USING COTMAN™ TO DETERMINE YIELD LOSSES DUE TO THE ROOT-KNOT NEMATODE IN COTTON GROWN IN NORTHEAST ARKANSAS

N. Ray Benson, Terry L. Kirkpatrick, and Fred M. Bourland[1]

RESEARCH PROBLEM

Recent surveys have suggested the frequency of root-knot nematode- (*Meloidogyne incognita*) infested fields is increasing in cotton-growing counties of Arkansas (Kirkpatrick *et al.*, 1992; Bateman and Kirkpatrick, 2000). Although cotton yields often are suppressed as a result of *M. incognita* infestations, cotton continues to be the major row crop produced in northeast Arkansas. Landowner preferences and commodity prices have forced producers in this area to abandon crop rotation strategies that could help reduce the effects of *M. incognita* on cotton yield. In order to maintain profitable production, accurately quantifying crop loss due to root-knot and identifying effective and economically feasible control measures are required.

BACKGROUND INFORMATION

Recently, both increased rates and multiple applications of Temik® (aldicarb) have been shown to improve yield of cotton grown in fields infested with *M. incognita*. Benson *et al.* (1994) showed positive yield responses when Temik was applied in-furrow at planting. Temik rates used in this study ranged from 3.5 to 7.0 lb/acre. Although initial root-knot nematode populations ranged from 106 to 280/500 cm^3 soil, yields resulting from the varying nematode populations were not analyzed. Studies in southwest Georgia resulted in no significant yield increases from nematicides when nematode populations varied across the test site (McGriff *et al.*, 1997). These data suggest a "lower-end" threshold should be defined. Lorenz *et al.* (1999) indicated that yields were significantly increased above that of untreated plots when Temik was applied at planting (5.0 lb/acre) followed by an additional 5.0 lb/acre sidedressed at pinhead square. Temik applied at these rates would exceed $30.00 per acre, and may not be cost effective in low or moderate *M. incognita* infestations.

---

[1] Research Associate, Northeast Research and Extension Center, Keiser; Plant Pathologist, Southwest Research and Extension Center, Hope; and Plant Breeder, Northeast Research and Extension Center, Keiser.

Economic threshold levels for root-knot have been established for cotton and are used by the Arkansas Nematode Diagnostic Laboratory in making recommendations to growers relative to the risk of nematode-induced crop loss. Unfortunately, these thresholds are very conservative, and the research that was used to establish threshold levels was conducted 15-20 years ago, often in other states, and using cotton cultivars that are no longer popular with growers. There is no recent data indicating the relationship between nematode population densities and crop performance. Plant monitoring using COTMAN provides a mechanism to quantify the effects of varying population densities of *M. incognita* on cotton growth, development, and yield. COTMAN monitoring has allowed early detection of plant stress (Benson *et al.*, 1999; Teague *et al.*, 1999). Monitoring growth and development of cotton has shown that early-season stress and premature cutout (NAWF = 5) are likely results of *M. incognita* infestations (Kirkpatrick *et al.*, 1996; Wheeler *et al.*, 1996). Quantification of nematode effects on the crop across a range of population densities may allow currently used threshold levels to be modified so that they are more economically useful to growers in determining the need for nematicides on an individual field basis.

MATERIALS AND METHODS

Cotton (*Gossypium hirsutum L.* cv. Paymaster 1218BGRR) was planted on 8 May 2000 in a northeast Arkansas field with a history of high levels of root-knot nematodes. Treatments included: Temik 15G applied in-furrow at planting (5 lb product/acre); a side-dress application of Temik 15G (5 lb product/acre) applied at approximately first square; Temik 15G applied in-furrow at planting (5 lb product/acre) followed by a side dressed application (5 lb product/acre) at approximately first square; and a control receiving no Temik 15G. To help insure adequate early-season insect control, all plots were planted with Gaucho-treated seed. Prior to squaring, soil samples were collected from each plot and analyzed for root-knot nematode populations. Height-to-node ratio measurements were collected from each plot at approximately the third true-leaf state. Weekly COTMAN measurements, as described by Tugwell *et al.* (1998), were collected from each plot beginning at approximately first square. COTMAN data were collected until all plots had reached cutout (NAWF = 5). Production practices, including irrigation, fertilization, insect and weed control, and defoliation, were consistent across all plots. Four rows from each plot were machine harvested on 18 October 2000. A second soil sample was collected from each plot just following harvest to determine final root-knot nematode numbers.

RESULTS

Low numbers of root-knot nematodes were found across all plots at the first sample. Samples collected following harvest, however, indicated a relatively high root-knot nematode population (Table 1). Final root-knot nematode population densities tended to be higher in control plots where no Temik 15G had been applied, but numbers were not significantly different (P=0.05) among treatments. Cotton yield was numerically, but not significantly, higher following in-furrow application of Temik 15G in plots either with or without an additional sidedress application than where sidedress treatment alone was used. All Temik 15G treatments were higher in yield than the control.

Severe sand and wind damage delayed collection of plant map data until almost first square. Plant height/node ratios (collected at approximately first square) were significantly increased in plots receiving in-furrow applications of Temik 15G. Cotton seedling height-to-node ratios have been shown to be a sensitive indicator of early-season nematode effects on cotton seedlings (Walker *et al.*, 2000), and even where nematode population densities were low early in the growing season, this measurement appeared to have reflected differences in early seedling damage in response to nematicide application. No other plant development measurements were significantly affected by the different treatments and no obvious trends were observed (Figs.1- 4). Maturity, as measured by nodes above white flower (NAWF), was not affected by any treatment. Early-season crop delays associated with wind and sand damage as well as the low population of root-knot nematodes early in the season may have masked pre-square detection of nematode induced stress.

Yields were not statistically different. Cost per acre of Temik 15G, as applied in this study, represented substantial increases in production expenses compared to the standard Temik 15G rates (3.5 lb/acre) used in this region for early-season insect control. These results suggest that nematode population densities will have to be substantially higher before increasing Temik 15G rates will be economically beneficial.

PRACTICAL APPLICATION

Some trends for increased lint yield and reduced late-season populations of the root-knot nematode were observed with application of Temik 15G at rates of 5.0 lb/acre or greater, but no significant yield increase was seen in this site. Early-season sand and wind damage and low initial root-knot nematode population densities may have prevented the detection of plant responses to nematode stress. Plant monitoring, particularly early-season height/node ratios, does, however, appear to offer some ability to quantify the effects of nematodes on cotton growth and development. Additional studies conducted across a range of initial nematode population densities and without the confounding effects of extreme adverse environmental conditions early in the growing season (sand and wind damage) are needed.

REFRENCES

Bateman, R.J. and T.L. Kirkpatrick. 2000. Incidence of plant-parasitic nematodes in Arkansas, 1990-1999. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN (*in press*).

