msucares
Coordinated Access to the Research and Extension System
Mississippi Agricultural and Forestry Experiment Station

Revised Protocol for Scouting Arthropod Pests of Cotton in the Midsouth

M.R. Williams
Extension Specialist, Entomology
Department of Entomology and Plant Pathology
Mississippi State University

T.L. Wagner
Research Entomologist
USDA-ARS, Crop Simulation Research Unit

J.L. Willers
Research Entomologist
USDA-ARS, Crop Simulation Research Unit

Published by the Office of Agricultural Communications, Division of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University. Edited by Keith H. Remy, Senior Publications Editor. Cover designed by M.R. Williams, Senior Author, and Betty Mac Wilson, Graphic Artist.

Contents

Abstract
Introduction
Management Unit
Generalized Sampling Methods
Line-Intercept Sampling Method
Quadrat Sampling Method
Scouting Protocol
PGSO - Preplant
PGS1 - Planting to Crop Emergence
PGS2 - Emergence to Third True Leaf
PGS3 - Third True Leaf to Pinhead Square
PGS4 - Pinhead Square to Match-Head Square
PGS5 - Match-Head Square to First Bloom
PGS6 - First Bloom to Cutout
PGS7 - Cutout to Defoliation
PGS8 - Defoliation to Harvest
Conclusions

References Cited
Glossary
Appendix I -- Standardization of Data
Appendix II -- Placement and Maintenance of Pheromone Traps
Appendix III -- Scouting Forms
Form 1: Pheromone Trap Data
Form 2: PGS2 -- Emergence to Third True Leaf
Form 3: PGS3 -- Third True Leaf to Pinhead Square
Form 4: PGS4 -- Pinhead Square to Match-Head Square
Form 5: PGS5 -- Match-Head Square to First Bloom
Form 6: PGS6 -- First Bloom to Cutout
Form 7: PGS7 -- Cutout to Defoliation
Table 1
Table 2
Table 3

Abstract

A protocol is presented for scouting cotton arthropod pests in the Midsouth region. This protocol represents a major revision of an earlier method of scouting cotton pests (Williams et al., 1991). The protocol features a new line-intercept method for scouting early in the growing season and a refined quadrat method used during the mid-to-late season. These methods are suitable for sampling multiple pest species and numerous crop attributes, and they utilize sound data collection and statistical techniques. Efforts have been made to streamline procedures, simplifying the task of collecting quality data for decision-making. The methods have specific application to the computer decision-support system, GOSSYM/COMAX/WHIMS, but they can also be used independently by commercial scouts, consultants, Extension personnel, or researchers.

Introduction

The purpose of scouting cotton is to provide up-to-date information on which to make management decisions. It requires the systematic collection of data on arthropod pests and beneficial species in and near the field, observations on plant growth and development, and an assessment of pest damage to the crop. The type and amount of information required for sound decision-making change during the season because different pest species are associated with the crop as it matures. Not only does the pest complex change as the crop matures, but the location and abundance of individual species on the plant and in the field change.

Prior to sampling, there is no way to know exactly which pest species will be encountered in a particular field, where they will be located, or what their abundance will be. The job of the scout is to obtain this information. Because cotton grows in a predictable manner (Elsner et al., 1979; Mauney and Stewart, 1986), the scout should know the stage of the crop prior to going into the field. This knowledge provides an excellent foundation for organizing a scouting protocol.

Scouts must possess certain skills in order to obtain the proper information at the appropriate time. They must identify the arthropod species associated with cotton, recognize the type(s) of damage caused by each, and know when to look for the different species. Scouts must also adjust to new or unusual developments that occur spontaneously. This protocol assists in these tasks. It presents a unified and specific plan for sampling the principal pest species that could be encountered at a given time. To accomplish this task, the season is divided into nine distinct periods, eight of which are associated with phenological events of cotton that have significance to pest population dynamics and management (Williams et al., 1992). The eight plant growth

stages (PGS's) are listed in Table 1.

The prominent and occasional pest species associated with each PGS are summarized in Table 1. These species are only potential pests, for not all species will be found in a field at a particular time. At times, pests classified as occasional will be more abundant than those classified as prominent. Other problems may develop on rare occasions that involve atypical species not listed in the protocol. If these species are encountered, they also must be identified and reported. Remember, agroecosystems are very complex and dynamic; unexpected events will occur. For these reasons, a scout must examine the crop carefully, reporting observations in a useful and unbiased manner. Data forms have been developed to assist in these tasks (Appendix III, pages 27-35).

Adherence to the protocol will provide quality data for decision-making; however, the application of this information alone will not guarantee that quality decisions are made. Sound decision-making involves the integration and analysis of information from sources other than just the scout. In recognition that scouting (data collection) is a necessary step to sound decision-making, we have designed and integrated this protocol with a computerized decision-aid for cotton pest management (Wagner et al., 1995). This system is called rbWHIMS (**r**ule-**b**ased (**W**)**H**olistic **I**nsect **M**anagement **S**ystem). rbWHIMS integrates the knowledge and experience of multiple experts with supplemental information to analyze the data provided by the scout. It provides pest management recommendations for 13 species or species groups over the entire growing season. rbWHIMS is a component of the computer-based cotton management system, GOSSYM/COMAX (Baker et al., 1983; Lemmon, 1986; McKinion et al., 1989). This specific application of the scouting protocol does not exclude its use by commercial scouts, consultants, and Extension entomologists who wish to make recommendations independent of rbWHIMS. In this case, the scouting data obtained from the protocol may be standardized for decision-making using examples provided below and in Appendix I.

Management Unit

No sampling protocol is complete without a discussion of the management unit. A management unit (MU) is a specified area of land on which decisions are made and actions taken. The actions taken on this unit are carried out uniformly over this area and include such activities as tilling, planting, cultivating, fertilizing, irrigating, scouting, and applying chemicals for arthropod, weed, and disease control. In agriculture, it is customary but not necessarily correct to think of a "field" as a management unit. At times, it is appropriate to subdivide a field into several units or consolidate several fields into one management unit. The apportionment of a farm into management units is the primary responsibility of the farm manager, but others may influence this decision. This task has important implications on farm operations, including scouting and pest control.

The size, shape, and location of management units are important because these characteristics influence the ability to implement decisions and take actions in a cost-effective manner. Defining management units on a farm depends on the land-use patterns over the farm and the specific management objectives for each land area. For example, the primary objective of cotton production is to promote the uniform growth and development of the crop in a manner that maximizes yields and minimizes production inputs (and thus costs). In this context, the crop management unit should be easily accessed and worked and have similar soil type and topography. Farming activities carried out on this unit (e.g., cultivation, fertilization, irrigation, etc.) strive to promote uniform plant growth and development.

There are other objectives of crop management that place different constraints on the size and shape of the management unit. Arthropod pest management is an excellent example, with its primary objective to maintain pest populations below damaging levels in a cost-effective and environmentally sound manner. To minimize the potential impact of arthropod pests on the crop, pest population densities must be maintained at relatively low levels (e.g., below thresholds). To accomplish this task, the spatial and temporal patterns of pest population dynamics must be considered.

Some pest species are more common in certain fields or parts of fields year after year. The population of these species is initially clumped, with patches of higher densities dispersed in a field that otherwise has few individuals in it. These areas are referred to as "hotspots." The identification of "hotspots" provides an opportunity to evaluate and (if needed) treat populations before they become a more serious problem. As these

patches of higher density enlarge, often rapidly, they encroach on more land until the population occupies the entire field or several contiguous fields. Depending on the species, this situation may threaten crop production and should be avoided, or at least monitored very closely.

