi. Although this sooty mold results in a black residue on both leaves and open lint, it also has the beneficial effect of consuming the honeydew and thus reducing the potential for sticky cotton.

By far the greatest potential damage associated with whiteflies is their ability to vector several serious diseases of cotton. Fortunately, none of these diseases are currently a problem within the United States. Whiteflies are considered an occasional pest of cotton and very little yield loss is attributed to this pest in most years. However, heavy, prolonged infestations can cause significant yield reductions in infested fields.

Control: Cotton plants can tolerate relatively high populations of whiteflies without suffering yield loss, and whitefly numbers are usually kept below damaging levels by beneficial insects. However, when beneficial insect populations are destroyed by insecticide treatments targeted against other pests, potentially damaging whitefly infestations can occur. When whitefly outbreaks do occur, insecticide treatments are often required. Treatment thresholds vary among states as well as due to environmental conditions. Because they occur on the undersides of leaves, where they are protected from insecticide applications, and because they exhibit high levels of resistance to many insecticides, whitefly infestations can be very difficult to control. Because of this, very few insecticides are even recommended for control of whiteflies.

Treatments used against bandedwinged whiteflies are systemic insecticides that are targeted against the adults and feeding immatures. Because eggs and pupae are not susceptible to such treatments, multiple applications, applied at approximately five-day intervals, are required for successful control. Although some of the IGR type treatments that are used against

Bemisia whiteflies are also effective against bandedwinged whiteflies, they are not normally used against this species because of cost.

Treatments recommended for control of *Bemisia* whiteflies are either tank mixtures of systemic insecticides and certain pyrethroids or insect growth regulator (IGR) type treatments. Although the IGR products are usually very costly, a single application may provide effective control. However, successful control of *Bemisia* whiteflies with the systemic insecticide tank mixtures usually requires multiple applications applied on approximately five day intervals.

Table 7: Insecticides Recommended for Control of Bandedwinged Whiteflies

Insecticide	Class	Trade Name	Lbs ai/acre
Acephate	OP	Orthene (Generics)	0.5 to 1.00
Methamidophos	OP	Monitor	0.25 to 0.5
Thiamethoxam	Neonicotinoid	Centric	0.047
Bifenthrin	SyP	Capture	0.06 – 0.1
Acetamiprid	Neonicotinoid	Intruder	0.025-0.05

Table 8: Insecticides Recommended for Control of *Bemisia* Whiteflies

Insecticide	Class	Trade Name	Lbs ai/acre
pyriproxyfen	IGR	Knack	0.054 to 0.067
Fenpropathrin + Acephate	SyP + OP	Danitol + Orthene	0.15 to 0.3 + 0.5 to 0.9
Acetamiprid	Neonicotinoid	Intruder	0.025-0.05

Loopers: **Soybean Looper** (*Pseudoplusia includens)*
Cabbage Looper (*Trichoplusia ni)*

Research Priorities

- Can looper infestations be predicted? What are the causes of outbreaks?
- When do loopers cause economic damage to Bt and non-Bt cotton? What are the thresholds?
- How important is biological control in looper control?
- Studies on species composition.
- Insecticide efficacy of new and existing compounds.
- Impact of defoliation on fiber quality.
- What are the conditions that favor outbreaks?

Regulatory Priorities

- Keep labeled, effective materials (e.g., thiodicarb – also serves as a resistance management tool) on this occasional pest.

Educational Priorities

- Traditional information about identification, when to treat, what to treat with, etc.
- How do we distinguish between the two species, how does this impact management?

- Thresholds, timing of applications, etc.

Two species of loopers attack cotton in the Midsouth. These are the soybean looper, *Pseudoplusia includens*, and the cabbage looper, *Trichoplusia ni*. Both species are occasional late-season pests that rarely cause serious economic loss.

In both species feeding is confined to leaves and other foliage. When numbers are high, caterpillars may consume the bracts of squares and bolls, but direct feeding on the fruit itself is rare. Thus any damage caused by loopers is "indirect damage" due to premature defoliation. Low levels of defoliation (less than approximately 20%) cause no adverse effects, and it is commonly believed that excessively thick canopied fields may actually benefit from low levels of late season defoliation by loopers, due to improved air movement and reduced boll rot. However, excessive defoliation that occurs before the last harvestable bolls are fully mature can adversely affect both yield and quality of lint. Because they rarely build to damaging levels until very late in the season when many bolls are already mature, loopers do not have the potential to totally destroy a crop, like many other cotton pests. However, heavy infestations of loopers can completely defoliate a crop within just a few days, and this can cause several hundred pounds of yield loss when it occurs in fields that are some weeks from maturity.

Over the past five years estimated yield losses attributed to loopers have remained consistently below 0.1%, and there have been no catastrophic regional outbreaks of loopers (48). However, premature defoliation of late maturing crops can cause several hundred pounds of yield loss in individual fields. Late maturing fields are more vulnerable to damage by loopers than early maturing fields.

Control: Looper populations are normally held in check by the large array of predators and parasitoids. Heavy insecticide use can destroy these beneficial insect populations and increase the potential for looper outbreaks to occur, especially if the insecticides being used do not have activity against loopers. When outbreaks do occur they often crash quickly due to epizootics of fungal or viral diseases that attack loopers. When making looper treatment decisions, it is important to be aware of the potential for these disease outbreaks because, when they occur, they can preclude the need for insecticide treatments. However, because heavy infestations of large caterpillars can defoliate a crop so quickly, insecticide treatment is sometimes required to prevent excessive defoliation. Treatment thresholds vary among states as well as due to environmental conditions. Loopers can damage Bt cotton, as well as non-Bt, but the second generation Bt cotton, which contains both the Cry 1 Ac and Cry IIAb endotoxins, is much more effective against loopers. Treatments recommended for control of loopers are listed below. Because soybean loopers are the more common species in cotton, and because soybean loopers are more difficult to control than cabbage loopers, insecticides are recommended based on their efficacy against soybean loopers.

Table 9: Insecticides Recommended for Control of Loopers

Insecticide	Class	Trade Name	Lbs ai/acre
Indoxacarb	Oxadiazine	Steward	0.09 - 0.11
Methoxyfenozide	IGR	Intrepid	0.06 to 0.1
Tebufenozide	IGR	Confirm	0.12 – 0.25
Spinosad	Spinosyn	Tracer	0.067 - 0.089
Thiodicarb	Car.	Larvin	0.60 -0.90

Other Priorities for Insect Management in Cotton

- Revise sampling plans to develop economic thresholds (i.e., transgenics, post eradication, selective insecticides). The development of economic thresholds for insect pests in transgenic cotton is a **high priority**.
- What are the relationships between cotton insect control and other production variables? Total crop production? Total farm production? Total regional production?
- How can we reduce the costs of cotton insect control and maintain production capacity?
- How do we develop more sophisticated management systems and reform our delivery systems to capitalize on better management?
- As seed delivered technologies become more common, how do we value and optimize the use of these technologies?
- Implementation and monitoring of insect resistance management (refugia, etc.).
- How important is the "precision agriculture" movement for individual growers? What are the optimum scales of management for insect pests?
- Can we maintain the effective life of Bt cottons? What is the probability of a general mechanism of resistance that will confirm resistance across Bt toxins? What are the options for other non-Bt proteins?
- How do the polyphagous insects disperse and distribute across our diverse agricultural mid-south?
- How do insects impact quality?
- Are long-term insecticide use patterns impacting the species complex and resistance levels in key pest species?
- Increase educational efforts, aimed at growers and other stakeholders, on proper insect identification.
- Is there a cap on management intensity? What is the maximum level possible? How does one recover the value of good management?
- Can we monitor genetic changes in pest populations? How do we use this information?
- What is the role of states' Department of Agriculture in insect management landscapes? Can we predict these distributions and manipulate them in a population regulation manner?
- What do we need to grow cotton without insecticides in the mid-south? If insect costs were dramatically reduced, how much cotton could we grow economically in the mid-south?
- Support EPA Resistance management mode of action labeling (regulatory priority). Does EPA need to be more involved? Maybe not. We need to be working towards insect resistance statements on labels. All stakeholders in the industry need to be involved.
- Seek more areas of collaboration with EPA (i.e., links, cooperative agreements with universities)
- Systems approach to insect management
- Cost-benefit analysis of intensive scouting versus less-intensive scouting (across all insects)
- Emphasize to growers the need for quantitative scouting. Look at insect/plant based thresholds.
- Survey occasional pests that may appear with new management practices.
- Alternative methods of monitoring and detection (pheromone traps, etc.)
- Develop thresholds for beneficial arthropods.
- Maintain aerial applications for insecticides.

- Research on agricultural landscapes
- Research on GPS and GIS for sampling and insecticide applications
- Developing resistant risk profiles for prolonging life/use of insecticides.
- Verification that insecticide selectivity reduces or increases insecticide applications/use.
- Improvement of cotton insect loss estimates

Table 10. Insecticides Used, Percentage of Acres Treated by State, and Average Number of Applications per Growing Season for Selected Insects (Midsouth Cotton Entomologists Estimates - 2002).