Benson, N.R., W.C. Robertson, G.M. Lorenz, and K.J. Bryant. 1999. Validation of the insecticide termination component of COTMAN. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Benson, N.R., T.L. Kirkpatrick, and K.F. Martin. 1994. Effects of nematicides and a moderately resistant cultivar on root-knot nematode control in cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pp. 278.

Kirkpatrick, T.L. 1996. The importance of nematodes in early growth and development of cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pp. 242-243.

Kirkpatrick, T.L., J.D. Barham, and R.J. Bateman. 1992. Incidence of plant-parasitic nematodes in cotton fields in Arkansas. *In:* D. M. Oosterhuis (ed.) Proc. 1992 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 158:57-62, Fayetteville.

Lorenz, G.M., T.L. Kirkpatrick, C. Coker, R.T. Robbins, and C. Bonner. 1999. Root-knot and reniform nematode suppression with selected nematicides in Arkansas. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pp. 109-110.

McGriff, D.E., W.H. Gregory, K. Harris, and A.L. Jennings. 1997. Evaluation of nematicides for southern root-knot nematodes. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pp. 101-102.

Teague, T.G., E.D. Vories, N.P. Tugwell, and D.M. Danforth. 1999. Using the COTMAN system for early detection of stress: triggering irrigation based on square retention and crop growth. *In:* D.M. Oosterhuis (ed.) Proc. 1999. Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 193:46-55, Fayetteville

Walker, N.R., T.L. Kirkpatrick, and C.S. Rothrock. 2000. Influence of *Meloidogyne incognita* and *Thielaviopsis basicola* populations on early-season disease development and cotton growth. Plant Disease 84:449-453.

Wheeler, T.A., K. Hake, K. Stair, and H.W. Kaufman. 1996. The relationship between root-knot nematode and growth of cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pp. 280-282.

Table 1. 2000 RKN study at Wildy Farms, Manila, Arkansas.

Treatment	Yield	Ht/node	Gall rating[z]	RKN[y]	PHT	Cutout
	(lb/acre)	(in.)		(No./pint)	(in.)	(days to)
No Temik	678	0.59	2.9	5152	43.4	100
In-furrow + side dressed	813	0.69	2.0	3371	43.3	102
In-furrow only	864	0.77	3.1	2690	43.6	99
Side dressed only	724	0.57	2.8	3447	44.6	100
LSD (0.10)	NS	0.06	NS	NS	NS	NS
Mean	770	0.66	2.7	3665	43.7	100
C.V.	13	5.6	22.5	50	2.0	2
R-squared	78	91.3	87.1	54	42.8	49

[z] Root gall values based on average visual ratings (0 = no galls & 4 = 100% infected) collected from 5 plants per plot following harvest.

[y] Root-knot nematode numbers/pint of soil collected following harvest. Early-season sample produced insufficient root-knot nematode numbers for statistical analysis.

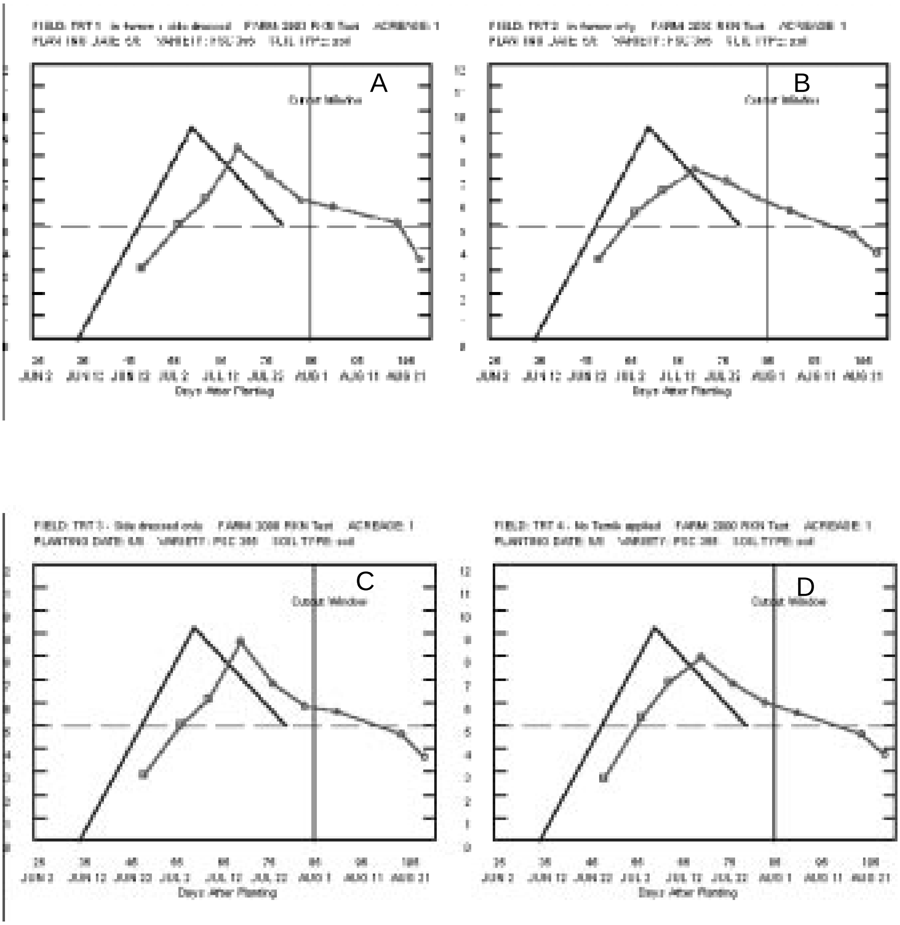


Fig. 1. BOLLMAN NAFS/NAWF graphs showing the treatment growth curve compared to the TDC. Wildy Farm, Manila, Arkansas. 2000.

PHYSIOLOGICAL RESPONSES OF COTTON TO APHID DAMAGE

S. Karen Gomez, Derrick M. Oosterhuis, Donald Johnson, and Donald Steinkraus[1]

RESEARCH PROBLEM

In Arkansas, current recommendations are vague, not based on actual damage/ number studies and not related to the effect of the damage on plant growth and the economic impact thereof. Understanding the physiological nature of aphid damage to cotton and quantification of this effect would allow us to formulate improved and more appropriate treatment-control recommendations. The purpose of this study was to investigate the effect of aphids on a single leaf and the whole cotton plant.

BACKGROUND INFORMATION

In 1991, cotton aphids were considered the number one cotton pest in the United States, causing a 2% yield reduction (Head, 1992). Eight aphid species colonize cotton (*Gossypium hirsutum* L.) in the United States (Stoetzel *et al.*, 1996), but the cotton aphid (*Aphis gossypii* G.) is a key pest in mid-South cotton (O'Brien *et al.*, 1992). The cotton aphid represents a tremendous threat to cotton because of its ability to change its morphology, reproduction rate, and behavior (Miyazaki, 1987) based on changes in temperature, day length (Rosenheim *et al.*, 1994), leaf reflectance, leaf moisture, and leaf nitrogen content (Slosser *et al.*, 1992). In addition, the aphid's ability to detoxify compounds (Miles and Peng, 1989) generated by the plant as defense makes cotton even more vulnerable. The cotton aphid's constant ability to develop resistance to different classes of insecticides (Grafton-Cardwell, 1991) diminishes one of the control alternatives.