Given that pest population densities can change dramatically in time and space, the challenge of pest management is to hold populations in check while preserving natural control agents and crop yields. Sound management attempts to maximize the benefits of natural control agents without assuming undue risk of pest outbreaks. Natural control agents can be a formidable and cost-effective means of maintaining populations at low levels, but patience and restraint from insecticide use must be exhibited for them to work effectively. In general, insecticides should be used only as a last resort, authorized when potential production losses from no control outweigh the costs of control. Once insecticides have been applied, the likelihood of their recurrent use will increase because of disruption to the ecosystem.

A good scouting protocol provides the proper information, at an appropriate level of detail, keeping the farm manager well informed of the status of the cropping system through time. With this knowledge, the manager can weigh the risks of pest losses and better assess the need for direct control. Greater restraint from insecticide use should result. Systematic scouting provides the means to identify changes in pest location and abundance. To facilitate this process, we recommend uniform management units of 100 acres or less. Scouting on relatively small management units provides better knowledge on the status of the crop and associated pests, and this knowledge should lead to enhanced decision-making, reduced pesticide usage, and lower production costs, while conserving beneficial species and the environment.

Generalized Sampling Methods

Gathering quality information is not easy, especially if the sampling plan is designed to benefit multiple users with different objectives and operating constraints. The plan must be applicable to all pests that might occur over the course of the growing season. This is a difficult task, given the changes that occur in the growth and development of the crop and the pest associations. No single method will be equally effective under all situations. We therefore developed two basic sampling methods for collecting crop and pest information over the season.

Line-Intercept Sampling Method

The line-intercept method was adapted from forestry and wildlife biology (Kaiser, 1983). We recommend it for use in cotton early in the season when plants are small (PGS2-3). This method uses a reference baseline that runs along a cotton row (forming the long side of an imaginary rectangle), and a transect line that originates from a point on the baseline and runs across the rows (forming the short side of the rectangle). The rectangle is one acre in size (43,560 square feet), and this area forms the basic unit on which sample estimates are made. Samples are drawn from a fixed or variable length of row in each row along the transect line depending on the attribute being estimated (Willers et al., 1992, 1995).

Fixed Row-Length. A starting point for sampling is chosen at random in the management unit. This point represents the intersection of the baseline and the transect line. Sampling is conducted along the transect line, across consecutive rows. All plants are examined for the attributes of interest (e.g., plant, pests, and damage characteristics) in a fixed section of each row on the line. Typically, data are collected from 1- to 3-foot sections of row. The process of moving across rows gives this method its strength by capturing the variability in the crop caused by planting irregularities that occur among planter boxes. We recommend sampling all rows laid down by one to four consecutive planter passes. For each planter pass added to the transect line, the sample area is incremented by a quarter of an acre; thus, four passes define the maximum length of a transect line representing a sample area of one acre.

The exact number of rows sampled depends on the configuration of the planter (e.g., the number of planter boxes and row spacing). For example, one pass of an eight-row planter will yield a transect line of eight rows,

two passes will yield 16 rows, and so on. This process of sampling consecutive rows is repeated using four or more transect lines in the management unit. The precision of the estimate depends on the variability of the sample attribute in the field and the length and number of transect lines along which samples are taken. Estimates also vary slightly because of rounding errors and the number of significant digits used in the calculations.

Calculations. The length of the transect line and baseline must be known to calculate a per acre estimate of the sample attribute using the line-intercept method. The length of the transect line is determined by the planter configuration and the number of planter passes sampled. For example, this line is 101.33 feet if an eight-row planter is set to 38-inch row spacing and four planter passes are sampled (8 x 4 x 38 ÷ 12). By definition, four planter passes represent a transect line of one acre; therefore, the baseline length is 429.9 feet (43,560 ÷ 101.33).

We extend this example to estimate the number of cotton plants per acre. Plant counts from 3-foot sections of row over 32 rows are taken and comprise the series: 9, 6, 5, 10, …, 11, 7, 10, and 8. These numbers are summed across rows (e.g., 288) and multiplied by the baseline length of 429.9 feet (e.g., 123,811). This value is divided by the length of row examined (3 feet) to yield the number of plants per acre, in this case 41,270. To add precision to the estimate, the process is repeated along four or more transect lines in the field.

If fewer than four planter passes are used in the sample, adjustments in the calculations will provide estimates of plants in quarter-acre increments. In the example above, a transect line of eight rows represents a sample of one-quarter acre, 16 rows represent a sample of one-half acre, and 24 rows three-quarters of an acre. The final estimate can be converted easily to a per-acre basis. To simplify the calculations, scaling factors are provided for the common planter configurations and fixed row-lengths sampled (Table 2). Sample counts of specific attributes taken within a particular length of row are simply summed across all sampled rows and multiplied by the correct value to convert to an estimate per acre.

Variable Row-Length. Another powerful application of the line-intercept method involves the estimation of stand loss. Stand loss results from poor germination or seedling disease due to cool, wet weather early in the season or from cutworms that destroy sections of row. In either case, variable lengths of row are damaged, and if damage is widespread throughout the stand, all or part of the crop may require replanting. Stand loss can be estimated using the line-intercept method by measuring the lengths of damaged row (skip lengths) for all rows along multiple transect lines (Willers et al., 1992). This procedure is very similar to that described above, except the nature of the sample attribute (damaged row-length) requires observations of a variable row-length instead of a fixed row-length. We recommend measuring only damaged lengths of row that are 3 feet or greater encountered along the transect line. As remaining plants grow, they will close gaps of 3 feet or less (McCarty, 1989, 1991).

Calculations. The following data represent a typical series of 10 damaged row-lengths collected from a transect line of 32 rows established with an 8-row planter set at 38-inch spacing: 9.7, 8.5, 5.4, 3.1, 3.8, 8.0, 5.1, 8.2, 6.7, and 3.2 feet. To estimate the number of skips per acre, sum the reciprocals of these values (e.g., 0.10 + 0.12 + 0.19 + ... + 0.15 + 0.31), and multiply the sum (e.g., 1.9) by 429.9 -- the baseline of the rectangle that is also the scaling factor for 1 foot of row sampled along 32 rows for an 8-row planter set at 38-inch spacing (Table 2). In this example, there are 817 skips per acre. The average skip length is estimated by dividing the number of skips encountered along the transect line (e.g., 10) by the sum of the reciprocals (1.9), or an average of 5.26 feet per skip. Percent stand loss is derived by multiplying the average skip length (5.26) by the number of skips per acre (817). The product (4297) is then divided by the total linear feet per acre for the row spacing used (e.g., 13,756.8), and the quotient is multiplied by 100 to yield 31.2 stand loss. All measurements and calculations should be repeated along four or more transect lines in the management unit.

Quadrat Sampling Method

The quadrat sampling method is recommended for use during the mid-to-late season (PGS4-7). It uses a sampling unit called a quadrat (or stop), which is defined as two adjacent 9-foot sections of row randomly

located in the management unit. Five or more representative plants are selected alternately from the two rows of the quadrat, and they are examined for the attributes of interest. Three to seven quadrats are sampled per management unit. The range in quadrat number provides flexibility to handle all situations encountered in the field, but it also requires judgment on the part of the scout. With experience, scouts will develop an intuitive feel for the proper sampling intensity based on what they encounter in the field. For example, if no pests are found or many are found, the information from three quadrats may be enough to make sound decisions. If pest abundance is at intermediate levels, causing apprehension in the proper course of action, then information from seven quadrats may be required. Quadrats should be separated in the management unit by at least 150 feet and located no less than 100 feet from the edge of the field. The entire perimeter of the unit should be sampled over a 2-3 week period.