Insecticide	Type	Percentage of Acres Treated and Average Number of Applications (in parentheses) by State for the Specified Insecticides and the Listed Insect Pests																	
		Boll Weevil			Cotton Bollworm			Tobacco Budworm			Thrips			Plant Bugs			Aphids		
		AR	LA	MS	AR	LA	MS	AR	LA	MS	AR	LA	MS	AR	LA	MS	AR	LA	MS
Acephate	OP				<5 (1.5)			<5 (1.5)			<1 (1.0)	45 (1)	40 (1)	30 (1.5)	60 (3.5)	60 (3)			
Acetamiprid	Misc.																<1 (1)		
Aldicarb	Car.										71 (1.0)	50 (1)	59 (1)						
Azinphosmethyl	OP	1-5 (2.5)																	
Bifenthrin	SyP	<1			<5			<5									<1 (1)		
Chlorpyrifos	OP				<1 (2.5)			<1 (2.5)						<1 (1.5)					
Cyfluthrin	SyP	<2 (2.5)			35 (3.5)	30 (2.5)	31 (2.5)	35 (3.5)											
Cyhalothrin	SyP	<2 (1.5)			32 (2.5)	30 (2.5)	38 (1)	32 (2.5)											
Cypermethrin	SyP				<1 (2.5)	15 (2.5)	13 (1)	<1 (2.5)											
Deltamethrin	SyP	<1			<1			<1											
Dicrotophos	OP											10 (1.5)	15 (1)	25 (1.5)	60 (3.5)	20 (2)	<1 (1)	5 (1)	5 (1)
Dimethoate	OP												5 (1)	4 (1.5)	50 (3)				
Disulfoton	OP										<1 (1.0)		3 (1)						
Emamectin	SyP				<5		<3	<5											
Esfenvalerate	SyP	<1 (2.5)			8 (3.5)		5 (1)	8 (3.5)											
Imidacloprid	Misc.										20	33	9 (1)		5 (1)	8 (1)	5 (1)	40 (2)	
Indoxacarb	Misc.				<5	10 (1)	<3	<5	10 (1)	5 (1)									
Malathion	OP	<5 (10)		38 (1.2)															
Methamidophos	OP																		
Methomyl	Car.				1-5 (2)			1-5 (2)											
Methyl parathion	OP	<5 (2)																	
Oxamyl	Car.	<1 (3.5)												5 (1.5)		14 (1)			
Phorate	OP										<1 (1.0)								
Profenofos	OP				<5 (1.5)	5 (1.5)	5 (1)	<5 (1.5)	30 (1.5)	5 (1)				<1					
Spinosad	Misc.				25	15	15 (1)	25	90 (2)	15 (3)									
Thiamethoxam	Misc.															7 (1)	3 (1)	10 (1)	7 (1)
Thiodicarb	Car.				1-5 (1.5)	2 (1)	<3	1-5 (1.5)		<3									
Tralomethrin	SyP	<1			<1 (7.5)			<1 (7.5)											
Zeta-cypermethrin	SyP	<1 (2.5)			15 (5.5)	30 (5.5)	5 (1)	15 (5.5)											

WEED CONTROL

The key to weed management in cotton is providing the seedling cotton plant with conditions that allow cotton to outgrow weeds, thus establishing a height difference for directed sprays. While pre-plant and pre-emergence herbicides must be used to control or suppress weed growth, the application of timely post-directed herbicides is often required to maintain a successful weed control program. Cultural practices that promote rapid germination and vigorous cotton seedling growth are very important in allowing timely post-emergence applications. The weed species composition of the cotton crop is important in selection of the best weed control program. The proper identification of the weed complex will determine the best program to use.

The pre-plant herbicides are utilized to control several weeds including annual grass suppression, morningglory suppression, and seedling johnsongrass control. The pre-emergence herbicides are used to control the broadleaf complex including prickly sida, morningglory, and cocklebur. The post-emergence herbicide applications are directed toward control of grasses and broadleaf weeds that occur including johnsongrass, annual grasses, cocklebur and morningglory.

The recent development and selection of genetically modified cotton varieties that are resistant to certain herbicides has dramatically changed the weed control practices of Midsouth cotton farmers. Cotton varieties have been developed that are resistant/tolerant to the herbicide glyphosate and bromoxynil. Both of these active ingredients are systemic, foliar applied herbicides that control a wide range of annual and perennial weeds. Both herbicides are lethal to cotton varieties without the resistance gene(s).

Glyphosate (trade name is Roundup Ultra and various others) is a broad spectrum, systemic herbicide that can be applied over the top (postemergence) of glyphosate resistant (Roundup Ready™) cotton varieties until the cotton has reached the four leaf stage. In addition, glyphosate can be post-directed to larger cotton provided the spray does not contact leaves. In some cases the use of glyphosate on glyphosate-resistant cotton reduces the need for preemergence herbicides and other postemergence herbicides.

Midsouth cotton farmers have quickly adopted the glyphosate resistant technology. Approximately 70-80 percent of the cotton acres in 2002 were planted with glyphosate resistant varieties. Applications of glyphosate are normally made soon after the cotton and weeds emerge. A second application is often made within a few days to control weeds not killed by the first application. Application rates average 0.75 pounds a.i. per acre per application depending on a number of circumstances such as the weed species present, the timing, or the level of management that can be provided by the grower. The REI for glyphosate is 4 hours. The preharvest interval is 14 days.

Bromoxynil (trade name Buctril) is a broad-spectrum herbicide that can be applied as an overtop or post-directed application to bromoxynil resistant cotton varieties (BXN™). In some cases the use of bromoxynil on bromoxynil-resistant cotton reduces the need for preemergence herbicides and other postemergence herbicides. However, university data suggests that the use of a preemergence herbicide is beneficial if pigweeds are present.

Approximately 8-10 percent of the cotton acres in 2002 were planted with bromoxynil resistant cotton varieties. Applications of bromoxynil are normally made soon after cotton and weeds emerge. A second application is often made within a few days to control weeds not present at the first application. Application rates average 0.375 pounds a.i. per acre. The REI for bromoxynil is 12 hours. The pre-harvest interval is 60 days.

The herbicides used, percentage of acres treated by state, and average number of applications per growing season are listed in Table 11. The percentage of infested acres for each weed in each state and the estimated minimum yield loss if the weed is not controlled is listed in Table 12.

ANNUAL GRASSES

Research Priorities

- Resistance management (**High Priority**)
- Competition by time of removal in transgenic systems.
- Impacts of population shifts in transgenic systems.
- Weed management in reduced-tillage systems.
- Step up efforts to mitigate reduced use of residual herbicides.

Regulatory Priorities

- Something to replace cyanazine. Best candidate is Valor (flumioxazin).
- Need to reconsider labels as they relate to crop rotation restrictions.

Educational Priorities

- Application timing for reduced rate applications.
- Resistance management

ANNUAL GRASSES: Barnyardgrass (*Echinocloa crus-galli*), Crabgrass (*Digitaria* spp.), Broadleaf signalgrass (*Brachiaria platyphylla*), Goosegrass (*Eleusine indica*), Foxtail (*Setaria* spp.), Seedling johnsongrass (*Sorghum halapense*), Fall panicum (*Panicum dichotomiflorum*), browntop millet (*Panicum ramosa)*, **Perennial grasses**: Bermudagrass (*Cynadon dactylon*), Johnsongrass (*Sorghum halapense*)

Frequency of occurrence: Every year.

The damage done by the pests: Competition with the cotton crop for water, sunlight, and nutrients.

Life cycle: Summer annuals and perennials

Critical timing of control measures: To best prevent cotton yield losses, annual grasses should be controlled as early as possible. Buchanan and Burns (1970) determined that cotton should be kept weed free for at least the first 8 to 12 weeks after emergence to maximize cotton yield. Preplant incorporated and preemergence applications of these herbicides provide good early season control of the annual grasses. Post emergence applications of certain herbicides will also control the annual and perennial grasses that escape early season applications.

Chemical Control - Preplant Incorporated Treatments for Grasses

Trifluralin

Numerous trade names are available. Most applications are made by ground equipment. Application rates average 0.62 pounds a.i. per acre. Trifluralin effectively controls all of the listed annual grasses except goosegrass. The typical REI for trifluralin on cotton is 12 hours. A pre-harvest interval is not listed on the label.

Norflurazon

Trade name is Zorial Rapid 80. Most applications are made by ground equipment. Application rates average 0.56 pounds a.i. per acre. Norflurazon effectively controls all of the listed annual grasses. The REI for norflurazon on cotton is 12 hours unless it is soil incorporated (i.e., preplant incorporated). If soil incorporated the REI is not applicable in most cases. A pre-harvest interval is not listed on the label. Price, availability, and recrop restrictions has limited the use of norflurazon.

Pendimethalin

Trade names are Prowl 3.3 EC and Pendimax. Most applications are made by ground equipment. Application rates average 0.58 pounds a.i. per acre. Pendimethalin effectively controls all of the listed annual grasses except goosegrass. If soil incorporated the REI is not applicable in most cases. A pre-harvest interval is not listed on the label.

Fluometuron

Trade names are Cotoran and Meturon formulated as a 4L or DF. Most applications are made by ground equipment. Application rates average 0.8 pounds a.i. per acre. Fluometuron effectively controls all of the listed annual grasses except barnyardgrass and seedling johnsongrass. The REI for fluometuron on cotton is 24 hours unless it is soil incorporated (i.e., preplant incorporated). If soil incorporated the REI is not applicable in most cases. The pre-harvest interval is 60 days. Although fluometuron is labeled for preplant incorporated application, virtually none of the cotton acreage receives this treatment.

Chemical Control - Preemergence Treatments for Grasses

Metolachlor

Trade names are Dual Magnum and Dual II Magnum. Most applications are made by ground equipment. Application rates range from 0.66 to 0.75 pounds a.i. per acre. Metolachlor effectively controls all of the listed annual grasses except seedling johnsongrass. The REI for metolachlor is 12 hours. A pre-harvest interval is not listed on the label. The potential for crop injury limits the amount of metolachlor applied to cotton.