MATERIALS AND METHODS

Three identical experiments were conducted in a growth chamber at the Altheimer Laboratory, University of Arkansas in Fayetteville. The growth chamber was pro-

---

[1] Graduate Assistant and Distinguished Professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville; Pest Management Section Leader and IPM Coordinator, Cooperative Extension Service, Little Rock; and Professor, Department of Entomology, Fayetteville.

grammed for 14:10 hours (day/night), with day/night temperatures ranging from 28 to16°C and 75% relative humidity. The cotton cultivar Stoneville 474 was planted in 2-L pots filled with sunshine mix (soilless horticultural media). All pots were watered with half-strength Hoagland's nutrient solution to maintain a well-watered status. Cotton aphids were collected from cotton fields at Lonoke, Arkansas, and reared in the laboratory. At 14 days after planting (DAP) the first unfurled leaf from the apex of each plant was tagged. Plants were divided into two groups, one group receiving aphids and the other one without aphids. At 20 DAP, 100 aphids (wingless adults + nymphs) were individually transferred to the selected leaf with a moist paintbrush. In addition, the rest of the leaves were infested with 5 aphids per leaf. Aphids were allowed to increase in numbers and an average of 363 aphids per tagged leaf were recorded when measurements were taken. Net photosynthetic rate, stomatal resistance, transpiration rate, and chlorophyll were measured before infesting the cotton plants (20 DAP) with aphids and after 9 days of exposure to aphids. At the same time, nonstructural carbohydrate concentrations of the leaves were determined. Additionally, leaf length, leaf area, dry weight of leaves, stems, and petioles were measured. The physiology portion of the experiment was arranged in a split-plot-in-time design with a factorial structure. The leaf area and plant dry weight parts of the experiment were arranged in a completely randomized design with six replications, and *t*-tests were performed at alpha 0.05.

RESULTS AND DISCUSSION

The leaf length of a single leaf and its leaf area were not significantly affected by aphids. In terms of a whole plant leaf area, there was no significant difference between aphid-infested and non-infested leaves (data not shown).

Photosynthesis and transpiration were higher in aphid-infested leaves after 9 days of exposure to aphids, but these differences were not significant when compared to non-infested leaves (data not shown). Hawkins *et al.* (1987) reported increased photosynthesis in broad bean (*Vicia faba* L.) and in cowpea (*Vigna unguiculata* L.) after aphid feeding. Similar results were also reported by Way and Cammell (1970) with cabbage. These authors suggested that aphids acted as a sink leading to photosynthesis stimulation. On the other hand, Shannag *et al.* (1998) observed decreased photosynthesis in cotton after 18 days of aphid feeding. Our results showed that stomatal resistance and chlorophyll index did not change due to aphid feeding.

Because aphids ingest large volumes of phloem sap due to their amino acid requirements, most of the carbohydrates extracted from the plant are excreted as aphid honeydew (Mittler and Meikle, 1991). Starch concentration in aphid-infested leaves was significantly lower than in non-infested leaves, but sucrose, glucose and fructose concentrations were similar between treatments. Photoassimilates translocating in the sieve elements are directly taken up by the aphids, and plant compensation may lead to a reduced starch accumulation in aphid-infested leaves.

Total leaf, stem, and plant dry weights appeared to be lower in aphid-infested plants at 9 DAT, but their time by treatment interaction was not significant. This probably accounts for the stunted growth of aphid-infested plants. Petiole dry weights were not affected by aphids.

PRACTICAL APPLICATION AND FUTURE RESEARCH

These studies showed that an aphid population ranging from 100 to 363 per leaf and feeding for 9 consecutive days did not alter leaf photosynthetic rates and transpiration rates. Furthermore, this level of aphid infestation and feeding duration did not affect the length and area of leaves. Leaf, stem, petiole, and plant dry weights were similar in aphid-infested and non-infested plants. However, cotton aphids negatively affected starch concentration in leaves. Aphid feeding did not change the soluble carbohydrates concentration in leaves. Overall, the physiology of cotton leaves that were exposed to an aphid population ranging from 100 to 363 for 9 days was not altered.

In order to better understand the physiological changes in cotton due to aphid damage, this research is being continued with additional focus on the carbon budget and antioxidant response of aphid-infested leaves.

ACKNOWLEDGMENTS

We thank Dr. D. Zhao, Dr. S. Rajguru, and C. Meek for their invaluable assistance in this study. We appreciate the comments and suggestions of Drs. D. Hendrix and J. Slosser, USDA-ARS-WCRL, Phoenix, AZ, and Texas A&M Agricultural Experiment Station, Vernon, TX, respectively. We are grateful to Dr. R. McNew for his assistance with the data analysis.

LITERATURE CITED

Grafton-Cardwell, E.E. 1991. Geographical and temporal variation in response to insecticides in the various life stages of *Aphis gossypii* (Homoptera: Aphididae) infesting cotton in California. J. Econ. Entomol. 84:741-749.

Hawkins C.D.B., M.J. Aston, and M.I. Whitecross. 1987. Short-term effects of aphid feeding on photosynthetic CO_2 exchange and dark respiration in legume leaves. Physiol. Plant. 71:379-383.

Head, R.B. 1992. Cotton insect losses 1991. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 621-625.

Miles, P.W. and Z. Peng. 1989. Studies on the salivary physiology of plant bugs: detoxification of phytochemicals by the salivary peroxidase of aphids. J. Insect Physiol. 35:865-872.

Mittler, T.E., and T. Meikle. 1991. Effects of dietary sucrose concentration on aphid honeydew carbohydrate levels and rates of excretion. Entomol. Exp. Appl. 59:1-7.

Miyazaki, M. 1987. Morphology of aphids. *In:* A.K. Minks and P. Harrewijn (eds.). Aphids: their biology, natural enemies and control. 2a:1-23. Elsevier, Amsterdam.

O'Brien, P.J., M.B. Stoetzel, B.R. Leonard, and J.B. Graves. 1992. Taxonomy and biology of *Aphis gossypii* Glover in the mid-South. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 646-648.

Rosenheim, J.R., L.R. Wilhoit, and R.G. Colfer. 1994. Seasonal biology and polymorphism of the cotton aphid, *Aphis gossypii,* in California. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 125-131.

Shannag, H.K., H. Thorvilson, and M.K. El-Shatnawi. 1998. Changes in photosynthetic and transpiration rates of cotton leaves infested with the cotton aphid, *Aphis gossypii*: Unrestricted infestation. Ann. Appl. Biol. 132:13-18.