Calculations. The following example illustrates the calculations required to estimate the percentage of cotton plants infested with bollworm/budworm eggs. Similar steps apply to other arthropod life stages found on plants. Plant terminals (the five uppermost mainstem nodes) are inspected and the number containing eggs are counted. Plants with more than one egg are counted only once. For simplicity, five plants in each of five quadrats (stops) are sampled in the management unit. Visual counts of infested plants per number of plants inspected per stop are 1-in-5, 1-in-5, 0-in-5, 0-in-5, 1-in-5. To estimate the infestation rate of plants with eggs, the number of plants with eggs is divided by the total number of plants sampled (e.g., 3 ÷ 25). This calculation suggests that 12 of the plants are infested with eggs, and although this is a standard estimate applied in scouting, we feel that it can be improved upon. This estimate neglects the fact that two of the five stops in the unit have no eggs -- valuable information that can be used to improve the estimate of infested plants.

Bayesian statistical methods are being developed for use in rbWHIMS to adjust the estimates of sample attributes, such as the infestation rates of insect pests (Willers et al., 1990). This computational method requires a computer and cannot be easily calculated by hand. An easy method of calculation that approximates the Bayesian estimate applies the square root of the ratio: the number of quadrats with eggs divided by the total number of quadrats sampled. In our example, the value is 0.77 (square root of 3÷5). This proportion is multiplied by the proportion of infested plants (0.12) to yield an adjusted infestation rate of 9. The adjusted estimate is used in decision-making. Similar steps are followed for other attributes of interest.

Scouting Protocol

Dividing the crop into eight plant growth stages (PGS's) focuses attention on the arthropod pests that occur during a particular period of crop development (Table 1). These divisions should help scouts identify developing problems in a timely manner, whether they arise from common or occasional pests. A good scouting protocol provides the proper information, at an appropriate level of detail, needed to keep the decision-maker well informed on the status of the crop throughout the season. It standardizes the collection of data, allowing comparison among fields or farms within or between growing seasons.

The following sections organize the scouting protocol by plant growth stage. This protocol is summarized in Table 3.

PGS0 -- PREPLANT

General Information. Preplant encompasses the period from the end of one cropping season to the start of the next (Figure 1). Important farm activities during this time include an evaluation of the past season and planning for the coming season. Records kept for a number of years may be helpful in determining the locations of potential pests for each management unit. From the standpoint of scouting, this stage begins about 30 days before planting with the placement and early monitoring of pheromone traps.

General Sampling Protocol. During this time scouts should familiarize themselves with changes in farm

operations, e.g., crop rotations among fields. Pheromone traps for boll weevils, bollworms, and budworms should be placed around fields, and monitoring should begin prior to planting (Form 1).

Bollworm and Budworm Moths. Place pheromone traps at the edges of cotton fields as early as 30 days before planting (see Appendix II). No fewer than one trap should be distributed per species per farm. If possible, traps should be located near known problem areas. Count and record the number of moths captured per trap every 5-7 days. If traps are unavailable, obtain counts from the nearest source (e.g., local county agent).

Boll Weevils. Place pheromone traps at the edges of cotton fields at or slightly before planting (see Appendix II). One or more traps should be distributed per field, not to exceed one per 20 acres, adjacent to known problem areas. Count and record the number of captured weevils per trap every 5-7 days. If traps are unavailable, obtain counts from the nearest source (e.g., local county agent).

PGS1 -- PLANTING TO CROP EMERGENCE

General Information. This stage delineates the period from planting to crop emergence and lasts about eight days (Figure 2). Crop emergence is defined as that time when 50 of the plants have unfolded cotyledonary leaves. If crop emergence takes longer than 8 days, the crop may receive physiological and pathological injury. Plants of low vigor will have reduced growth and development, be exposed to pests longer, and be at greater risk of attack by pests.

General Sampling Protocol. Scouting activities are confined to checking the crop for emergence and monitoring pheromone traps around the field (Form 1).

Bollworm and Budworm Moths. Monitor pheromone traps every 5-7 days.

Boll Weevils. If pheromone traps have not been set out, do so immediately according to the instructions in PGS0; otherwise, monitor traps every 5-7 days.

PGS2 -- EMERGENCE TO THIRD TRUE LEAF

General Information. This growth stage extends from crop emergence to third true leaf and typically lasts about 21 days (Figure 3). Prominent pests (designated by an asterisk) are thrips and cutworms. Occasional pests are boll weevils, aphids, whiteflies, spider mites, plant bugs, and yellowstriped armyworms.

General Sampling Protocol. Use the line-intercept method to scout cotton (Form 2) and continue monitoring pheromone traps (Form 1). Unless the situation calls for an early return to the field, we recommend scouting on a 7-day routine schedule during this growth stage.

Stand. Record the date of crop emergence. Record the numbers of plants in 3-foot sections of row across consecutive rows established by one to four planter passes. Repeat the process along four or more transect lines. If germination is poor due to adverse weather or seedling diseases are prevalent, consider using the line-intercept method to determine the percent stand loss, and thus the need for replanting. Record the lengths of damaged rows without seedlings (skips) in excess of three feet across consecutive rows established by four planter passes along four transect lines.

Bollworm and Budworm Moths. Monitor pheromone traps every 5-7 days.

Boll Weevils. Monitor pheromone traps every 5-7 days. If plants with flags are observed, record the numbers of plants with terminal damage in 5-foot sections of row across consecutive rows along four transect lines. Weevil flags are identified as the terminal leaf dead or dying with the petiole cut.

***Early Season Thrips (Primarily Tobacco Thrips).** Record the numbers of adult and immature (pale green) thrips on all plants in 1-foot sections of row across consecutive rows established by at least one planter pass. Dislodge thrips from plants by gently striking the plants over a white paper, cloth, or cigar box. Record the

number of plants sampled in each row (even if no thrips are observed). Repeat the process on at least four transect lines in the management unit. Watch for other pests while sampling thrips; if observed, use the line-intercept method to sample these species.

***Cutworms (Black, Variegated, Granulate, Army, Pale-Sided).** If cutworm damage is observed, record the lengths (in inches) of damaged rows (skips) in excess of 3 feet across consecutive rows established by four planter passes along four transect lines. Record the numbers of cutworm larvae found in these skips. Larvae can be located beneath clods or trash within a 6-inch band along the drill in the damaged areas.

Aphids, Whiteflies, Spider Mites, Plant Bugs (Tarnished Plant Bugs, Cotton Fleahoppers). If any of these pests are observed, estimate their abundance using another set of four transect lines. For example, estimate and record the numbers of aphids, whiteflies, spider mites, and plant bugs found by visual inspection of all plants in 1- to 3-foot sections of row across consecutive rows established by at least one planter pass. Also note the presence or absence of a fungal disease on aphids, whiteflies, and mites. If spider mites are abundant in hotspots, locate their presence on a map of the management unit. If plant bugs are present, record the number of plants with terminal damage (flags) in an extended 5-foot section of row for each row along the transect lines. Plant bug flags are identified as the terminal leaf dead or dying with the petiole intact.

Yellowstriped Armyworms. While sampling other pests, examine seedlings for armyworm damage (e.g., holes in leaves). If damage is present, record the numbers of plants with armyworms in 1- to 3-foot sections of row across consecutive rows established by at least one planter pass along four transect lines.

PGS3 -- THIRD TRUE LEAF TO PINHEAD SQUARE

General Information. The stage from third true leaf to pinhead square lasts about 14 days (Figure 4). The crop is usually growing vigorously at this time, although plants are not yet producing squares. Generally, arthropod pests are not a problem, but when cotton is stunted, thrips and cutworms may persist. Occasional pests are plant bugs, bollworms, budworms, boll weevils, aphids, whiteflies, spider mites, and yellowstriped armyworms. In areas where weevils are common, the decision to spray at pinhead square must be made during PGS3.