Fluometuron

Trade names are Cotoran and Meturon formulated as a 4L or DF. Most applications are made by ground equipment. Application rates average 0.67 pounds a.i. per acre. Fluometuron effectively controls all of the listed annual grasses except barnyardgrass and seedling johnsongrass. The REI for fluometuron on cotton is 24 hours. The pre-harvest interval is 60 days.

Norflurazon

Trade name is Zorial Rapid 80. Most applications are made by ground equipment. Application rates average 0.51 pounds a.i. per acre. Norflurazon effectively controls all of the listed annual grasses. The REI for norflurazon on cotton is 12 hours. A pre-harvest interval is not listed on the label. Price, availability, and recrop restrictions has limited the use of norflurazon.

Pendimethalin

Trade name is Prowl 3.3 EC and Pendimax. Most applications are made by ground equipment. Application rates average 0.37 pounds a.i. per acre. Pendimethalin effectively controls all of the listed annual grasses except goosegrass. The typical REI for pendimethalin on cotton is 12. A pre-harvest interval is not listed on the label.

Chemical Control - Postemergence Treatments for Grasses

MSMA

Many formulations exist (i.e., many trade names). Applications are made post-directed by ground equipment and 1 to 2 applications each year is the average. MSMA is often tank-mixed with another postemergence herbicide. By itself, MSMA is effective in controlling sedges and all of the listed annual grasses except for goosegrass. Application rates average 1.4 pounds a.i. per acre. The REI for MSMA is 12 hours. The pre-harvest interval is not applicable.

Prometryn

Trade name is Caparol and Cotton-Pro. Applications are normally tank-mixed with other herbicides made post-directed (postemergence) by ground equipment and 1 to 2 applications each year is the average. Application rates average 0.5 to 0.75 pounds a.i. per acre. Prometryn effectively controls all of the listed annual grasses. The REI for prometryn is 12 hours. A pre-harvest interval is not listed on the label. Prometryn also provides residual weed control to suppress weeds that germinate after the initial application.

Diuron

Trade names are Karmex and Direx. Approximately 40 to 60 percent of the cotton acreage receives a diuron application each year (on 30 percent of the acres it is tank-mixed with MSMA). Applications are normally tank-mixed with other herbicides and made post-directed (postemergence) by ground equipment and 1 to 2 applications each year is the average. Application rates average 0.5 to 1 pound a.i. per acre. Diuron effectively controls crabgrass, barnyardgrass, foxtail, and seedling johnsongrass. The REI for diuron is 12 hours. A pre-harvest interval is not listed on the label. Diuron also provides residual weed control to suppress weeds that germinate after the initial application.

Glyphosate

Numerous trade names are available. A large percentage of the cotton acres (representing the percentage of acres planted with glyphosate-resistant cotton) receives at least two postemergence applications of glyphosate. Approximately 50 percent of the glyphosate treated acres receive a third application of the herbicide and approximately 10 percent of those acres receive a fourth application. As a postemergence application for grasses and broadleaves glyphosate can only be applied to glyphosate-resistant cotton varieties. Glyphosate is effective in controlling all of the listed grass and broadleaf weeds except for spurred anoda, smartweed, and yellow nutsedge. Application rates are 0.75 pounds a.i. per acre per application or less, depending on weed size. The REI for glyphosate is 4 hours. The pre-harvest interval is 7 days. Glyphosate provides no residual weed control.

Fluometuron:

Trade names are Cotoran and Meturon formulated as a 4L or DF. Approximately 15 percent of the cotton acreage receives a postemergence fluometuron application each year (on approximately 40 percent of the acres it is tank-mixed with MSMA). All applications are made by ground equipment. Application rates average 0.8 pounds a.i. per acre. As a postemergence treatment, there are normally 1 to 2 applications per year. Fluometuron effectively controls all of the listed annual grasses except barnyardgrass and seedling johnsongrass. The REI for fluometuron on cotton is 24 hours. The pre-harvest interval is 60 days. Fluometuron does provide residual control of weeds not present at application.

Metolachlor

Trade names are Dual Magnum and Dual II Magnum. Metolachlor can be applied alone or in a tank-mix combination with glyphosate (approved formulation) in a Roundup Ready system to provide residual grass control between glyphosate applications. Applications can be made overtop (to at least 3 inch tall cotton with 4 leaves or less) or post-directed. Use rates are 0.48 to 1.27 pounds a.i. per acre. Pre-harvest interval is 100 days if applied overtop, or 80 days if post-directed.

Quizalofop (trade name: Assure II), Clethodim (Select 2EC), Fluazifop + Fenoxaprop (Fusion), Fluazifop (Fusilade DX), Sethoxydim (Poast Plus):

Approximately 5 percent of the cotton acreage receives either a broadcast over-the-top application or is "spot" treated with of one of the grass herbicides listed below.

Quizalofop: Rates - 0.031 to 0.063 lb a.i. per acre, PHI - 80 days, REI - 12 hours
Clethodim: Rates - 0.094 to 0.25 lb a.i. per acre, PHI - 60 days, REI - 24 hours
Fluazifop: Rate - 0.188 lb a.i. per acre, PHI - 90 days, REI - 12 hours
Fluazifop + Fenoxaprop: Rates - 0.094 to 0.188 lb a.i. per acre (fluazifop) and 0.026 to 0.053 lb a.i. per acre (fenoxaprop), PHI - 90 days, REI - 24 hours
Sethoxydim: Rates - 0.2 to 0.3 lb a.i. per acre, PHI - 40 days, REI - 12 hours

Other herbicides to control grasses: None identified.

Non-Chemical methods of grass control: Cultivation.

Pipeline materials for grass control: Glufosinate tolerant (Liberty Link) cotton.

BROADLEAVES - Annuals

Research Priorities - Annuals

- Need economical control of pigweeds that emerge throughout the crop season.
- Resistance monitoring and management.
- Species population shifts.

Regulatory Priorities - Annuals

- Need cyanazine replacement**.**
- Reconsider our constraints of rotational restrictions.
- Regulatory efforts needed to prevent movement of these weeds.

Educational Priorities - Annuals

- Educational programs and materials to educate on preventing movement/spread of problematic weeds.
- Broadleaf weed identification.

BROADLEAVES – Perennials

Research Priorities – Perennials

- Look at competitiveness at different population densities.
- Research on biology and control.
- Cultural practices that lead to increases in perennial populations.
- Timing of controls for perennials (more important for perennials than annuals).

Regulatory Priorities – Perennials

- Investigate and develop appropriate recrop intervals.

Educational Priorities – Perennials

- Need data before education can start.
- Greater emphasis on cultural practices to prevent new or spreading infestations.

The major broadleaf weeds in cotton include, Annuals: Prickly sida (*Sida spinosa*), Spurred Anoda (*Anoda cristata*), Velvetleaf *(Abutilon theophrasti*), Cocklebur (*Xanthium strumarium*), Pitted Morningglory (*Ipomoea lacunosa*), Entireleaf Morningglory *(Ipomea hederacea* var. *integriuscula*), Pigweed (*Amaranthus* spp.), Palmer Amaranth (*Amaranthus palmeri*), Spotted Spurge (*Euphorbia maculata*), Smartweed (*Polygonum* spp.), Sicklepod (*Senna obtusifolia*), and Hemp sesbania (*Sesbania exaltata*), **Perennials**: Redvine (*Brunnichia ovata*), trumpetcreeper (*Campsis radicans*), honeyvine milkweed (*Ampelamus albidus*), horsenettle (*Solanum carolinense*).

Frequency of occurrence: Every year.

The damage done by the pests: Competition with the cotton crop for water, sunlight, and nutrients. There is a potential for reduced harvest efficiency and cotton quality reduction if populations are high.

Life cycle: Summer annuals and perennials

Critical timing of control measures: To best prevent cotton yield losses, broadleaves should be controlled as early as possible. Buchanan and Burns (1970) determined that cotton should be kept weed free for at least the first 8 to 12 weeks after emergence to maximize cotton yield. Preplant incorporated and preemergence applications of these herbicides provide good early season control of most broadleaves. Postemergence applications of certain herbicides will also control the broadleaves that escape early season applications.

Chemical Control - Preplant Incorporated Treatments for Broadleaves

Trifluralin

Numerous trade names are available. Most applications are made by ground equipment. Application rates average 0.63 pounds a.i. per acre. Trifluralin is effective in controlling pigweed, purslane, and lambsquarter. The typical REI for trifluralin on cotton is 12 hours. A pre-harvest interval is not listed on the label.

Norflurazon

Trade name is Zorial Rapid 80. Most applications are made by ground equipment. Application rates average 0.56 pounds a.i. per acre. Norflurazon effectively controls all of the listed annual grasses. The REI for norflurazon on cotton is 12 hours unless it is soil incorporated (i.e., preplant incorporated). If soil incorporated the REI is not applicable in most cases. A pre-harvest interval is not listed on the label. Price, availability, and recrop restrictions has limited the use of norflurazon.

Pendimethalin

Trade names are Prowl 3.3 EC and Pendimax. Most applications are made by ground equipment. Application rates average 0.58 pounds a.i. per acre. Pendimethalin is effective in controlling pigweed, purslane, and lambsquarter. The typical REI for pendimethalin on cotton is 12 hours unless it is soil incorporated (i.e., preplant incorporated). If soil incorporated the REI is not applicable in most cases. A pre-harvest interval is not listed on the label.