Slosser, J.E., W.E. Pinchak, and D.R. Rummel. 1992. Population development and regulation of the cotton aphid. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 649-651.

Stoetzel, M.B., G.L. Miller, P.J. O'Brien, and J.B. Graves. 1996. Aphids (Homoptera: Aphididae) colonizing cotton in the U.S. Florida Entomol. 79(2):193-205.

Way, M.J., and M.E. Cammell. 1970. Aggregation in relation to food utilization by aphids. *In:* Adam Watson (ed.). Animal populations in relation to their food resources: A symposium of the British ecological society, Aberdeen, 24-28 March 1969. Oxford, Blackwell Scientific Publications. pp. 229-247.

COTTON RESPONSE TO SQUARE LOSS PRIOR TO FIRST FLOWER – A COMPARISON OF MANUAL REMOVAL AND TARNISHED PLANT BUG FEEDING

Tina Gray Teague, N. Philip Tugwell, and Eric J. Villavaso[1]

RESEARCH PROBLEM

How a cotton crop compensates from insect-induced loss of squares and bolls varies with the pest and growing conditions. There are three likely scenarios for crop compensation after loss of fruiting structures: 1) cotton plants under-compensate for losses and lose yield; 2) they over-compensate by producing more bolls and lint than uninjured plants; or 3) they fully adjust and produce fiber weights equal that of normal, undisturbed plants (Sadras, 1995). Which of these three scenarios occurs often seems to be left to the roll of the dice. Perhaps this is why so many crop advisors and growers consider a crop protection strategy based on compensation too risky; likened to a trip to a Mississippi gambling house. Unfortunately, this view often leads to an extreme risk-averse production strategy, one with little tolerance for any insect-induced loss of squares and bolls. It is a costly strategy, heavily dependent on insecticides.

BACKGROUND INFORMATION

Crop advisors and growers need a crop monitoring system that provides real-time data showing whether or not their crop is doing well, even without protective sprays. The system must be a workable method of information synthesis that can be used for rapid communication among growers, their support groups, and the farm manager. Research in Arkansas and other states has been directed at developing such a system, e.g., COTMAN (Danforth and O'Leary, 1998). COTMAN includes monitoring responses of the cotton plant to injury occurring at different stages of plant development (Bagwell and Tugwell, 1992; Holman, 1996), and is capable of integrating crop management and pest management tactics (e.g., Bourland *et al.*, 1992; Teague *et al.*, 1999).

A current focus in COTMAN research is development of decision rules for managing square retention prior to first flowers, concentrating on how retention af-

[1] Professor, Arkansas State University, Jonesboro; Professor, Department of Entomology, Fayetteville; and Research Scientist, ARS-USDA, Mississippi State, MS.

fects crop carrying capacity and yield potential. Hearn and Constable (1984) described crop-carrying capacity as the boll load that slows terminal growth and the production of new squares to zero. Assuming good growing conditions, one can glean information on boll loading from a measure of the slowing of terminal growth after first flowers. A count of squaring **N**odes **A**bove the first position **W**hite **F**lower (NAWF) will provide a measure of boll-filling stress. We believe this stress can be anticipated because square retention prior to first flowers should reflect potential for that metabolic stress that results with boll filling. The connection between potential metabolic stress and actual metabolic boll-filling stress is a result of complex nutritional and hormonal influences and is poorly understood (reviewed by Sadras, 1995). We do know that if retention is high when first flowers appear, the cotton plant's natural feed-back mechanisms will alter metabolic stress by causing small bolls and tiny squares to shed during boll filling (Mauney, 1979; Guinn, 1979).

Tarnished plant bug is a key pest in mid-South cotton, and the perception by growers and crop advisors of its importance as a pest is likely to increase with boll weevil eradication and with widespread use of Bt transgenic cotton. It is unknown if results from crop compensation studies that have used manual square-removal methods adequately simulate plant bug injury. The objectives of the experiment reported here were: 1) to compare square losses caused by plant bugs and by manual removal, and 2) to assess plant responses with standardized procedures that synthesize information involving many potentially interacting factors affecting potential and actual metabolic stress and crop carrying capacity.

RESEARCH DESCRIPTION

The experiment was conducted on the University of Arkansas Cotton Branch Experiment Station in Marianna (Calloway silt loam). The growing season in the study area is May through October. The latest possible cutout dates for this production area – those dates with a 50% or 85% probability of attaining 850 DD60s from cutout – are 14 August and 9 August, respectively (Zang *et al.*, 1994; Danforth and O'Leary, 1996).

Cultivar Suregrow 125 was seeded on 3 dates – 16 May, 1 June, and 12 June – using a John Deere air planter in rows spaced 38 inches apart. Temik 15G (aldicarb) was applied in-furrow at planting at 3.5 lb formulation per acre. Furrow irrigation was initiated one week prior to flower in the earliest planting, and continued at weekly intervals until mid-September. Rainfall in May, June, July, August, September, and October was 4.92, 3.21, 0.27, 0.35, 1.12, and 0.27 inches, respectively. Defoliant was applied on 3 October to all plots.

There were 3 injury treatments: 1) artificial infestations of tarnished plant bug nymphs (Bug); 2) manual crushing of squares (Crush); and 3) no injury and sprayed with insecticide (Protected) (see Teague *et al.*, 2001 for experimental details). Dates of planting were randomized within the field and regarded as main plots with square injury treatments considered sub-plots. Each treatment was replicated three times. Sub-plots were 8 rows wide, 25 ft long with 2 unplanted rows. Three rows, each 10 ft long, were selected in each plot for injury treatments. Tarnished plant bugs were obtained from a colony maintained on artificial diet at the USDA-ARS Biological Control and Mass Rearing Research Unit at Mississippi State, MS (Cohen *et al.*, 2000). Final plant mapping was performed on 10 October using COTMAP (Bourland and Watson, 1990). Ten plants per plot were examined for node number of first (lowest) sympodial branch on the main axis, no. of monopodia, and no. of bolls on sympodia arising from monopodia. Bolls located on main stem sympodia (first and second position) were recorded as well as bolls located on the outer positions on sympodial nodes (>second position). The highest sympodium with 2 nodal positions and no. of bolls on sympodia located on secondary axillary positions were also noted. Plant height was measured as distance from soil to apex. Plots were hand harvested 3 times – 7, 17, and 24 days – after defoliant application. Lint samples were taken for each harvest date for each sample and sent to the Texas Tech Fiber Testing Laboratory, Lubbock, TX, for quality analysis.

RESULTS AND DISCUSSION

Square Shed

Bug and Crush treatments were initiated at approximately the same time period for each date of planting – 35 to 37 days after planting. The 1st plant monitoring data came approximately 4 days later (Table 1). In all 3 dates of planting, square shed differed significantly between treatments on most sample dates.