General Sampling Protocol. Use the line-intercept method to take stand counts and a sweepnet or dropcloth to sample plant bugs, boll weevils, and beneficials. Watch for the presence of other pests while collecting these samples; and if you observe other pests, use the line-intercept method to scout more thoroughly (Form 3). Continue to monitor pheromone traps (Form 1)). Unless the situation calls for an earlier return to the field, scout on a 7-day schedule during this growth stage.

Stand. Use the line-intercept method described in PGS2 to take plant counts. Evaluate and record plant vigor and the number of days to pinhead square (if less than 10 days). Plants are considered vigorous if they are growing and are considered nonvigorous if they are stunted and not growing.

Bollworm/Budworm Eggs, Larvae, Moths. If you observe these pests, record the numbers of plants with eggs and larvae in the terminal from 1- to 3-foot sections of row across consecutive rows established by at least one planter pass along four transect lines. Monitor pheromone traps every 5-7 days.

Boll Weevils. Use the sampling methods described in PGS2. Also, record the numbers of weevils from the same sweepnet or dropcloth samples used for plant bugs.

Early Season Thrips (Primarily Tobacco Thrips). Thrips should no longer be a threat to the crop unless the cotton is stunted and not growing vigorously. If this condition exists, apply the sampling methods described in PGS2.

Cutworms (Black, Variegated, Granulate, Army, Pale-Sided). Cutworms should no longer be a threat to the crop unless the cotton is stunted and not growing vigorously. If this condition exists, apply the sampling methods described in PGS2.

Plant Bugs (Tarnished Plant Bugs, Cotton Fleahoppers). Plant bugs become a greater concern as the crop approaches pinhead square, and a watchful eye should be kept on their presence. They are monitored using one of the following methods:

1. Sweep 25 times along a row with a 15-inch net in at least four random locations (preferred method).
2. Use a 3-foot dropcloth in at least four random locations. Shake plants over the cloth and count the dislodged bugs. Care should be taken not to disturb bugs prior to shaking the plants. Nymphs are easily counted by this method, but adults may fly off prior to counting.

If needed, record the numbers of plants with terminal damage (flags) in 5-foot sections of row across consecutive rows established by at least one planter pass along four transect lines (same as P GS2).

Aphids, Spider Mites, Whiteflies. If these pests are observed during spot checks, use the sampling methods described in PGS2.

Yellowstriped Armyworms. Use the sampling methods described in PGS2.

Beneficials. Record the numbers of beneficials from the same sweepnet or dropcloth samples used for weevils and plant bugs. These counts include all arthropod predators and parasites that attack cotton pests; e.g., lacewings, lady beetles, assassin bugs, big-eyed bugs, minute pirate bugs, nabids, spiders, braconid and ichneumonid wasps, tachinid flies, and others (Head, 1988).

PGS4 -- PINHEAD SQUARE TO MATCHHEAD SQUARE

General Information. The period from pinhead square to matchhead square lasts about 7 days (Figure 5). Prominent pests are plant bugs, bollworms, budworms, and boll weevils. Occasional pests are aphids, whiteflies, and spider mites.

General Sampling Protocol. Cotton is becoming more attractive to insects because flower buds (squares) are beginning to appear. In response to this development, routine scouting is intensified from once a week to twice a week. The sampling method is changed because plants are increasing in size, making it difficult to examine all plants efficiently in a section of row as required by the line-intercept method. The quadrat method is now recommended for scouting cotton (Form 4). Continue using the sweepnet or dropcloth and monitor pheromone traps (Form 1).

Plants Checked for Pests. Select 5-10 plants from two adjacent 9-foot sections of row in each of 3-7 random locations(stops) per management unit. Unless otherwise stated, sample pests only on these plants using the directions below. Record the number of plants sampled in each stop. A plant is considered infested with a particular pest species when one (or more) individual is found on it.

***Bollworm/Budworm Eggs, Larvae, Moths.** Record the numbers of plants with eggs and larvae in the terminals of all selected plants in each of 3-7 stops. Monitor pheromone traps every 5-7 days.

***Boll Weevils.** Record the number of plants with terminal damage (flags) from all plants in the two adjacent 9-foot sections of row in each of 3-7 stops. Weevil flags are identified as the terminal leaf dead or dying with the petiole cut. Record the numbers of weevils from the same sweepnet or dropcloth samples used for plant bugs. Some sampling should be conducted in known weevil hotspots if possible. Monitor pheromone traps every 5-7 days.

***Plant Bugs (Tarnished & Clouded Plant Bugs, Cotton Fleahoppers, Stink Bugs).** While moving between stops, record the numbers of bugs from sweepnet or dropcloth samples as described in PGS3.

Aphids, Whiteflies. Examine the underside of the first fully expanded leaf in the terminal of all selected plants in each of 3-7 stops. Record the number of plants with leaves infested with each species and an estimate of the average number of insects found on the infested leaves. Note the presence or absence of a fungal disease

on each species.

Spider Mites. Examine the underside of the first fully expanded leaf on all selected plants in each of 3-7 stops, and record the number of plants with 25 or more mites on these leaves. Note the presence or absence of a fungal disease. If spider mites are abundant in hotspots, locate their presence on a map of the management unit.

Beneficials. Use the sampling methods described in PGS3.

Square Set. Record the total numbers of fruiting sites and squares on **five** selected plants in each of 3-7 stops (no less than 25 plants per management unit). These counts are used to determine percent square set and are essential in evaluating plant bugs.

Fruit Counts. After sampling pests, record the number of squares on all plants in one, 3-foot section of row from at least three stops. Fruit counts are used to determine the number of fruit per acre and to adjust damage estimates to this unit of measure (e.g., number of damaged squares per acre). These counts are very time consuming and, depending on variability, they may not be needed from all stops sampled for insects.

PGS5 -- MATCHHEAD SQUARE TO FIRST BLOOM

General Information. The period from matchhead square to first bloom lasts about 15 days (Figure 6). Cotton grows faster at this time than any other, and the reproductive rate is high. Prominent pests are plant bugs, bollworms, budworms, boll weevils. Occasional pests are aphids, whiteflies, spider mites, beet armyworms, and western flower thrips.

General Sampling Protocol. Use the quadrat method described in PGS4 (Form 5), the sweepnet or drop cloth, and continue to monitor pheromone traps (Form 1). Unless the situation calls for an earlier return to the field, scout twice a week during this growth stage. Record the last two spray dates and whether it has been unusually hot and dry over the last 2 weeks.

Plants Checked for Pests. Use the quadrat method described in PGS4 to select plants for sampling arthropod pests.

***Bollworm/Budworm Eggs, Larvae, Moths.** Use the sampling methods described in PGS4. Also, pull 5-10 green squares (3/8 inch diameter or larger) off the selected plants in each stop. Record the number of squares inspected and the number containing a larva. Note the relative average size of all larvae found, where:
1 = less than 1/4-inch long,
2 = 1/4 to 1/2-inch long,
3 = greater than 1/2-inch long.

***Boll Weevils.** Use the same squares that were examined for bollworms/budworms, and record the number containing a weevil oviposition puncture. While moving between stops, look for and examine weevil-punctured squares on the ground, and record whether you find pupae or teneral adults in these squares. Discontinue checking weevil pheromone traps until PGS7.

***Plant Bugs (Tarnished & Clouded Plant Bugs, Cotton Fleahoppers, Stink Bugs).** Use the sampling methods described in PGS4.

Aphids, Whiteflies. Use the sampling methods described in PGS4.

Spider Mites. Use the sampling methods described in PGS4.