Chemical Control - Preemerge Treatments for Broadleaves

Fluometuron

Trade names are Cotoran and Meturon formulated as a 4L or DF. Most applications are made by ground equipment. Application rates average 0.67 pounds a.i. per acre. Fluometuron effectively controls prickly sida, cocklebur, morningglories, pigweed, purselane, hophornbeam copperleaf, ragweed, lambsquarters, and flatsedge. The REI for fluometuron on cotton is 24 hours. The pre-harvest interval is 60 days.

Norflurazon

Trade name is Zorial Rapid 80. Most applications are made by ground equipment. Application rates average 0.51 pounds a.i. per acre. Norflurazon effectively controls all of the listed broadleaves except velvetleaf, cocklebur, morningglories, spotted spurge, and smartweed.. The REI for norflurazon on cotton is 12 hours. A pre-harvest interval is not listed on the label. Price, availability, and recrop restrictions has limited the use of norflurazon.

Pyrithiobac

Trade name is Staple. Staple effectively controls morningglories, sida, spurge, velvetleaf, sedges, and non-ALS resistant pigweeds. Use rate is 0.6 to 6 ounces product per acre with a maximum application rate of 2.4 ounces product per acre per year. Due to cost limitations, much of the pyrithiobac applied preemergence is applied as an eight to 10 inch band to the top of the row. REI for pyrithiobac is 12 hours.

Chemical Control - Postemerge Treatments for Broadleaves

Fluometuron

Trade names are Cotoran and Meturon formulated as a 4L or DF. On approximately 40 percent of the acres treated with fluometuron it is tank-mixed with MSMA. Application rates average 0.8 pounds a.i. per acre. Fluometuron is effective in controlling prickly sida, cocklebur, morningglories, pigweed, purslane, hophornbeam copperleaf, ragweed, lambsquarter, and flatsedge. It is often tank-mixed with MSMA to provide additional grass control. The REI for fluometuron on cotton is 24 hours. The pre-harvest interval is 60 days. Fluometuron does provide residual control of the listed weeds not present at application.

Prometryn

Trade name is Caparol 4L and Cotton-Pro. On approximately 20 percent of the acres treated with prometryn it is tank-mixed with MSMA. Most applications are made by ground equipment and there is an average of 1 to 2 applications each year. Application rates average 0.5 to 0.75 pounds a.i. per acre. Prometryn is effective in controlling all of the listed broadleaves except spurred anoda, velvetleaf, spotted spurge, smartweed, and sedges. It is often tank-mixed with MSMA to provide additional grass control. The REI for prometryn on cotton is 12 hours. A pre-harvest interval is not listed on the label. Prometryn also provides residual weed control to suppress the listed weeds that germinate after the initial application.

Diuron

Trade names are Karmex and Direx. Applications are normally tank-mixed with other herbicides such as MSMA (to provide additional grass control) or glyphosate (to glyphosate-resistant varieties) and made post-directed (postemergence) by ground equipment and 1 to 2 applications each year is the average. Application rates average 0.5 - 1 pound a.i. per acre. Diuron is effective in controlling all of the listed broadleaves except spurred anoda, velvetleaf, spotted spurge, smartweed, and sedges. The REI for diuron is 12 hours. The pre-harvest interval is not applicable. Diuron also provides residual weed control to suppress weeds that germinate after the initial application.

Pyrithiobac

Trade name is Staple. Staple effectively controls morningglories, spurge, velvetleaf, sedges and non-ALS resistant pigweeds. Use rate is 1.2 to 1.8 ounces product per acre with a maximum application rate of 2.4 ounces product per acre per year. Due to cost limitations, much of the pyrithiobac is applied as a band overtop of the cotton. REI for pyrithiobac is 12 hours. The pre-harvest interval is 60 days.

Lactofen

Trade name is Cobra. Lactofen is normally tank-mixed with MSMA. Applications are made post-directed by ground equipment and 1 to 2 applications each year is the average. Application rates average 0.18 pounds a.i. per acre. Lactofen is effective in controlling all of the listed broadleaves except spurred anoda, palmer amaranth, sicklepod, and smartweed. It can be tank-mixed with MSMA to provide additional grass control. The REI for lactofen is 12 hours. The pre-harvest interval is 45 days. Lactofen does not provide residual weed control.

Glyphosate

Numerous trade names are available. A large percentage of the cotton acres (representing the percentage of acres planted with glyphosate-resistant cotton) receive at least two postemergence applications of glyphosate. Approximately 50 percent of the glyphosate treated acres receive a third application of the herbicide and approximately 10 percent of those acres receive a fourth application. As a postemergence application for grasses and broadleaves, glyphosate can only be applied to glyphosate-resistant cotton varieties. Glyphosate is effective in controlling all of the listed grass and broadleaf weeds except for spurred anoda, smartweed, and yellow nutsedge. Application rates are 0.75 pounds a.i. per acre per application. The REI for glyphosate is 4 hours. The pre-harvest interval is 7 days. Glyphosate does not provide residual weed control.

Carfentrazone

Trade name is Aim 2 EC. Carfentrazone is applied post-directed to cotton and provides effective control of morningglories, pigweeds, hemp sesbania, purselane, cocklebur and other broadleaf weeds. Carfentrazone provides no grass control or residual weed control. Use rates range from 0.8 to 1.6 ounces product per acre per application. No more than 3.2 ounces product per acre per season may be applied as a post-directed or lay by application. No more than 7.8 ounces product per acre may be applied in a single growing season (includes defoliation applications). Pre-harvest interval is seven days. REI is 12 hours.

Bromoxynil

Trade name is Buctril 4EC. Approximately 8 to 10 percent (represents the percentage of acres planted with bromoxynil-resistant cotton) of the total cotton acreage receives at least one application of bromoxynil each year. Almost all of the bromoxynil treated acres (>90%)

receive a second application of the herbicide. Bromoxynil can only be applied to bromoxynil-resistant cotton varieties. Bromoxynil effectively controls cocklebur, morningglories, hophornbeam copperleaf, ragweed, smartweed, and jimsonweed. Application rates average 0.375 pounds a.i. per acre. The REI for bromoxynil is 12 hours. The pre-harvest interval is 60 days. Bromoxynil does not provide residual weed control.

IPM issues for weed control: The use of Roundup Ready cotton varieties is changing the spectrum of weeds around the cotton field and this has led to an increase of host plant species for the plant bugs.

Alternatives

Alternatives to pesticides for weed control in cotton include mechanical cultivation, hand labor, and flame cultivation. With the adoption of reduced tillage systems, only about 50% of the cotton acreage is mechanically cultivated to remove weeds in-season. Spot spraying is used on a small number of acres to control weeds. In these cases only the infested areas of a field receive a pesticide application. Hand labor is very seldom used for weed control.

Other alternatives for broadleaf control: None identified.

Pipeline materials for broadleaf control: Flumioxazim (Valor) shows promise as a broadleaf herbicide. Use rates will be 1 to 2 ounces product per acre applied post-directed or at layby. The anticipated date of availability is 2004.

Enhanced glyphosate resistant cotton varieties are expected that will allow overtop applications of glyphosate beyond the current cutoff of four-leaf stage of cotton. The anticipated date of availability is unknown.

Glufosinate tolerant cotton (Liberty Link™) is also in the pipeline. The anticipated date of availability is 2004.

Trifloxysulfuron-sodium (trade name Envoke). Provides effective control of sicklepod, hemp sesbania, cocklebur, non-ALS resistant pigweed. Use rates range from 0.1 to 0.15 oz/A overtop (at lest 5 leaf cotton), or 0.15 to 0.25 oz product per acre post-directed. Anticipated date of availability is 2004.

PREPLANT BURN-DOWN HERBICIDES

Virtually all of the cotton acres planted on stale seedbeds (40% of all cotton acres) receive burn-down herbicides to control existing vegetation before planting. The standard burn-down application consists of 1.5 pint of Roundup Ultra Max (glyphosate) plus 1 pint of 2,4-D per acre as a tank mix. Approximately 50 percent of the conventional till acres also receive the glyphosate + 2,4-D burn-down application.

Research Priorities for Yellow Nutsedge (*Cyperus esculentus*)**, Purple Nutsedge** (*Cyperus rotundus*)

Glyphosate, MSMA/DSMA, pyrithiobac + glyphosate, and metolachlor + fluometuron provide limited to good control of yellow and purple nutsedge (see herbicide specific information listed above). Since the nutsedges are not classified as broadleaves or grasses, the Advisory Committee listed the following priorities for nutsedge control in cotton:

Research Priorities

- Competition research
- Biology of sedges
- Biological controls
- Evaluation of how they are spread.

Regulatory Priorities

- Evaluation of how they are spread and what can be done to prevent the spread.

Educational Priorities

- Emphasize cultural practices to reduce spread.
- Emphasize sequential applications of herbicides for nutsedge control.
- How to control herbicide resistant "volunteer crops".

Other Priorities for Weed Management in Cotton

- Volunteer crops (i.e., Roundup Ready crops acting as "volunteer" weeds in Roundup Ready crops)
- Invasive species monitoring
- Competition in our new systems (more conservation till, transgenics). Available data is out-dated.
- Impacts of population shifts (herbicide induced population shifts and/or naturally occurring)
- Various components in weed management systems

Table 11. Herbicides Used, Percentage of Acres Treated by State, and Average Number of Applications per Growing Season (Estimates provided by Weed Scientists from the Midsouth – 2002).