In the first date of planting, total percent shed of first position squares was remarkably similar for Crush and Bug – 53% and 43% shed at 56 days after planting compared to 7.3% in the Protected treatment (Table 1). Shed of large and small squares was different between the Crush and Bug treatments. Large square shed was significantly higher in Crush compared to Bug treatments in the second and third sampling dates. Conversely, small shed was higher for Bug compared to Crush treatments during the same sampling period. Although large square shed was lower in the Bug injury treatment, squares may have been sufficiently large that plant bug feeding would not result in abscission. Squares were not dissected to determine injury (Williams *et al.*, 1987).

Unlike the first date of planting, the later planting dates received the Bug or Crush treatments on just 2 occasions rather than 3. Square shed from Bug treatments in the third date of planting was comparable to that observed in the May planting, but shed associated with plant bugs was lower in the second date. Insecticide drift from a neighboring field on the experiment station during the experiment was thought to have occurred, affecting 2 of 3 Bug treatment plots. The low level of injury for those Bug treatment plots (<10%) for that date of planting is attributed to mortality from the insecticide (Table 1).

Squaring Nodes

There were no differences in mean nunmber of squaring nodes per plant until after first flowers (Table 2). Mean number of squaring nodes for each date of planting at the time of injury treatments ranged from 2.8 to 5.8 (Table 2). These data are plotted as nodes above first square and nodes above white flower in COTMAN growth curves in Fig. 1. When compared to the COTMAN target development curve, it is apparent the rate of squaring node accumulation was lower than expected in the first date of planting in the days leading to first flowers (Fig. 1a). This was probably due to heat and water stress (irrigation was initiated simultaneously across all dates of planting so the early date of planting was exposed to dry conditions for a longer period than other dates). Growth curves were slightly above target in the latest date of planting, indicating rapid growth in the warmer conditions of mid-June (Fig. 1b and c). Growth curves are not continuous for Bug and Crush treatments in the first and third dates of planting because samplers took only NAWF readings on those dates, and because of injury treatments, no flowers were present in those plots. In the second date of planting, the sample data were taken before flowers therefore nodes above first square were counted.

Numbers of squaring nodes per plant for the first date of planting were not affected by injury treatments until after first flowers (Table 2). Boll loading is a major metabolic stress-producing factor so a decline in NAWF is expected after flowering. If it does not occur, one must be alert for problems with boll retention and/or boll filling. Differences in NAWF in the Protected compared to Bug and Crush injury treatments in the 16 May and 12 June plantings indicate reduced strain associated with lower square retention (Table 1). COTMAN growth curves for the 1st date of planting clearly show differences in NAWF between treatments and reflect crop delay in the Bug treatment (Fig. 1). Days to cutout (no. of days from planting until mean NAWF = 5) were significantly higher -10 to 11 days - for the Bug treatment compared to either Crush or Protected (Table 3).

There was a significant difference in the second date of planting between injury treatments in squaring nodes at day 57 just before flowers (Table 2). After that, NAWF values were very similar. For this date of planting, there was insufficient injury from Bug treatments to result in delay of cutout (Table 3). For the third date of planting significant differences in squaring nodes were apparent at 73 days after planting (Table 2). Days to cutout were significantly higher for Bug compared to Protected treatments. There was no difference in days to cutout between the treatment plots with manual square removal as compared to the sprayed plots (Table 3).

Final Plant Mapping

Significant differences in plant structure were observed between injury treatments for all dates of planting as measured in final plant mapping. As with the COTMAN shed and squaring node data, differences were most obvious in the first and third dates of planting; however, for all three dates, significant differences in boll distribution were observed. Percentage of total bolls associated with first sympodial position was significantly higher in Protected plants compared to plants with insect- and manually-induced square shed. Percent early boll retention, defined as first plus second position bolls on the five lowest sympodia, was also higher in Protected plants. Number of aborted terminals was negligible in any treatments. For the first and third dates of planting where insect feeding effects were most apparent, there were significant differences between the Bug and Protected treatments in several measures of plant structure (including the number of fruiting sites and number of fruiting forms) including: total nodes; total number of sympodia; total outer bolls (bolls on sympodial positions >2); highest sympodia with two nodal positions; and number of effective sympodia. Plant height of the Crush treatment was greater than the Protected plants in the first date of planting; however, the Bug treatment was significantly greater than both.

Yield and Quality

Significantly lower yields in the first harvest of the earliest date of planting were associated with the Bug injury treatment compared to Protected plots (Table 4). Crush treatment yields were intermediate. By the second harvest, compensation appeared complete in both Bug and Crush treatments, and there were no differences in final yield. No delay or reduction in yield was observed in the second date of planting, but delay, and loss of yield to Crush and Bug treatments were observed in the 12 June planting date. There was insufficient time for time-dependent compensatory response in this very-late planted cotton, and yields from the Protected treatment were significantly higher than either Bug or Crush treatments. Injury treatments had no significant effect on fiber quality. Micronaire values were very low in the final harvest in the June 12 planting (Table 5). A change in experimental protocol would be necessary to evaluate injury treatments on lint quality with timing of crop termination (defoliation) dependent on cutout date. In this study, defoliant was applied on 3 October, and DD60s (heat units) from cutout varied from 543 to 1206 between the different treatments (Table 3). COTMAN assumes maturity of last effective boll population is at 850 DD60s (Wells, 1991).

PRACTICAL APPLICATION

Sadras (1995) suggested an account of growing conditions is essential to understand compensation. One way for crop managers to dictate their own luck with compensation is to make management choices that do not decrease the crop's compensation capacity. Appropriate choices for dates of planting with suitable temperatures for a selected cultivar, type of seed bed, herbicide selection and application timing, plant stand density, timely and adequate irrigation and fertilizer applications, correct use of plant growth regulators, and proper pest control all affect *time* available for compensation. These management choices also affect *extent* of compensation. To adequately investigate the complexities of compensatory response of cotton, researchers must use an integrated approach that considers multiple factors including water, nitrogen, carbon, and arthropod herbivory (Sadras, 1995). The research reported here represents initiation of a series of stress experiments that will be expanded in 2001. The overall goal is development of decision aids that allow a grower to economically exploit the upper levels of the crop's carrying capacity when compensation is not needed or to any extent possible.

ACKNOWLEDGMENTS

The authors thank Mr. Claude Kennedy, director of the Cotton Branch Experiment Station, and his staff for their assistance in the study. We also acknowledge support from USDA-ARS research entomologist Dr. Bill McGovern, and Ms. Gay McCain, USDA-ARS, Mississippi State, MS, for providing the tarnished plant bugs.

LITERATURE CITED

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. The concept for monitoring the growth and development of cotton plants using main-stem node counts. J. Prod. Agric. 5:532-538.

Danforth, D.M. and P.F. O'Leary (ed.). 1998. COTMAN expert system 5.0. user's manual. University of Arkansas, Agricultural Experiment Station, Fayetteville, AR; and Cotton Incorporated, Raleigh, NC.