Late-Season Thrips (Western Flower Thrips). Examine the underside of a mature leaf located in the lower third of all selected plants in each of 3-7 stops. Record the number of plants with infested leaves and an estimate of the average number of thrips found on the infested leaves.

Beet Armyworms. Sample beet armyworms only if serendipitous observation indicates their presence. While moving between stops, record the number of "hits" in 100 feet of row. A 'hit" is defined as an egg mass or group of small larvae on a plant. For practical purposes, a hit can be defined as a distinct area of skeletonized leaves on one or several adjacent plants.

Beneficials. Record the numbers of beneficials from the same sweepnet or dropcloth samples used for plant bugs.

Square Set. Record the total numbers of fruiting sites and squares **in the top five nodes of five** selected plants in each of 3-7 stops (no fewer than 25 plants per management unit).

Fruit Counts. Use the sampling methods described in PGS4.

PGS6 -- FIRST BLOOM TO CUTOUT

General Information. The period from first bloom to cutout is the longest plant growth stage, lasting about 50 days (Figure 7). The length of the stage depends on the variety of cotton grown and the weather. Unusually hot and dry conditions in late July and August will shorten the stage and make cutout more difficult to distinguish. As the stage progresses, boll loads increase and vegetative and reproductive growth decrease and eventually stop. Cutout reflects this process of diminished growth, and it is defined as a condition of the crop when 50 or more of the plants in a stand have white blooms at the fifth mainstem node from the top (Oosterhuis et al., 1993). Multiple pest species are commonly found in the field during this period. Prominent pests are bollworms, budworms, boll weevils, and aphids. Occasional pests are plant bugs and stink bugs, beet and fall armyworms, western flower thrips, whiteflies, loopers, and spider mites. In recent years, tarnished plant bug has become more prominent late in the season.

General Sampling Protocol. The quadrat method is used in scouting cotton as described in PGS4 (Form 6). Visual or dropcloth samples are taken and pheromone traps are monitored (Form 1). Sweepnets are no longer used because of the increased size of the plant canopy. Unless the situation calls for an earlier return to the field, scout twice a week during this growth stage. Record the last two spray dates, whether you find open bolls in the stand, and whether it has been unusually hot and dry over the last 3 weeks.

Plants Checked for Pests. Use the quadrat method described in PGS4 to select plants for sampling arthropod pests.

***Bollworm/Budworm Eggs, Larvae, Moths.** Record the numbers of plants with eggs and larvae in the terminals of all selected plants in each of 3-7 stops. If the weather is extremely hot, also check lower portions of the plants including stems, bloom tags, and fruit bracts for eggs and larvae. Pull 5-10 green squares (3/8-inch diameter or larger) off the selected plants in each stop. Record the number of squares inspected and the number containing a larva. Examine (but do not remove) 5-10 green bolls from the selected plants in each stop. Record the number of bolls inspected and the number containing a larva. Note the relative average size of larvae in squares and bolls (sizes given in PGS5). Monitor pheromone traps every 5-7 days.

***Boll Weevils.** Use the same squares and bolls that you examined for bollworms/budworms, and record the number of each containing a weevil oviposition puncture. While moving between stops, look for and examine weevil-punctured squares on the ground, and record whether you find pupae or teneral adults in these squares. Also, check white blooms for weevils.

Stink and Plant Bugs (Several Species of Stink Bugs, Clouded and Tarnished Plant Bugs). Use the same squares and bolls examined for bollworms/budworms and weevils, and record the number containing plant bug damage. Damaged squares are identified by blackened anthers, and damaged bolls contain characteristic necrotic areas. Record the number of plants with stink bugs and clouded plant bugs on all selected plants in each of 3-7 stops. While moving between stops, record the number of tarnished plant bugs you observe along 25 feet of row or use a 3-foot dropcloth in at least four random locations as described in PGS3.

***Aphids, Whiteflies.** Use the sampling methods described in PGS4. If open bolls are present, record whether the lint is at risk of damage from honeydew.

Spider Mites. Use the sampling methods described in PGS4. **Late-Season Thrips (Western Flower Thrips).** Use the sampling methods described in PGS5.

Beet Armyworms. Use the sampling methods described in PGS5. Also, record whether larvae are feeding on fruit.

Fall Armyworms. Because this insect is difficult to detect and occurs only sporadically in cotton, superficial scouting is probably all that is needed until you find fall armyworms in the field. While moving between stops, examine the same white blooms used for boll weevils. If you find small larvae in blooms, intensify scouting by examining bolls in stops. Use the same bolls examined for bollworms/budworms, weevils and bugs, and record the number containing an armyworm. Sample additional bolls if needed. Fall armyworms often feed on bracts before boring into the base of bolls. Once in the boll, the larvae are extremely difficult to control.

Beneficials. Record the numbers of beneficials from the same visual or dropcloth samples used for tarnished plant bugs.

Fruit Counts. After sampling pests, record the numbers of squares and bolls on all plants in one 3-foot section of row from at least three stops. Fruit counts are very time consuming and, depending on the variability, they may not be needed from all the stops sampled for insects.

PGS7 -- CUTOUT TO DEFOLIATION

General Information. The period from cutout to defoliation lasts 45 days or more (Figure 8). As bolls mature in this final stage of plant development, they become less susceptible to insect damage and loss. Prominent pests are bollworms, budworms, and boll weevils. Occasional pests are aphids, plant and stink bugs, beet and fall armyworms, whiteflies, spider mites, and loopers.

General Sampling Protocol. In-field scouting becomes progressively more difficult during this stage because of plant size and lodging. The quadrat method (Form 7) should be used as long as possible while the plants are green. Pheromone traps should be monitored every 5-7 days (Form 1). Unless the situation calls for an earlier return to the field, scout every seven days. Record the last two spray dates, and estimate the number of days to defoliation (if less than 20 days).

Plants Checked For Pests. Use the quadrat method described in PGS4 to select plants for sampling arthropod pests.

***Bollworm and Budworm Eggs, Larvae, Moths.** Record the number of plants with larvae in the terminals of all selected plants in each of 3-7 stops. Examine, but do not remove, 5-10 green bolls (less than 2-cm diameter) from the selected plants in each stop. Record the number of bolls inspected, the number containing a larva, and the relative average size of all larvae found (defined in PGS5). Monitor pheromone traps every 5-7 days.

***Boll Weevils.** Use the same bolls examined for bollworms/budworms, and record the number containing a weevil oviposition puncture. Farmers who desire diapause control treatments may want to reset and begin monitoring pheromone traps.

Stink and Plant Bugs (Several Species of Stink Bugs, Clouded and Tarnished Plant Bugs). Use the sampling methods described in PGS6, but examine only bolls for damage.

Aphids, Whiteflies. Use the sampling methods described in PGS6.

Spider Mites. Use the sampling methods described in PGS4.

Beet Armyworms. Use the sampling methods described in PGS6.

Fall Armyworms. Use the sampling methods described in PGS6.

Beneficials. Use the sampling methods described in PGS6.

Fruit Counts. After sampling pests, record the number of bolls on all plants in one 3-foot section of row from at least three stops. Fruit counts are very time consuming and, depending on the variability, they may not be needed from all the stops sampled for insects.

PGS8 -- DEFOLIATION TO HARVEST

General Information. The period from defoliation to harvest generally runs from late September through October in the Midsouth (Figure 9). Scouting activities are finished by this stage. If you have initiated boll weevil diapause treatments, continue to check pheromone traps until stalk destruction. Otherwise, remove pheromone traps as time permits.

Conclusions

The sampling methods proposed in this protocol have been developed in cotton over the last 7 years, and in this time, they have been well tested in the field. The methods are applicable for sampling multiple pest species and numerous crop attributes over the duration of the cropping season, and they use sound data collection and statistical techniques.