Preplant Incorporated Herbicides	Control Spectrum (Grasses, Broadleaves)	Percentage of Acres Treated by State for the Specified Herbicides and the Average Number of Applications (in parentheses).		
		Arkansas	Louisiana	Mississippi
Trifluralin	Both	3 (1)	1 (1)	35 (1)
Norflurazon	Both	<1 (1)	<1 (1)	-
Pendimethalin	Both	5 (1)	1 (1)	30 (1)
Fluometuron	Both	1 (1)	1 (1)	3 (1)
Preemergence Herbicides				
Metolachlor	Both	1 (1)	<1 (1)	13 (1)
Fluometuron	Both	10 (1)	15 (1)	40 (1)
Norflurazon	Both	1 (1)	1 (1)	1 (1)
Pendimethalin	Both	10 (1)	10 (1)	1 (1)
Clomazone	Both	-	?	2 (1)
Postemergence Herbicides				
MSMA	Both	27 (1.5)	30 (2)	30 (1.5)
Prometryn	Both	10-15 (1.5)	10 (1)	3 (1)
Diuron	Both	40 (1.5)	60 (1)	8 (1)
Glyphosate	Both	80 (2.5)	70 (2.5)	34 (2.5)
Fluometuron	Both	10-15 (1.5)	15 (1)	10 (1)
Quizalofop	Grasses	<5 (1)	5 (1)	<3 (1)
Clethodim	Grasses	<5 (1)	10 (1)	<3 (1)
Fluazifop	Grasses	<5 (1)	5 (1)	<3 (1)
Fenoxaprop	Grasses	<5 (1)	5 (1)	<3 (1)
Sethoxydim	Grasses	<5 (1)	10 (1)	<3 (1)
Lactofen	Broadleaves	2 (1)	2-3 (1)	-
Bromoxynil	Broadleaves	9 (1)	10 (2)	8 (1)
Carfentrazone	Broadleaves		30 (1)	
Pyrithiobac	Broadleaves		50 (2)	
Preplant Burndown				
Glyphosate + 2,4-D	Both	60 (1)	60 (1)	43 (1)

Table 12. Percentage of Infested Acres for Each State and the Estimated Minimum Yield Loss (%) Using Current Control Methods (Estimates provided by Weed Scientists from the Midsouth – 2002)

Weed	Percentage of Infested Acres (2002)			Estimated Minimum Yield Loss Using Current Control Methods		
	AR	LA	MS	AR	LA	MS
Barnyardgrass	20	20	9	2	2	1
Crabgrass	37	40	47	2	1	2
Broadleaf signalgrass	5	10	6	1	1	1
Goosegrass	5	5	22	1	1	1
Foxtail						
Seedling Johnsongrass	10	10	44	1	1	9
Fall panicum	1	1	1	1	1	
Morningglory spp.	79	80	71	25	25	27
Spotted spurge	42	30	53	14	10	5
Nutsedge spp.	4	5	23	5	5	3
Hemp sesbania		5	18		5	8
Common cocklebur	32	10	57	10	5	10
Prickly sida	53	30	51	10	5	6
Pigweed spp.	32	40	32	10	10	15
Bermudagrass	2	30	25		10	8
Redvine		10			10	
Trumpetcreeper		<5	2		1	
Sicklepod		20			10	
Velvetleaf	1	1	1	1	1	
Smartweed	3	2	9	1	1	6
Spurred anoda	1	1	4	2	1	1

DISEASE CONTROL

Research Priorities for Seedling Diseases

- Develop an effective and dependable model to determine when in-furrow fungicides are economically advisable.
- Investigate the involvement of nematodes in seedling disease incidence and severity.
- Product evaluations
- Biocontrol possibilities (trade names: Bioyield, Biophos, Mycostop, Primastop)
- Combinations of products, application techniques, seed treatments.
- Screening for host resistance particularly in transgenic varieties.
- Effects of hopperbox treatments (i.e., mechanical damage potential) on growth and vigor.

Regulatory Priorities for Seedling Diseases

- Protocols for seed treatment

Educational Priorities for Seedling Diseases

- Protocols needed for seed treatment to insure effectiveness and minimize detrimental effects due to seed treatment procedures.
- Fungicide resistance management issues need to be addressed.
- Emphasize cultural practices (soil fertility, vascular disease, correct soil temps, depths, planting dates) to reduce seedling diseases.
- Aid growers in determining when they should buy in-furrow materials and when seed treatment alone will be adequate (economics and education).

Research Priorities for Fusarium Wilt

- Determine the incidence and impact of Fusarium in "symptomless" plants.
- Clarify the concept of "tolerance to the Fusarium wilt/root knot disease complex.
- Screening transgenics for resistance.

Regulatory Priorities for Fusarium Wilt

None

Educational Priorities for Fusarium Wilt

None

Research Priorities for Verticillium Wilt

- Improve Verticillium wilt resistance or tolerance in cultivars.

Regulatory Priorities for Verticillium Wilt

None

Several diseases are economically important in Midsouth cotton production. Pathogen levels, seedling vigor, weather, and environmental conditions all affect the incidence and severity of disease each year. Most of the major cotton diseases are soil-borne and survive from year to year in the cotton field. The causal agents that cause seedling diseases include *Pythium* spp., *Fusarium* spp., *Rhizoctonia solani*, and *Thielaviopsis basicola*. These seedling disease pathogens may cause disease individually or they may interact to form a disease complex that can be more severe than the individual pathogen effects. Symptoms of seedling disease include pre-germination decay of the seed, decay of the seedling on the way to the soil surface (pre-emergence damping off), partial or complete girdling of the emerged seedling at or near the soil surface and seedling root rot. Fungicides are generally effective in controlling most seedling diseases.

Fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*) and Verticillium wilt (*Verticillium dahliae*) both may affect cotton in the Midsouth. The significance of these diseases in the cotton crop varies from year to year. Fusarium wilt is often associated with the root knot nematode. This disease may be controlled to some degree using resistant varieties, although when nematodes are also present even resistant varieties may exhibit moderately severe disease. Practices that reduce nematode populations in cotton along with the use of Fusarium wilt resistant cultivars are effective in controlling this disease. Planting tolerant varieties, crop rotation, avoiding deep cultivation and careful management of irrigation and nitrogen can reduce Verticillium wilt severity. Pesticides are not effective in the control of Fusarium or Verticillium wilts.

Chemical Control - Diseases

Metalaxyl

Trade name is Allegiance (seed treatment). Approximately 90 percent of the cotton acreage is planted using metalaxyl treated seed. Metalaxyl is effective in controlling Pythium seedling diseases. Application rates average 0.75 to 1.0 fluid ounce per 100 pounds of seed. The REI for Allegiance is 24 hours unless the seed is treated and the treated seed is soil incorporated or soil injected. A pre-harvest interval is not listed on the label.

Triadimenol

Trade name is Baytan (seed treatment). Baytan is usually applied in combination with metalaxyl to seed for activity against *R. solani* in the Midsouth and southeastern U.S. and at higher rates for control of *T. basicola* in the western U.S. A pre-harvest interval is not listed on the label.

PCNB

Trade names are Terraclor 2E, Terraclor Super X (when combined with etridiazole), Terraclor Super X + Disyston EC, Terraclor 10G, Terraclor 75WP, and Ridomil Gold PC (mefenoxam + PCNB). At least 15 percent of the cotton acreage receives a single in-furrow PCNB application at planting to control seedling diseases. Application rates average from 0.5 to 1.0 pounds a.i. per acre. PCNB is effective in controlling Rhizoctonia. The REI for PCNB is 12 hours unless it is soil incorporated. The REI for PCNB + disulfoton is 48 hours unless it is soil incorporated. The pre-harvest interval is not applicable.

Mefenoxam

Trade name is Ridomil Gold PC (mefenoxam + PCNB). At least 15 percent of the cotton acreage receives a single in-furrow mefenoxam application at planting to control seedling diseases. Application rates range from 7 - 10 pounds per 13,000 linear feet of row. The REI for the product is 48 hours unless soil incorporated or soil injected. A pre-harvest interval is not listed on the label.

Iprodione

Trade name is Rovral. Rovral is effective as an in-furrow treatment for control of *R. solani*. Approximately 5% of the cotton acreage receives a single in-furrow iprodione application at planting, generally in combination with mefenoxam for control of both *R. solani* and *Pythium* spp. Application rates range from 3.2 -8.7 ounces of Rovral per acre. The REI for the product is 24 hours. A pre-harvest interval is not listed on the label.

Other fungicides for the control of diseases: Azoxystrobin (Quadris) was labeled for use in cotton in 2002. It will be packaged with metalaxyl (Ridomil) and will be labeled for in-furrow applications. Myclobutanil (Nuflow M) is used as a seed treatment for the control of *Theilaviopsis basicola*.

Alternatives for disease control: Delayed planting, adequate drainage, and high quality seed all aid the control of cotton diseases.

Pipeline materials for disease control: None identified.

NEMATODES

Research Priorities for Root-Knot Nematode

- Develop precision farming technology to allow variable-rate and site-specific nematicide application.
- Work to develop site-specific, variable rate thresholds
- Develop resistant cultivars that have good yield. Use genetic markers to identify resistance quickly and efficiently.
- Crop rotation effect or other cultural practices effects

Regulatory Priorities for Root-Knot Nematode

- Maintain registration of aldicarb and other existing products.

Educational Priorities for Root-Knot Nematode

- Importance of sampling to determine population densities
- Education on crop rotations for specific nematodes diseases

Research Priorities for Reniform Nematode

- Identify a source of resistance.
- Develop resistant cultivars.
- Develop more effective and economical nematicides (product rates, timing, rotational schedules).
- Understand the basic ecology of the reniform nematode in the mid-south.