Mauney, Jack. 1979. Production of fruiting points. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp 256-258.

Sadras, V.O. 1995. Compensatory growth in cotton after loss of reproductive organs. Field Crops Res. 40:1-18.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Comparison of cotton plant response to square loss following manual removal or tarnished plant bug feeding – results from field trials in 2000. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1149-1157.

Teague, T.G., E.D. Vories, N.P. Tugwell, and D.M. Danforth. 1999. Using the COTMAN system for early detection of stress: Triggering irrigation based on square retention and crop growth. *In:* D.M. Oosterhuis (ed.). Proc. 1999 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 193:46-55, Fayetteville

Williams, L. III, J.R. Phillips, and N.P. Tugwell. 1987. Field technique for identifying causes of pinhead square shed in cotton. J. Econ. Entomol. 80:527-531.

Table 1. Total, large, and small square shed (% of first-position floral buds) as influenced by square injury treatments for 3 dates of planting[z]. 2000.

Date of planting	Square size[y]	Time of injury	Sample time	Mean no. shed squares				
				Bug[x]	Crush	Protected	*Pr>F*	$LSD_{0.05}$
		----- (DAP)[w] ----		-------------------------- (%) -------------------------				
16 May	Total	37	41	32.9	26.8	4.5	0.04	20.0
		44	50	42.6	41.0	6.7	0.001	10.6
		52	56	53.3	43.3	7.3	0.008	20.9
	Large	37	41	59.1	86.7	8.4	0.02	43.0
		44	50	71.1	35.0	13.8	0.001	17.8
		52	56	75.6	42.0	12.8	0.003	23.9
	Small	37	41	25.5	10.6	3.4	0.09	20.3
		44	50	16.7	4.5	0.6	0.009	7.7
		52	56	25.5	6.7	1.1	0.03	15.8
1 June	Total	36	40	9.1	8.3	0.0	0.08	–
		43	47	25.8	71.7	0.3	0.006	28.9
	Large	36	40	11.1	61.1	0.0	0.03	39.8
		43	47	39.2	100.0	0.0	0.005	37.9
	Small	36	40	8.7	4.2	0.0	0.07	–
		43	47	17.8	56.1	0.6	0.007	23.5
12 June	Total	35	42	34.9	25.3	3.7	0.03	20.9
		42	46	47.7	53.7	8.1	0.001	3.9
	Large	35	42	58.8	50.3	7.0	0.04	39.6
		42	46	69.2	92.0	9.3	0.001	9.6
	Small	35	42	16.6	2.2	1.7	0.002	5.0
		42	46	23.3	5.6	6.7	0.01	9.1

[z] Data are means of 3 replications. Square shed percentages were determined from 10 plants per plot using standard COTMAN procedures.

[y] Small squares were 1st position squares in the top 3 sympodia; large squares were all squares from the 4th sympodia down the plant; total were all 1st position squares.

[x] Insecticide drift for the 1 June date of planting affected Bug injury.

[w] Days after planting (DAP).

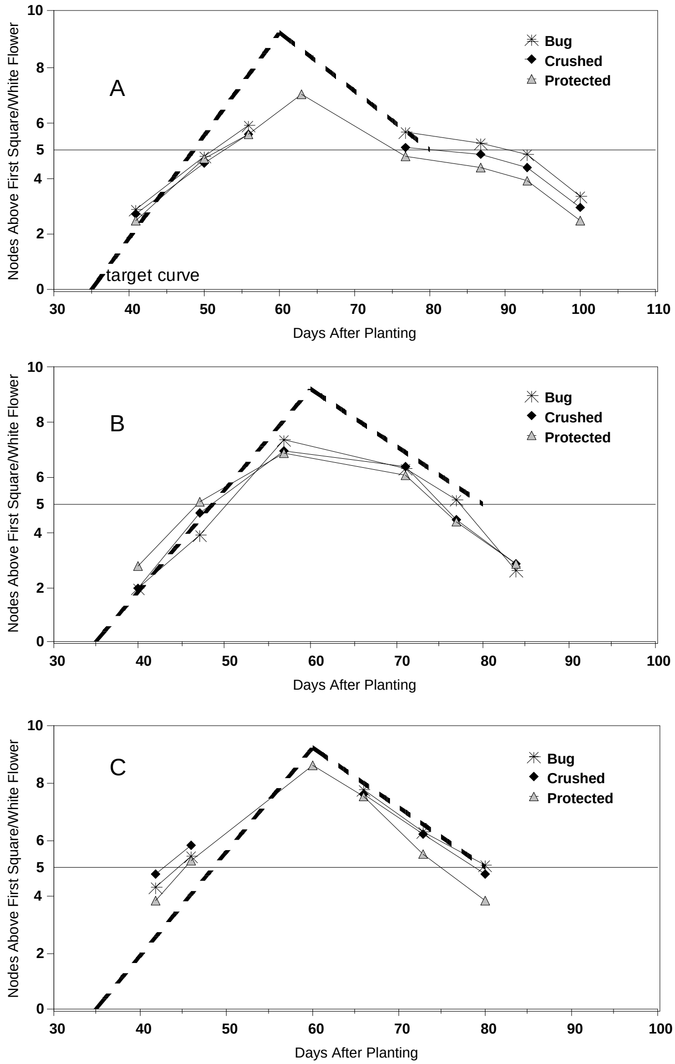


Fig. 1. COTMAN growth curves for three dates of planting: A) 16 May, B) 1 June, and C) 12 June, 2000. Curves depict growth of plants exposed to tarnished plant bug nymphs, plants with manually removed squares, or plants protected with insecticide.

Table 2. Squaring node number as influenced by square injury treatment for 3 dates of planting[z].

Date of planting	Sample date (DAP)[y]	Mean no. squaring nodes				
		Bug	Crush	Protected	Pr>F	$LSD_{0.05}$
16 May	26 June (41)	3.9	3.7	3.5	0.42	–
	5 July (50)	5.8	5.6	5.7	0.19	–
	11 July (56)	6.9	6.6	6.6	0.61	–
	1 August (77)	5.7	5.1	4.8	0.007	0.37
	11 August (87)	5.3	4.9	4.4	0.21	–
	17 August (93)	4.9	4.4	3.9	0.03	0.67
	24 July (100)	3.4	3.0	2.5	0.57	–
1 June	11 July (40)	3.0	3.0	2.8	0.62	–
	18 July (47)	4.9	4.7	5.1	0.65	–
	28 July (57)	7.4	7.0	6.9	0.02	0.28
	11 August (71)	6.6	6.4	6.1	0.16	–
	17 August (77)	5.2	5.5	5.4	0.71	–
	24 August (84)	3.6	3.9	3.9	0.63	–
12 June	24 July (42)	5.3	5.8	4.9	0.04	0.61
	28 July (46)	6.4	6.8	6.3	0.05	0.35
	17 August (66)	7.8	7.6	7.5	0.29	–
	24 August (73)	6.3	6.2	5.5	0.02	0.49

[z] Data are means of 3 replications. Squaring nodes were counted on 10 plants per plot using standard COTMAN procedures.
[y] Days after planting (DAP).