Like all new methods, however, the use of this protocol will require change among those who apply it. For this reason, there will be some who judge it with skepticism. Similarly, widespread use of the protocol will bring refinement to the described procedures. We believe these changes will be for the good of all. The protocol strives to provide quality data, from relatively small sample sizes, on which to make decisions. It standardizes the collection of data, which will allow the direct comparison of data collected elsewhere. It is flexible enough to allow customization without the loss of statistical integrity. For example, any number of crop or pest attributes can be added to the sample during any plant growth stage, although we advise against deleting those already in the protocol. These modifications can be made by simply penciling in the appropriate labels and information on the data forms.

References Cited

Baker, D.N., J.R. Lambert, and J.M. McKinion. 1983. GOSSYM: A simulator of cotton crop growth and yield. S.C. Agric. Exp. Stn. Tech. Bull. 1089.

Elsner, J.E., C.W. Smith, and D.F. Owen. 1979. Uniform stage descriptions in upland cotton. Crop Sci. 19: 361-363.

Head, R.B. 1988. Cotton insect identification guide. Miss. Coop. Ext. Serv. Publ. 1640. Kaiser, L. 1983. Unbiased estimation in line-intercept sampling. Biometrics 39: 965-976.

Lemmon, H.E. 1986. COMAX: An expert system for cotton crop management. Science 233: 29-33.

Mauney, J.R., and J.M. Stewart (eds.). 1986. Cotton Physiology. Cotton Foundation Ref. Book Series No. 1. Cotton Foundation Publ., Memphis, TN. 786 pp.

McCarty, W. 1989. Mississippi cotton crop running late. Delta Farm Press, Friday, May 26. p. 8.

McCarty, W. 1991. Cotton situation goes from serious to critical. Delta Farm Press, Friday, May 26. p. 9.

McKinion, J.M., D.N. Baker, F.D. Whisler, and J.R. Lambert. 1989. Application of the GOSSYM/COMAX system to cotton crop management. Agric. Systems 31: 55-65.

Oosterhuis, D.M, F.M Bourland, N.P. Tugwell, and M.J. Cochran. 1993. Terminology and concepts related to crop monitoring, maturity and defoliation. Ark. Agric. Exp. Stn. Spec. Rep. 162: 239-249.

Wagner, T.L., M.R. Williams, J.L. Willers, D.C. Akins, R.L. Olson, and J.M. McKinion. 1995. Knowledge-base of rbWHIMS: An expert system for managing cotton arthropod pests in the Midsouth. Miss. Agric. For. Exp. Stn. Tech. Bull. 205.

Willers, J.L., R.L. Olson, M.R. Williams, and T.L. Wagner. 1990. Developing a Bayesian approach for estimating the proportion of cotton plants at risk to insect attack. Proc. Beltwide Cotton Conf., Natl. Cotton Council Am., Memphis, TN. pp. 246-247.

Willers, J.L., S.R. Yatham, M.R. Williams, and D.C. Akins. 1992. Utilization of the line-intercept method to estimate the coverage, density, and average length of row skips in cotton and other row crops. Proc. Applied Stat. Agric., Kansas State Univ., Manhattan.

Willers, J.L., R.A. Sequiera, T.L. Wagner, and M.R. Williams. 19995. A line-intercept sampling protocol for use in row cops. J. Agric. Biol. Environ. Stat. (submitted).

Williams, M.R., T.L. Wagner, J.L. Willers, and R.L. Olson. 1991. Scouting protocol for arthropod pests of cotton in the Midsouth. Miss. Agric. For. Exp. Stn. Bull. 977.

Williams, M.R., T.L. Wagner, J.L. Willers, and R.L. Olson. 1992. Plant growth stages for cotton. Proc. Beltwide Cotton Conf., Natl. Cotton Council Am., Memphis, TN. 2: 614-616.

Glossary

Bayesian -- a statistical approach that features the ability to take into account, or describe, subjective (personal) belief during the making of management decisions.

Beneficials -- parasites and predators that feed on cotton pests. rbWHIMS categorizes their relative abundance as low (>10 per 100 row feet of cotton), medium (10-20 per 100 row feet), and high (%20).

Boll -- developing cotton ovary (and associated tissues) after anthesis (flowering).

COMAX -- Cotton **MA**nagement e**X**pert system used with GOSSYM.

Cutout -- a condition of a cotton crop when 50% or more of the plants in a stand have white blooms at the fifth mainstem node from the top, typically signalling the end of the growing season.

Flagging -- plants with terminal leaf dead or dying from cut petiole (boll weevil) or intact but damaged petiole (plant bugs).

GOSSYM -- simulation model describing growth and development of the cotton plant (see COMAX).

Hit-- a beet armyworm egg mass or group of small larvae on a plant.

Hotspot -- a localized area in a field in which a pest is found at higher than normal densities.

Line-Intercept Sampling Method -- a sampling method used to scout cotton during PGS2-3, based on the examination of all plants in a fixed length of row along transect lines that run across consecutive rows or the measurement of variable lengths of damaged row along similar transect lines.

Mainstem Terminal -- apical portion of the mainstem shoot along with its associated leaves, flower buds, and lateral shoots. By convention, we define the mainstem terminal as the top five fruiting nodes. This region varies in size depending on plant maturity and growing conditions. For example, prior to the onset of fruiting (occurring at the end of PGS3), the terminal represents the entire plant with the exception of the cotyledonary leaves. The terminal stops growing late in the season (PGS7), and therefore is very short and compact.

MU-- see management unit.

Management Unit -- a homogeneous unit of cotton on which (pest) management decisions are made, independent of surrounding units.

Matchhead Square -- flower bud measuring 2-4 mm diameter, excluding bracts or a condition of a cotton crop when a matchhead square first appears on 50% of the plants in a stand.

PGS -- plant growth stages that include PGS0 -- preplant, PGS1 -- planting to crop emergence, PGS2 -- emergence to third true leaf, PGS3 -- third true leaf to pinhead square, PGS4 -- pinhead to match-head square, PGS5 -- match-head square to first bloom, PSG6 -- first bloom to cutout, PGS7 -- cutout to defoliation, and PGS8 -- defoliation to harvest. All crop phenology events in rbWHIMS occur when 50% of the plants exhibit the noted characteristic.

Pinhead Square -- a flower bud measuring <2 mm diameter ((excluding bracts), or a condition of a cotton crop when a pinhead square first appears on 50% of the plants in a stand.

Quadrat -- the basic sampling unit of the quadrat sampling method, defined as two adjacent 9-foot sections of row randomly selected in a management unit. Used to scout cotton during PGS4-7.

Quadrat Sampling Method -- a sampling method used to scout cotton during PGS4-7, based on the selection of 5-10 plants in quadrats (stops) measuring two adjacent rows by 99 feet long. Three to seven quadrats are sampled per management unit.

rbWHIMS -- rule-based (W)Holistic Insect Management expert System.

Reciprocal -- the quotient obtained by dividing unity (one) by the number of interest; e.g., 1 divided by x is the reciprocal of x.

Skip -- missing plants within a row length longer than 3 feet.

Square -- flower bud of cotton (see match-head and pinhead square).

Stop -- see quadrat.

Teneral Adult -- an adult immediately after eclosion, characterized by soft cuticle and immature coloration.

Terminal -- apical portion of the mainstem or lateral shoots. Unless otherwise stated, all references to terminal in this document refer to the mainstem terminal.

Transect Line -- a sampling path that cuts across a designated number of consecutive rows as part of the line-intercept sampling method used to scout cotton during PGS2-3.