Regulatory Priorities for Reniform Nematode

- Maintain aldicarb and other existing products registration.
- Encourage investigation of new chemistries and bio-control possibilities/products.

Educational Priorities for Reniform Nematode

- Improve awareness of the spread of this nematode in the mid-south.
- Importance of sampling to determine population densities
- Education on crop rotations for specific nematodes diseases

Two species of nematodes occur in the Midsouth that can cause economic yield losses in cotton. These are the root-knot nematode (*Meloidogyne incognita*) and the reniform nematode (*Rotylenchus reniformis*). Region wide, approximately 30 percent of the cotton acreage in any given year is infested by one or the other of these two species, but in areas of historically high cotton acreage and long monoculture, the percentage of fields infested may reach 60 percent. Root-knot is found in all areas of the region, while the reniform nematode has so far been found primarily in Mississippi, Louisiana and several counties in southeastern Arkansas. The symptoms associated with nematodes are often mistaken for other problems such as nutritional imbalance, soil compaction, and water stress. Characteristic root galls are associated with root-knot nematode infection, while reniform nematodes do not cause galls.

Crop rotation is generally the most cost-effective method of nematode control over time, but rotational crops may be of relatively low economic value. Production of rice, corn, grain sorghum, or peanut or resistant soybean cultivars for one or two years in rotation with cotton may improve crop performance by lowering reniform nematode populations. Careful selection of rotation crops, based on the nematode species to be controlled, is essential.

Although there have been some cotton varieties in the past that have shown moderate resistance to root-knot nematodes, these varieties are no longer used in the Midsouth. Currently there is only one cotton variety, Stoneville 5599BR, that has shown slight root-knot resistance. There are no cotton varieties that have resistance to reniform nematodes.

Nematode Control

Aldicarb

Trade name is Temik 15G. Application rates range from 0.5 to 1.5 lbs a.i. per acre. The application of aldicarb up to 1.05 lb a.i. can be applied in the furrow at planting or 0.75 lb a.i. can be applied in furrow at planting and then another 0.75 lb a.i. per acre can be side-dressed after the cotton emerges (before pin-head square). The REI for aldicarb is 48 hours unless it is soil incorporated. The pre-harvest interval is 90 days.

Other nematicides for the control of nematodes diseases: The use of dichloropropene (Telone II) is small but growing especially in southern Arkansas.

Alternatives for nematode control: Rotation to corn or grain sorghum can help reduce reniform nematode populations. If root-knot nematode is the problem then peanuts or rice are the only effective rotation crops.

Pipeline materials for nematode control: None identified.

Table 13. The Percentage of Infested Acres for Each State and the Estimated Minimum Yield Loss if the Disease or Nematode is Not Controlled (Midsouth Plant Pathologist's Estimates – 2002).

Disease	Percentage of Infested Acres (2002)			Estimated Minimum Yield Loss If the Disease or Nematode is not Controlled		
	AR	LA	MS	AR	LA	MS
Pythium spp.	20	100	30	3.75 for all Seedling Diseases (1995-98)	2 – 4 for all seedling diseases	3-4
Fursarium spp.	30	100	50			<1
Rhizoctonia solani	80	100	50			1-2
Thielaviopsis basicola	30	100	5			<1
Fusarium wilt	20	100	<1			<1
Verticillium wilt	20	10	<1			1-2
Root-knot nematode	40	10	10		6	2
Reniform nematode	10	50	50		30	8

Table 14. The Percentage of Acres Treated for Each State and the Average Number of Applications for the Specified Fungicides and Nematicides (Midsouth Plant Pathologist's Estimates – 2002)

Fungicide	Percentage of Acres Treated and Average Number of Applications (in parentheses) by State for the Specified Fungicides and Nematicides.		
	Arkansas	Louisiana	Mississippi
Metalaxyl	90 (1)	25(1)	30 (1)
Triadimenol			
PCNB	15 (1)	30(1)	15 (1)
Mefenoxam	15 (1)	10-15(1)	2 (1)
Iprodione	5 (1)	5(1)	<1 (1)
Azoxystrobin		5(1)	
Myclobutanil			
Nematicide			
Aldicarb	50 (1)	65(1)	45 (1)
Dichloropropene	2 (1)	<1(1)	<1 (1)

Other Priorities for Disease and Nematode Management

- Additional research on boll rot complex
- Fungicides for control (and efficacy) of boll rot
- More research on influence of virus diseases on yield

WORKER ACTIVITIES

Insect Scouting: Scouting for insects and monitoring plant development is the primary activity requiring pedestrian workers to enter cotton fields during the growing season. Scouting is performed by professional crop consultants and summer scouts (usually high school or college aged individuals) employed by these consultants, as well as by producers and industry fieldmen. Full-time cotton scouts normally work in excess of 40 hours per week and much of this time is spent walking through cotton fields, counting insects and collecting information on plant development. Ideally, cotton is scouted twice weekly from emergence through the boll opening period. Full-time cotton scouts are in direct contact with plants for a large portion of the day, each day of the work season.

Irrigation: A large percentage of the cotton grown in the Midsouth is irrigated (> 20% in Mississippi, > 60% in Arkansas, and > 30-40% in Louisiana). Irrigation pipe must be placed in fields after all tillage operations are completed for the season and removed before harvest. This requires pedestrian workers to enter fields at least twice during the growing season to place and remove pipe. Workers may also be required to enter fields during the irrigation process, to make repairs and to manage the irrigation procedure. Workers performing such irrigation procedures may be in direct contact with plants, but this occurs during a limited portion of the season.

Hand Weeding: Hand weeding is uncommon, but is still performed occasionally by workers who are “chopping” weeds or “spot spraying” with a hand carried sprayer. Workers performing such procedures are in direct contact with plants for a large potion of the time period during which the procedure is being performed, but this occurs during a limited portion of the season.

Tillage, Spraying, and Harvest: Individuals performing normal cultivation, spraying and/or harvest operations are operating motorized equipment, usually from an enclosed cab. Occasionally it is necessary for equipment operators to dismount in the field to perform minor repairs, such as adjusting cultivators or unclogging spray nozzles. Workers are in direct contact with plants during the time that they are dismounted, but this represents only a small portion of the work day.

REFERENCES

1. Agusti, N. and A.C. Cohen. 2000. *Lygus hesperus* and *L. lineolaris* (Hemiptera: Miridae), Phytophages, Zoophages, or Omnivores: Evidence of Feeding Adaptations Suggested by the Salivary and Midgut Digestive Enzymes. J. Entomol. Sci. 25:176-186.

2. Buchanan, G.A. and E.R. Burns. 1970. *Influence of weed competition on cotton*. Weed Sci. 18:149-154.

3. Byrd, J.D. 2002. *Report of the Cotton Weed Loss Committee for 2002 Beltwide Cotton Council.* Department of Plant and Soil Science, Mississippi State University, Mississippi State University Extension Service.

4. Hollingsworth, R.G., D.C. Steinkraus, and N.P. Tugwell. 1997. *Responses of Arkansas Populations of Tarnished Plant Bugs* (Heteroptera: Miridae) *to Insecticides, and Tolerance Differences Between Nymphs and Adults.* J. Econ. Entomol. 90(1):21-26

5. Johnson, D.R. *Pesticide Use Survey on the 1992 and 1993 Cotton Crops of Arkansas*. Cooperative Extension Service, University of Arkansas. Unpublished.

6. Johnson, D. R., R. E. Caron, R. B. Head, F. G. Jones, and J. S. Tynes. 1996. *Insect and mite pest management in the Mid-south.* Ch. 21, pp. 673-692, in E. G. King, J. R. Phillips, and R. J. Coleman (Eds.) *Cotton Insects and Mites: Characterization and Management, Reference Book Three, Cotton Foundation Reference Book Series*, 1008 pp.

7. Kirkpatrick, T.L. and R.T. Robbins. 1998. *Nematodes of Cotton in Arkansas*. Cooperative Extension Service, University of Arkansas Fact Sheet FSA 7523-3M-4-98RV.

8. Kirkpatrick, T.L. and C.S. Rothrock. 1996. *Fungicides for Cotton Seedling Disease Control*. Cooperative Extension Service, University of Arkansas Fact Sheet FSA7524-2M-4-96N-S608.

9. Layton, M.B. 2002. *Cotton Insect Control Guide, 2002*. Mississippi State Univ. Ext. Serv. Publ. 343. 35 p.

10. Layton, M.B., M.R. Williams, and S. Stewart. 1997. *Bt-cotton in Mississippi: The first year.* Proc. Beltwide Cotton Conf. Vol II. p. 861-863.

11. Layton, B., S.D. Stewart, and M.R. Williams, 1998, *Performance of Bt cotton in Mississippi, 1997*. Proc. Beltwide Cotton Conf. Vol II, p. 970-973.

12. Layton, M.B., S.D. Stewart, M.R. Williams, and J.L. Long, 1999, *Performance of Bt cotton in Mississippi, 1998.* Proc. Beltwide Cotton Conf. Vol II, p. 942-946.

13. Layton, M.B., M.R. Williams, and J.L. Long, 2000, *Performance of Bt cotton in Mississippi, 1999*. Proc. Beltwide Cotton Conf. Vol II, p. 1037-1039.

14. Layton, M.B., M.R. Williams, and J.L. Long, 2001, *Performance of Bt cotton in Mississippi, 2000.* Proc. Beltwide Cotton Conf. Vol II, p.847-849.

15. Layton, M.B., M.R. Williams, and J.L. Long, 2002, *Performance of Bt cotton in*

Mississippi, 2001. Proc. Beltwide Cotton Conf., 2002.