Table 3. Effect of injury treatments on no. of days to cutout for the 3 dates of planting, and the heat unit accumulation from date of cutout until application of defoliant on 3 Oct.

Date of planting	Injury treatment	Mean date of physiological cutout[z]	Mean no. days to cutout	DD60s from cutout to defoliation on 3 Oct
16 May	Bug	14 Aug	90.3	923
	Crush	03 Aug	79.7	1166
	Protected	02 Aug	78.0	1206
	p>F		0.02	0.03
	$LSD_{0.05}$		8.06	187.5
1 June	Bug	18 Aug	78.0	835
	Crush	20 Aug	79.7	794
	Protected	19 Aug	79.0	811
	p>F		0.70	0.58
	$LSD_{0.05}$			
12 June	Bug	31 Aug	80.3	543
	Crush	29 Aug	78.7	577
	Protected	26 Aug	75.7	637
	p>F		0.04	0.44
	$LSD_{0.05}$		3.42	–

[z] Date at which the mean no. of squaring nodes above white flower = 5 (NAWF = 5).

Table 4. Cumulative mean lint yield over 3 harvest dates taken for each injury treatment for the 3 dates of planting.

Date of planting	Injury treatment	Cumulative lint yield at each date of hand harvest[z] 10 Oct	20 Oct	27 Oct
16 May	Bug	1064.1 b	1206.8 a	–
	Crush	1144.5 ab	1210.0 a	–
	Protected	1212.6 a	1247.0 a	–
	p>F	0.019	0.34	–
	$LSD_{0.05}$	81.8	–	–
1 June	Bug	766.6 a	1072.6 a	1109.0 a
	Crush	730.2 a	1012.0 a	1035.6 a
	Protected	808.9 a	974.1 a	998.4 a
	p>F	0.76	0.76	0.70
	$LSD_{0.05}$	–	–	–
12 June	Bug	92.8 b	369.1 b	554.6 b
	Crush	72.2 b	493.5 b	624.1 b
	Protected	272.9 a	712.2 a	783.7 a
	p>F	0.003	0.003	0.01
	$LSD_{0.05}$	77.57	121.5	112.2

[z] Means with a column for each date of planting and harvest date followed by a similar letter are not statistically different.

Table 5. Micronaire values of lint samples taken for 3 harvest dates for each injury treatment for the 3 dates of planting.

Date of planting	Injury treatment	Mean micronaire value at each harvest date 10 Oct	20 Oct	27 Oct[z]
16 May	Bug	5.40	4.23	–
	Crush	5.40	4.36	–
	Protected	5.27	4.23	–
	p>F	0.51	0.65	–
1 June	Bug	4.96	4.40	–
	Crush	5.03	4.30	–
	Protected	4.87	4.03	–
	p>F	0.62	0.36	–
12 June	Bug	4.70	3.57	2.23
	Crush	4.10	3.90	2.37
	Protected	4.60	3.63	2.33
	p>F	0.08	0.11	0.36

[z] For 27 Oct samples there was insufficient lint for quality analysis for 1 June date of planting; all cotton in 16 May date of planting had been harvested by 20 Oct.

SUMMARY OF SELECTED HERBICIDE EVALUATIONS IN COTTON

Marilyn McClelland, Jim Barrentine, and Oscar Sparks[1]

RESEARCH PROBLEM

Herbicidal weed control is economically important for production of cotton. New herbicides and expanded uses for existing herbicides must be tested for efficacy and for their inclusion into various weed management programs. The objective of these experiments was to evaluate efficacy of herbicides on a broad spectrum of cotton weeds in several locations in Arkansas. Studies summarized in this report are those conducted at Fayetteville and Marianna by researchers located at Fayetteville. Data and specific field information for each experiment can be found at www.uark.edu/depts/agripub/Publications, under "Herbicide Evaluation in Arkansas Cotton, 2000."

BACKGROUND INFORMATION

The weed science program for cotton is a comprehensive state-wide program designed to evaluate weed management practices annually under a number of soil and environmental conditions. The program also provides a strong training ground for graduate students, who will conduct future cotton research in industry, extension, regulatory agencies, educational institutions, and on farms. Data from these studies are compiled annually by weed science researchers (McClelland *et al.*, 1999; Smith *et al.*, 2000) and are used as a basis for making and updating Arkansas weed control recommendations (Baldwin *et al.*, 2001).

PROCEDURES

Experiments were conducted at Fayetteville and Marianna, Arkansas. Standard small-plot research procedures were followed. Plots were established on raised planting beds at both locations. Herbicides were applied with a tractor-mounted sprayer or a CO_2-pressurized backpack sprayer at 15 to 20 gal/acre carrier volume. Herbicide rates are expressed in lb active ingredient/acre.

---

[1] Senior Research Associate, Professor/Head, and Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

Climatological data, specific herbicide application data, general field conditions, and crop and weed sizes and densities were recorded at each herbicide application. Effects of herbicide treatments were evaluated by visual weed control ratings and crop injury ratings. Ratings were based on a percentage scale: 0% represents no control or crop injury and 100% represents complete kill. The effect of glyphosate (Roundup Ultra and Touchdown formulations) on cotton growth and development was evaluated in two experiments using the COTMAN in-season crop monitoring program (Danforth and O'Leary, 1998). Cotton was harvested for yield data in some experiments.

RESULTS

Glyphosate (weed control)

Glyphosate (several formulations, including Roundup Ultra™, Touchdown™, Glyphomax™, and Glyfos™) was evaluated on Roundup Ready™ (glyphosate-tolerant) cotton in several experiments. In a program approach with Roundup Ultra, plots treated with pendimethalin (Prowl™) plus fluometuron (Meturon™) preemergence (PRE) and followed by glyphosate over-the-top did not need another herbicide application before the layby application. A post-directed application of glyphosate was needed if a PRE was not applied. However, this experiment emphasized that many application timing options with glyphosate are effective for broad-spectrum weed control. The Touchdown and Roundup Ultra formulations of glyphosate were equally active. Repeat applications of either formulation were needed to control pitted morningglory, one of the more resistant weeds to glyphosate. Glyfos, another glyphosate formulation, was evaluated with several adjuvants, including Array™, INT-EXP 113™, Surf King™, Intensify™, and JS 80:20™. Effect on cotton was generally comparable to that of Glyfos X-tra™ and Roundup Ultra. Although early cotton injury was slightly higher with Surf King and Intensify, no visible injury was evident by 6 weeks after planting.