APPENDIX I

Standardization of Data

Scouting data derived from field counts need to be converted to a standard measure for decision-making (e.g., number per area). Three examples are provided to convert raw data to numbers per acre. A fourth example

determines the percent square set on plants. All conversions are performed by rbWHIMS if using the expert system in pest management decision-making.

Example 1: Convert square counts obtained from 3-foot sections of row at four random locations per management unit to number per acre (PGS4-6). Assume the crop was planted with an 8-row planter set to 38-inch row spacing:

1. Count the number of squares on all plants in the 3-foot sections of row from four stops.
2. Sum the squares across the four stops.
3. Multiply the sum (from step 2) by 1,146.4 to convert to squares per acre. Although the square counts are obtained from random locations (stops) using the quadrat sampling method, the four 3-foot sections of row can be thought of as four consecutive rows taken along a transect line. Table 2 can therefore be used to derive the correct scaling factor to convert to squares per acre. For example, the value 573.2 is obtained from Table 2 (under 3 feet of row sampled across eight consecutive rows in a stand planted at 38-inch row spacing with an 8-row planter). This value is multiplied by 2 to adjust for the number of rows sampled (from eight to four). The product is 1,146.4.

1.

Example 2: Convert insect, square, or boll counts in any length of row to the number per acre:

1. Count the number of insects in X-row feet.
2. Divide the number of insects by the number of row feet sampled.
3. Multiply the quotient (from step 2) by the number of linear feet per acre to convert to insects per acre. The number of linear feet per acre is determined by the row spacing. For example, there are 43,560 square feet per acre; therefore, 38-inch rows will have 13,756 linear feet per acre [43,560 ÷ (38÷12)] and 40-inch rows will have 13,068 linear feet per acre.

1.

Example 3: Convert insect, square, or boll counts on a given number of plants (not drawn from quadrats) to number per acre:

1. Count the number of insects on X-number of plants.
2. Divide the number of insects by the number of plants.
3. Multiply the quotient (from step 2) by the number of plants per acre to convert to insects per acre.

Example 4: Determine the percent square set on plants (PGS4-5, plant bugs):

1. Count the number of first- and second-position fruiting sites (those closest to the mainstem) in the top five fruiting nodes on five plants in each of five random locations per management unit. Count all sites on plants with fewer than five fruiting nodes.
2. Count the number of squares associated with the sites examined.
3. Sum the number of sites and the number of squares across the five stops.
4. Divide the total number of squares by the total number of sites and multiply by 100 to convert to percent square set.

APPENDIX II

Placement and Mainentance of Pheromone Traps

The proper placement of pheromone traps is critical to obtaining useful information. The following are some simple guidelines for establishing and maintaining traps:

1. Set traps away from areas which will obstruct farm equipment or interfere with field operations.
2. Set traps in areas where air flow is not obstructed. Traps should not be placed under trees, behind hedgerows, or under high voltage power lines.
3. Bollworm and budworm traps must be at least 50 yards apart. The Virelure and Zealure are similar in chemical composition, and cross contamination may occur. DO NOT HANDLE both baits at the same time.
4. Bollworm and budworm traps should be placed so that the bait is about 40 inches above the ground.
5. Count insects in traps every 5-7 days. Empty traps but do not release captured insects back into the field.
6. Re-bait traps according to the instructions on the pheromone package, usually every 2 weeks.
7. Traps not capturing insects over a 5-6 week period should be relocated, especially if other traps are capturing insects.
8. Keep vegetation away from traps.

APPENDIX III

Scouting Forms

Guidelines for Using Forms

Do not use the forms until the general and specific sampling techniques are understood for each plant growth stage and pest. The instructions describing the use of the scouting forms do not supersede those of the scouting protocol described above. Because the protocol was designed for use with rbWHIMS, the appearance of the scouting forms is very similar to the windows interface of WHIMS. This consistency provides ease of data entry into the computer system.

General Instructions

Use one form per management unit on each scouting date. Comments can be recorded on the back side of each form. Forms should be retained in a loose-leaf notebook, organized by management unit, scout, or PGS (whichever is most convenient). We have found it useful to place the most recent forms at the front of the notebook. Pheromone trapping data (Form 1) should be kept together in a separate location from the other scouting data (Forms 2-7). These records become valuable tools as they accrue over the years.

Form 1

Pheromone traps are used to monitor boll weevils every 5-7 days in PGS0-4. Farmers who desire diapause control treatments may want to reset these traps in PGS7. Bollworm and budworm moths are monitored using traps during all plant growth stages. The insect count from each trap is recorded in the appropriate cell on Form 1. When the pheromone dispenser is replaced, check the cell in the column labeled **BAIT**.

Form 2

The sampling attributes examined during PGS2 are listed at the top of Form 2. Each attribute is represented by an abbreviation. For example, **A1** represents the number of aphids estimated on all plants in 1-3 foot (fixed-length) sections of row for each row of transect lines. All data associated with an attribute are entered in the cells of a chosen column. To record the estimate of aphids in each row of a transect(s), simply enter **A1** in any cell of the row labeled **ATTRIBUTE**. Enter the length of row examined (in inches) in the cell below (associated with the row labeled **FIX LGTH or "V"**). In the same column, enter the total number of rows sampled along all transect lines (associated with the row labeled **ROWS SMPLD**). Lastly, enter the aphid counts in the cells associated with consecutively numbered rows of all transect lines. If the number exceeds 32, use an adjacent column(s) to record the remaining data for the attribute. It is not necessary to record a zero (0) when the sample attribute is not observed in a particular row. If the sample attribute involves thrips, enter the number of plants checked (**T1**) in each row even if you do not observe thrips. If the sample attribute is skip length (e.g., **C1** for cutworms and **S2** for stand), enter **V** in the appropriate cell of the row labeled **FIX LGTH or "V."** Record the crop emergence date at the bottom of the form.

With few exceptions, the protocol and its associated data forms describe only the sampling attributes used in rbWHIMS. Other information of interest to the scout can be collected and recorded with relative ease. For example, consider recording the number of live weevils on all plants examined in 1- to 3-foot sections of row across consecutive rows established by at least one planter pass along four transect lines. To record this information, simply choose a column on Form 2, identify the attribute with an appropriate abbreviation (e.g., BW2), and record the counts as described above.

Form 3

This form is very similar to Form 2 in design and use. It uses line-intercept sampling as the primary method of collecting and recording data; however, unlike Form 2, data are also recorded from sweepnet or dropcloth samples during PGS3. Record the numbers of beneficials, plant bugs, and boll weevils in the same sets of sweepnet or dropcloth samples. Also record the total number of row-feet checked using the chosen method in each of four or more locations in the management unit. You must enter the number of row-feet checked even if you do not observe any. Record whether plants are stunted and the number of days to pinhead square at the bottom of the form.

You can record information on other attributes besides those listed on this form. For example, if you observe bollworms and budworms, consider sampling and recording the number of damaged terminals with no larvae from 1- to 3-foot sections of row across consecutive rows of four transect lines. Plant bugs can also be counted from fixed row-lengths using the same procedures described above.

Form 4

Beginning with PGS4, the design of the scouting forms changes to accommodate the quadrat sampling method. In general, data are collected from 5-10 plants along two adjacent 9-foot sections of row in each of 3-7 random locations (stops) in the management unit. All data are arranged on the forms in columns associated

with each stop. For example, the number of plants examined for pests in the first stop is recorded in the first (top) cell of the first blank column. Fruit counts are recorded in the last cell because this information is collected last, after all other information associated with the stop. Information from sweepnet or dropcloth samples is recorded on the far right-hand column, just as on Form 3. It is not necessary to record zeros (0) when sample attributes are not observed.