16. Layton, M. B. unpublished, Profile of Cotton Entomology in Mississippi, 2002

17. Layton, M. B. unpublished, Survey of Insecticide Use in 133 Mississippi Cotton Fields, 1998

18. Layton, M. B. unpublished, Survey of Insecticide Use in 93 Mississippi Cotton Fields, 1999

19. Layton, M. B. unpublished, Survey of Insecticide Use in 59 Mississippi Cotton Fields, 2000

20. Layton, M. B. unpublished, Survey of Insecticide Use in 120 Mississippi Cotton Fields, 2001

21. Layton, M. B. unpublished, Survey of Insecticide Use in 114 Mississippi Cotton Fields, 2002

22. Luttrell, R. G. T. G. Teague, N. P. Tugwell, D. Wells, S.Coy, S. Wingard, C. Yates 2002. *Observations of the Cotton Fleahopper in Arkansas*. Beltwide Cotton Prod. Res. Conf., 2002.

23. Overstreet, C. and E.C. McGawley. 2000. *Management Options for Reniform Nematode in Cotton Production for Louisiana.* Nematropica 30: 142-143.

24. Overstreet, C. and E.C. McGawley. 2000. *Geographical Distribution of Reniform Nematode in Louisiana.* 2000 Proceedings of the Beltwide Cotton Conferences Vo. 1: 168-171.

25. Pack, T. M. and N. P. Tugwell. 1976. *Clouded and tarnished plant bugs on cotton: A comparison of injury symptoms and damage on fruit parts*. Ark. Agric. Exp. Stn. Rep. Tech. Bull. 226.

26. Snodgrass, G.L. 1996. *Insecticide Resistance in Field Populations of the Tarnished Plant Bug* (Herteroptera: Miridae) *in Cotton in the Mississippi Delta*. J. Econ. Entomol. 89(4):783-790

27. Tugwell, N. P., S.C. Young, JR., B. A. Dumas, & J. R. Phillips. 1976. *Plant bugs in cotton: importance of infestation time, types of cotton injury, and significance of wild host near cotton.* Ark. Agric. Exp. Stn. Rpt. Series 227. 24pp.

28. Williams, M.R., 2001. *Cotton Insect Losses Estimates 2000.* Proceedings 2001 Beltwide Cotton Production Conference, Vol. II. pp. 774-776.

29. Williams, M. R., 2002, *Cotton Insect Losses 2001*, *In* (online) Proceedings 2002 Beltwide Cotton Production Conference, National Cotton Council of America, Memphis, TN.

30. Williams, M. R., 2003, *Cotton Insect Losses 2002*, (online) Proceedings 2003 Beltwide Cotton Production Conference, National Cotton Council of America, Memphis, TN.

31. National Agricultural Statistics Service (http://www.usda.gov/nass/)

32. Arkansas Agricultural Statistics Service (http://www.nass.usda.gov/ar/)

33. Louisiana Agricultural Statistics Service (http://www.nass.usda.gov/la/)

34. Mississippi Agricultural Statistics Service (http://www.nass.usda.gov/ms/)

35. *1995 Cotton Production Recommendations* (AG422-4-95). Cooperative Extension Service, University of Arkansas.

36. *2003 Insecticide Recommendations for Arkansas* (MP-144). Cooperative Extension Service, University of Arkansas.

37. *2003 Recommended Chemicals for Weed and Brush Control in Arkansas* (MP-44).

38. *Arkansas Plant Disease Control Products Guide-2003* (MP-154). Cooperative Extension Service, University of Arkansas.

39. *2003 Insect Pest Management Guide.* Louisiana Cooperative Extension Service.

40. *2003 Plant Disease Control Guide*. Louisiana Cooperative Extension Service.

41. *Louisiana's Chemical Weed Control Guide for 2003*. Louisiana Cooperative Extension Service.

42. *Louisiana Summary Agriculture & Natural Resources 2000*. 2001. Louisiana Cooperative Extension Service Publication 2382. 322 pages.

43. *2003 Cotton Insect Control Guide*. Mississippi State University Extension Service.

44. *2003 Weed Control Guidelines for Mississippi*. Mississippi State University Extension Service.

45. *Cotton Seedling Disease Control*. Mississippi State University Extension Service.

46. *Insect Control Guide for Cotton Producers and Consultants*. 1993. Miles, Inc., Agriculture Division

47. *Insect Identification and Control Guide for Cotton Producers and Consultants*. 1993. Miles, Inc., Agriculture Division.

48. Proceedings of the Beltwide Cotton Conferences, 1996 – 2003. National Cotton Council of America.

49. *Weed Identification Guide*. Southern Weed Science Society.

Advisory Committee Members
Arkansas

Mr. Laudis Brantley, Cotton Producer, Lonoke, AR
Dr. Rick Cartwright, Extension Plant Pathologist, UACES
Dr. Mark Cochran, Professor – Agricultural Economics, University of Arkansas
Mr. Chuck Farr, Independent Consultant
Ms. April Fisher, County Extension Agent, Jefferson, Co., UA Extension Service
Dr. Jeremy Greene, Extension Entomologist, UA Extension Service
Mr. Blair Griffin, Staff Chairman, Johnson Co., UA Extension Service
Dr. Don R. Johnson, Extension Entomologist, UACES
Mr. Johnny Johnson, Cotton Producer, AR
Mr. Danny Keiser, Coordinator of Arkansas Boll Weevil Eradication Program
Dr. Terry Kirkpatrick, Professor – Nematology, Department of Plant Pathology, UA
Mr. Tim Kresse, Water Quality Specialist, Arkansas Department of Environmental Quality]
Dr. Timothy Kring, Professor – Biological Control, Department of Entomology, UA
Dr. Gus Lorenz, Extension IPM Coordinator, UACES
Dr. Randy Luttrell, Professor – Department of Entomology, University of Arkansas
Mr. Gene Martin, Cotton Commodity Specialist, Arkansas Farm Bureau
Mr. Johnny McGraw, Cotton Producer, Desha Co., AR
Dr. Derrick Oosterhuis, Professor – Crop Physiology, Department of Crop, Soil and Environmental Science, UA
Dr. Bill Robertson, Extension Agronomist – Cotton, UA Extension Service
Dr. Briggs Skulman, Senior Research Associate, Department of Crop, Soil and Environmental Science, UA
Dr. Ken Smith, Extension Weed Scientist, UACES
Mr. Ples Spradley, Extension Pesticide Assessment Specialist, UACES
Don Steinkraus, Professor – Department of Entomology, University of Arkansas
Dr. Glenn Studebaker, Extension Entomologist, UACES
Dr. Ron Talburt, IR-4 Coordinator, Department of Crop, Soil and Environmental Science, UA
Dr. Tina Teague, Professor – Entomology, Arkansas State University
Dr. N.P. Tugwell, Professor – Entomology (retired), Department of Entomology, UA
Mr. David Wildy, Cotton Producer, Mississippi Co., AR

Louisiana

Dr. John Andries, Louisiana Department of Agriculture and Forestry
Dr. Ralph Bagwell, Extension Entomologist, LSU

Dr. John Barnett, Extension Agronomist, LSU
Brian Breaux, Louisiana Farm Bureau
Dr. Mary Grodner, Pesticide Safety Education Specialist, LSU AgCtr.
Dr. Steve Kelly, Extension Weed Scientist, LSU
Dr. Roger Leonard, Entomologist, LSU
Dr. Charles Overstreet, Extension Nematologist, LSU
Matt Shipp, Extension Associate, LSU
Dr. H. Kenneth Whitam, Extension Plant Pathologist, LSU

Mississippi

Dr. John Byrd, Weed Scientist, MSU Extension Service
Dr. Frank L. Carter, Senior Scientist, National Cotton Council
John Coccaro, Agronomic Crops - Area Agent, MSU Extension Service
Elmo Collum, Pesticide Education Coordinator, MSU Extension Service
Bart Freeland, Physical Scientist, USDA Delta Branch Experiment Station
Dr. David Ingram, Extension Plant Pathologist, MSU Extension Service
Shedd Landreth, Environmental Engineer, Mississippi Department of Environmental Quality
Dr. Blake Layton, Extension and Research Entomologist, MSU Extension Service
Dr. Will McCarty, Extension Agronomist, MSU Extension Service
Phillip McKibben, Certified Crop Consultant, Eupora, MS
Edward McKnight, Cotton Producer, Vicksburg, MS
J.L. Slay, Director of Commodity Activities, Mississippi Farm Bureau
Dr. Jeannine Smith, Executive Director of Mississippi Boll Weevil Management Corp., MSU
Dr. Mike Williams, Extension and Research Entomologist, MSU Extension Service

Attendees of Cotton PMSP meeting held in Vicksburg, MS on April 24-25, 2003

Dr. John Andries, Louisiana Department of Agriculture and Forestry
Dr. Ralph Bagwell, Extension Entomologist, LSU
Jess Barr, Cotton Producer, Louisiana
Dr. Frank L. Carter, Senior Scientist, National Cotton Council
John Coccaro, Agronomic Crops - Area Agent, MSU Extension Service
Elmo Collum, Pesticide Education Coordinator, MSU Extension Service
Dr. Shani File, SRIPM Facilitator, University of Florida
Ms. April Fisher, County Extension Agent, Jefferson, Co., UA Extension Service
Bart Freeland, Physical Scientist, USDA Delta Branch Experiment Station
Joyce Gilmer, Administrative Assistant, MSU Extension Service
Dr. Jeremy Greene, Extension Entomologist, UA Extension Service
Dr. Mary Grodner, Pesticide Safety Education Specialist, LSU AgCtr.
William Gross, EPA/BEAD, Manassas, Virginia
Dr. David Ingram, Extension Plant Pathologist, MSU Extension Service
Dr. Don R. Johnson, Extension Entomologist, UACES
Mr. Danny Keiser, Coordinator of Arkansas Boll Weevil Eradication Program
Dr. Steve Kelly, Extension Weed Scientist, LSU
Shedd Landreth, Environmental Engineer, Mississippi Department of Environmental Quality

Dr. Blake Layton, Extension and Research Entomologist, MSU Extension Service
Dr. Roger Leonard, Entomologist, LSU
Dr. Gus Lorenz, Extension IPM Coordinator, UACES
Gene Martin, Cotton Commodity Specialist, Arkansas Farm Bureau
Phillip McKibben, Certified Crop Consultant, Eupora, MS
Edward McKnight, Cotton Producer, Vicksburg, MS
Dr. Norman Nesheim, SRIPM Co-Director, University of Florida
Dr. Bill Robertson, Extension Agronomist – Cotton, UA Extension Service
Matt Shipp, Extension Associate, LSU
J.L. Slay, Director of Commodity Activities, Mississippi Farm Bureau
Dr. Jeannine Smith, Executive Director of Mississippi Boll Weevil Management Corp., MSU
Dr. Ken Smith, Extension Weed Scientist, UACES
Dr. Charles Snipes, Extension/Research Professor, MSU Extension Service
Ples Spradley, Extension Pesticide Assessment Specialist, UACES
Nancy Strickland, Administrative Assistant, MSU Extension Service
Dr. Tina Teague, Professor – Entomology, Arkansas State University
Eugene Thilsted, EPA Region 6, Dallas, TX
Dr. N.P. Tugwell, Professor – Entomology (retired), Department of Entomology, UA
Dr. Mike Williams, Extension and Research Entomologist, MSU Extension Service

Acknowledgements

We wish to acknowledge the valuable contribution by all of the PMSP Advisory Committee members to this project. The committee members provided valuable information and expertise on the many aspects of pest management in cotton grown in the Midsouth. Special thanks are extended to Elmo Collum, Pesticide Education Coordinator, MSU Extension Service, Matt Shipp, Extension Associate, LSU AgCenter, Dr. Gus Lorenz, Extension IPM Coordinator, UA Cooperative Extension Service, Dr. Blake Layton, Extension Cotton Entomology Specialist, MSU Extension Service, and Dr. Randall Luttrell, Professor-Entomology, University of Arkansas for their extensive contributions of time and effort for this project.

Contacts:

Arkansas

Ples Spradley
Extension Pesticide Assessment Specialist
P.O. Box 391
2301 S. University
Little Rock, AR 72203
Phone: 501-671-2234
FAX: 501-671-2252
E-mail: pspradley@uaex.edu

Louisiana

Matt Shipp
Extension Associate
Louisiana State University
404 Life Sciences Bldg.
Baton Rouge, LA 70803
Phone: 225-578-4568
FAX: 225-578-2257
E-mail: MShipp@agctr.lsu.edu

Dr. Mary Grodner
Pesticide Safety Education Specialist
LSU AgCenter
404 Life Sciences Bldg.
Baton Rouge, LA 70803
Phone: 225-578-2180
FAX: 225-578-7829
E-mail: MGrodner@agctr.lsu.edu

Mississippi

Elmo Collum
Pesticide Education Coordinator
Mississippi State University Extension Service
1320 Seven Springs Road
Raymond, MS 39154
Phone: 601-857-2284
FAX: 601-857-2358
E-mail: elmoc@est.msstate.edu

ATTACHMENT

Additional Research Priorities for Cotton Bollworm and Tobacco Budworm as listed in the "Recommended Research Thrusts" document developed at the *Heliothis*/*Helicoverpa* Workshop in Dallas, Texas on March 25-28, 2003.

Recommended Research Thrusts

Biology and Ecology

BW – bollworm
TBW – tobacco budworm
CONS – consultant

1. Effect of new varieties, soil type, cover crops, crop rotation, conservation and other tillage systems, crop host termination, and Roundup-Ready systems on population dynamics of all leps in cotton (esp. BW/TBW), including overwintering, localized movement, and ovipositional behavior. (EPA, TAMU, Clemson, ARS, CONS)

2. Finalize potential value of attract 'n' kill systems, including use of food attractants, pheromones and insecticides (ARS, MSU).

3. Influence of cropping systems (i.e. corn, cotton, grain sorghum, peanuts and soybean intercropping in agroecosystem) on overall population dynamics of lepidoptera in cotton with emphasis on BW/TBW (ARS, EPA, TAMU).

4. Continue efforts on local and long-range movement of moths including use of isotope ratios and pollen grains as measures of influence of host plants, meterological events, new cultivars, and development of meteorological models for prediction (EPA, ARS, Auburn, Chem. Ind., MSU).

5. Use of isotope ratio mass spectrometry in determining larval food source of migrating moths (e.g. C3/C4 ratios, presence of gossypol, etc.) (ARS, EPA, NCSU).

6. In-depth genetic studies and life-table analyses of BW/TBW (EPA).

7. Initiate detailed movement studies and baseline host data for TBW (EPA, ARS).

8. Use of caloric analysis to evaluate fat body reserves to aid in determining long or short-range movement (ARS).

9. Attempt to correlate with models pheromone trap numbers and egg counts in the field (ARS).

10. Continue to study biology and host plants, including effect of last host in fall, overwintering, first host in spring, temperature, moisture, etc. on pest population development (MSU).

<u>Suppression Tactics and IPM</u>

1. Search for ovipositional attractants for BW/TBW (NCSU).

2. Determine effect of landscape patterns on BW/TBW populations (ARS).

3. Search for thresholds for natural enemies of BW/TBW (MSU).

4. Evaluate influence of conservation tillage on numbers of beneficial insects (ARS).

5. Study pheromone production in relation to attract ‘n’ kill systems and mating disruption (ARS).

6. Initiate studies to integrate multiple IPM tactics with insecticides in suppression (ARS, TAMU).

7. Search for female antagonists and an effective delivery system (ARS).

8. Study possible use of trap crops as a combined aggregation and refuge system (EPA).

9. Continue to study efficacy of pesticides against all pests, esp. BW and TBW.

10. Monitor pesticide resistance, as well as Bt (MSU).

11. Work on long-range, area-wide management of BW/TBW (MSU).

<u>HOST PLANT RESISTANCE</u> (HPR)

1. Continue to cooperate (through CRADA’s where possible) with industry in development and evaluation of new lines and improved varieties (ARS, MSU).

2. Combine conventional HPR research (e.g. low/high gossypol) in conjunction with transgenic varieties (Clemson).

3. Identify and characterize traits for incorporation into future lines (Chem. Ind.).

4. Study insect transmission of diseases (e.g. aflatoxin) in relation to HPR (ARS).

5. Develop molecular markers to incorporate into HPR research (EPA).

Transgenic Crops

1. Continue and expand BW/TBW Beltwide monitoring program (Cotton, Inc., ARS, CONS).

2. Conduct 2nd-year host study of BW, consider 2-years data, then determine need for continuation (ARS).

3. Initiate search for recessive resistance in BW/TBW using light traps and F_2 screens (ARS).

4. Conduct economic assessment of the value of transgenic crops, especially possible reduction in pesticide use (Bayer).

5. Determine effectiveness and differences in varietal expression of toxins in new transgenic products (Monsanto, EPA, Cotton, Inc., Auburn, LSU) and their effectiveness against other leps (LSU).

6. Determine possible differences in behavior of BW/TBW in response to pure Cry1Ac vs MPVII (Auburn).

7. Develop a multi-state, multi-commodity working group on BW/TBW (KSU).

8. Determine possible alternatives to cotton as active refugia, e.g. *Paulonia* (Monsanto, MSU).

9. Study influence of Bt corn (esp. sweet corn) on development of resistance in BW/TBW in cotton (Auburn).

10. Determine additive effect of transgenic crops and other IPM tactics (e.g. biological control) in BW/TBW management (EPA, LSU, CONS, MSU).

11. Develop resistant colonies of BW/TBW to study genetics and possible cross-resistance of Heliothines to multiple-toxin varieties (ARS).

12. Develop identification "kits" for various larval stages of BW/TBW in field (KSU) and diagnostic hit for assessing resistance in the field (LSU, Cotton, Inc.).

13. Determine synchrony of moths emerging from refuges with those emerging from Bt cotton (EPA, ARS).

14. Develop landscape models for Bt cotton and adjoining crops to simulate different movement and resistance development scenarios (EPA).

15. Use of remote sensing and global positioning systems to detect other crop/weed hosts as refuges and in monitoring and control studies (ARS, EPA, MSU).

16. Study influence of Bt crops on non-lepidopteran pests and beneficial insects (e.g. sucking pests), including changes in scouting techniques, new thresholds, etc.) (EPA, LSU, Cotton, Inc., CONS).

17. Conduct annual evaluation of all new Bt varieties as to yield, grade, staple, and micronaire (CONS, Cotton, Inc.).

18. Determine additive effects of pesticides and cultural practices on effectiveness of transgenics (CONS).

19. Use of genetic engineering to increase expression of all tissues in Bt crops (ARS).

20. Continue and expand research on feeding behavior and larval movement in relation to monitoring, scouting and Bt effectiveness (EPA).

21. Evaluate effects of transgenic crops on natural enemies and secondary pests (EPA).