The form has several blank rows for recording data on attributes not listed. For example, if you observe bollworms and budworms, consider sampling and recording the number of plants with terminal damage but no larvae from all selected plants in each of 3-7 stops.

Form 5

This form is very similar to Form 4 in design and use. Other than the number of attributes examined, the only difference occurs at the bottom of the form. The one boll weevil and two beet armyworm attributes listed at the bottom have columns offset from those associated with each stop, serving to indicate a change in sampling. For example, data on these attributes are collecting while moving between stops; thus, typically there will be one less or one more sample for these attributes relative to the number of stops. Record whether it has been hot and dry and the last two spray dates at the bottom of the form.

As before, information on other unlisted attributes can be recorded along the blank rows provided on the form. For example, of the 5-10 green squares removed from the selected plants in each stop, consider sampling and recording the number that are damaged by bollworms/budworm larvae, but have no worms present.

Form 6

More data are collected during PGS6 than in any other growth stage. As a result, Form 6 has more attributes than the other scouting forms. It is very similar to Form 5 functionally, with one noteworthy exception -- sweepnets are no longer used because of the increased size of the plant canopy. Instead, plants along 25 feet of row are visually inspected for tarnished plant bugs and beneficials while moving between stops. Record whether it has been hot and dry, the last two spray dates, and whether open bolls are present at the bottom of the form.

Although the number of square and bolls is not required in rbWHIMS, consider recording the number (of the 5-10 inspected from the selected plants in each stop) that are damaged by, but no longer contain, bollworms/budworm larvae. Sample loopers if serendipitous observation indicates their presence. Record the number of plants with loopers on leaves throughout the canopy of all selected plants in each of 3-7 stops.

Form 7

The design and use of Form 7 is the same as the previous form. Record the last two spray dates and the number of days to defoliation at the bottom of the form. Record the number of plants that have been defoliated by loopers if they are present in cotton. Estimate percent defoliation of plants and the size of area (acreage) infested.

Table 1. Prominent and occasional arthropod pests of cotton in the Midsouth by plant growth stage.

PLANT GROWTH STAGE	PROMINENT PESTS	OCCASIONAL PESTS

PGS0 -- preplant	none	none
PGS1 -- planting to emergence	none	none
PGS2 -- emergence to third true leaf	thrips, cutworms	boll weevils, plant bugs, aphids, yellowstriped armyworms, whiteflies, spider mites
PGS3 -- third true leaf to pinhead square	none	boll weevils, bollworms/budworms, cutworms, thrips, aphids, whiteflies, plant bugs, yellowstriped armyworms, spider mites
PGS4 -- pinhead square to matchhead square	boll weevils, bollworms/budworms, plant bugs	aphids, whiteflies, spider mites
PGS5 -- matchhead square to first bloom	boll weevils, bollworms/budworms, plant bugs	aphids, whiteflies, spider mites, beet armyworms, western flower thrips
PGS6 -- first bloom to cutout	boll weevils, bollworms/budworms, aphids	plant & stink bugs, beet & fall armyworms, western flower thrips, whiteflies, spider mites, loopers
PGS7 -- cutout to defoliation	boll weevils, bollworms/budworms	aphids, plant & stink bugs, beet & fall armyworms, whiteflies, spider mites, loopers
PGS8 -- defoliation to harvest	none	none

Table 2. Scaling factors for common planting patterns, number of rows sampled, and length of row sampled used to convert field counts to estimates per acre applying line-intercept sampling.

	40-Inch Row Spacing / 8 Row Planter / Planted Solid			
Length of Row Sampled	**8 Rows Sampled**	**16 Rows Sampled**	**24 Rows Sampled**	**32 Rows Sampled**
1 Foot	1,633.5	816.6	544.5	408.4*
3 Feet	544.5	272.3	181.5	136.1
5 Feet	326.7	163.3	108.9	81.7
	40-Inch Row Spacing / 6 Row Planter / Planted Solid			
Length of Row Sampled	**8 Rows Sampled**	**12 Rows Sampled**	**18 Rows Sampled**	**24 Rows Sampled**
1 Foot	2,178.0	1,089.0	726.0	544.5*
3 Feet	726.0	363.0	242.0	181.5
5 Feet	435.6	217.8	145.2	108.9
	38-Inch Row Spacing / 8 Row Planter / Planted Solid			
Length of Row Sampled	**8 Rows Sampled**	**16 Rows Sampled**	**24 Rows Sampled**	**32 Rows Sampled**
1 Foot	1,719.5	859.7	573.2	429.9*

3 Feet	573.2	286.6	191.1	143.3
5 Feet	343.9	171.9	114.6	86.0
	38-Inch Row Spacing / 6 Row Planter / Planted Solid			
Length of Row Sampled	**6 Rows Sampled**	**12 Rows Sampled**	**18 Rows Sampled**	**24 Rows Sampled**
1 Foot	2,292.6	1,146.3	764.2	573.2*
3 Feet	764.2	382.1	254.7	191.1
5 Feet	458.5	229.3	152.8	114.6
	30-Inch Row Spacing / 10 Row Planter / Planted Solid			
Length of Row Sampled	**10 Rows Sampled**	**20 Rows Sampled**	**30 Rows Sampled**	**40 Rows Sampled**
1 Foot	1,742.4	871.2	580.8	435.6*
3 Feet	580.8	290.4	193.6	145.2
5 Feet	348.5	174.2	116.2	87.1
	30-Inch Row Spacing / 10 Row Planter / 50 Inch Center Skip			
Length of Row Sampled	**10 Rows Sampled**	**20 Rows Sampled**	**30 Rows Sampled**	**40 Rows Sampled**
1 Foot	1,633.5	816.8	544.5	408.4*
3 Feet	544.5	272.3	181.5	136.1
5 Feet	326.7	163.4	108.9	81.7

*Scaling factors for one foot of row sampled across four planter passes equal the baseline length.

Table 3. General sampling protocol by plant growth stage.

PLANT GROWTH STAGE	SAMPLING PROTOCOL
PGS0 -- preplant	Set out pheromone traps & begin monitoring.
PGS1 -- planting to emergence	Monitor pheromone traps.
PGS2 -- emergence to third true leaf	Count thrips by gently striking all plants in 1-foot sections of row across consecutive rows along a transect line established by at least one planter pass (line-intercept sampling method). Collect data from at least 4 transect lines in each MU. If you observe other pests, count and record them from all plants in 1-3 foot sections of row from another set of 4 transect lines. Also count plants in 3-foot sections of row across consecutive rows along four transect lines. Monitor pheromone traps.
PGS3 -- third true leaf to pinhead square	Examine all plants in 1-3 foot sections of row along transect lines as in PGS2. Sweep 25 times at 4 locations in the MU. Monitor pheromone traps.
PGS4 -- pinhead square to matchhead square	Examine 5-10 plants for insects from two adjacent 9-foot sections of row in each of 3-7 random locations (stops) in the MU (quadrat sampling method). Count the total number of squares and fruiting sites on 5 sampled plants per stop. Sweep 25 times along 4 sections of row. Monitor pheromone traps.

PGS5 -- matchhead square to first bloom	Use quadrat sampling method described in PGS4. Examine 5-10 green squares for insects and damage from the selected plants in each stop. Count the total number of squares and fruiting sites in the top 5 nodes of 5 selected plants. Sweep 25 times along 4 sections of row. Monitor pheromone traps.
PGS6 -- bloom to cutout	Use quadrat sampling method described in PGS4. Examine 5-10 green squares and 5-10 green bolls from the selected plants in each stop. Monitor pheromone traps.
PGS7 -- cutout to defoliation	Use quadrat sampling method described in PGS4. Examine 5-10 green bolls from the selected plants in each stop. Monitor pheromone traps.