Glyphosate (cotton development)

Glyphomax Plus and Roundup Ultra were applied at 1 and 2 lb/acre at cotyledon to 1-leaf cotton and to 4-leaf cotton and at 1 lb/acre in repeated applications at cotyledon to 1-leaf cotton + 4-leaf cotton + 8-leaf cotton + 13-leaf cotton. Applications were made according to the glyphosate label; i.e., over-the-top through the 4-leaf stage and post-directed at 8- and 13-leaf cotton. Cotton was monitored using COTMAN. Percent square shed, number of squares/acre, number of fruiting nodes/plant, and plant height did not differ among treatments, which were all within the glyphosate label. First fruiting node ranged from 6.2 to 6.9 and did not differ among treatments. Glyphosate did not affect maturity as indicated by NAWF and days to NAWF=5. Position of fruit tended to differ slightly with application stage. Cotton treated with glyphosate at the 4-leaf stage or with four applications (total of 4 lb/acre, the maximum allowed by the label) tended to have less sympodial branches with 1st-position bolls and more with 2nd-position bolls. Percent boll retention at the 1st position was also less for these 4-leaf or repeated treatments. Yields, however, did not differ among treatments. It appears that both glyphosate formulations caused some stress on the cotton plant when applied at the 4-leaf stage or with a total of 4 lb/A applied throughout the season, but the cotton plant compensated with 2nd-position fruit, and no yield reduction occurred.

Glyphosate/pyrithiobac (Staple) combinations

The benefits of including Staple, which has residual soil activity, in glyphosate programs have been evaluated in several experiments. Grass species are generally controlled adequately with glyphosate alone. However, in some experiments, tank-mixing Staple at even one-half the labeled rate of 0.063 lb/acre with glyphosate increased control of smooth pigweed (*Xanthium strumarium*), prickly sida (*Sida spinosa*), and pitted morningglory (*Ipomoea lacunosa*). Examples include increased smooth pigweed control from 90% with two applications of glyphosate alone (at 0.75 lb/acre) to 96% with one application of glyphosate + Staple at 0.031 lb/acre; increased pitted morningglory control from 69% with glyphosate alone to 75% with the single glyphosate + Staple treatment to 96% with repeated applications of glyphosate + Staple (reduced rates of 0.5 + 0.031 lb/acre); and increased prickly sida control from 91 to 98% and 70 to 98% with glyphosate alone and glyphosate + Staple, respectively. Staple, therefore, can be of benefit in a Roundup Ready weed control program under conditions such as high weed populations, difficult-to-control weeds such as pitted morningglory, and frequent rainfall or irrigation that promotes several "flushes" of emergence that can be controlled with the residual activity of Staple.

Fomesafen (Reflex)

Fomesafen was more active this year than in some other years of testing. Fomesafen PRE following trifluralin (Treflan) PPI significantly increased control of all species over control with trifluralin alone at 3 and 5 weeks after treatment (WAT) and did not differ from control with trifluralin PPI *fb* fluometuron (Meturon) PRE. There was no rate response from fomesafen at 0.25 or 0.375 lb/acre when combined with fluometuron. However, fomesafen at 0.25 lb/acre with pyrithiobac was weaker than 0.375 lb/acre on prickly sida, smooth pigweed, and morningglory species. Although cotton injury was moderate (16 to 38%) from all treatments early in the season, injury from fomesafen exceeded that from fluometuron, and injury from 0.375 lb/acre was greater than from 0.25 lb/acre. Injury was manifested primarily as stunting.

CGA-362,622

CGA-362,622 is a herbicide under development from Syngenta Co. (previously Novartis). Its activity is somewhat similar to that of Staple, and it is being developed for over-the-top and post-directed use in cotton. Extensive work with this compound is being conducted in Arkansas by Ken Smith and Jeff Branson at the Southeast Branch Research and Extension Center at Monticello (Branson and Smith, 2001). At the Fayetteville location this year, CGA-362,622 continued to give excellent control of pigweed species with both PRE and POST applications. As in 1999, control of pitted morningglory with POST applications was good (80 to 95%), although regrowth occurred by 5 to 6 weeks after application. Control of prickly sida with CGA-362,622 was very poor. Although the compound has some PRE activity, cotton injury was 13 to 41% and will probably not be developed for PRE use.

Flumioxazin (Valor) layby

Cyanazine (Bladex) has been a popular standard for post-directed weed control at layby. Because it is no longer marketed, other options are being evaluated. Layby treatments of flumioxazin, flumioxazin + glyphosate, and flumioxazin + MSMA all gave excellent weed control, and flumioxazin is a viable alternative to cyanazine for layby control [see paper entitled “Valor (Flumioxazin) Herbicide Applied Layby in Cotton” elsewhere in this report series].

Bromoxynil (Buctril)

Bromoxynil is still being evaluated postemergence in Buctril-tolerant (BXN) cotton. At Marianna, bromoxynil alone failed to control prickly sida and smooth pigweed at 3 WAT, but good control (82 to 92%) was obtained with pyrithiobac + bromoxynil over-the-top. Morningglory species were controlled ≥80% with all treatments of bromoxynil + pyrithiobac. There was a slight advantage to applying pyrithiobac PRE before pyrithiobac + bromoxynil at 0.25 lb/acre or using a 0.375 lb/acre bromoxynil rate for broad-spectrum weed control.

Weed and insect management in transgenic cotton cultivars

Experiments were begun in 2000 at Marianna and Rohwer to evaluate efficacy and economics of weed and insect control programs in transgenic cultivars, including Roundup Ready, BT, BXN, and ‘stacked’ Roundup Ready/BT. These experiments will continue in 2001, after which preliminary data will be available.

PRACTICAL APPLICATION

Results from these experiments serve both industry and Arkansas agriculture by providing information on the selectivity of herbicides still in the developmental stage and comparing the activity of new herbicides with that of recommended herbicides. These comparisons allow producers to determine the most effective and economical herbicides for their particular weed management programs.

LITERATURE CITED

Baldwin, F.L., J.W. Boyd, and K.L. Smith. 2001. Recommended chemicals for weed and brush control. University of Arkansas Cooperative Extension Service, Little Rock. Misc. Pub. 44. 149 pp.

Branson, J.W. and K.L. Smith. 2001. Characterization and utilization of CGA 362622 for broadleaf weed control in cotton. In: D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 204:128-130, Fayetteville.

Danforth, D.M. and P.F. O'Leary (eds). 1998. COTMAN expert system 5.0. University of Arkansas, Agricultural Experiment Station, Fayetteville; and Cotton Incorporated, Raleigh, NC.

McClelland, M., J. Barrentine, K. Smith, and N. Burgos. 2000. Herbicide evaluation in Arkansas cotton, 1999. University of Arkansas, Agricultural Experiment Station Research Series 477. 129 pp. Fayetteville

Smith, K., J. Branson, R. Namenek, M. Burton, B. Allen, C. Bryant, and J. Dickson. 2000. Weed control demonstrations. University of Arkansas Southeast Research and Extension Center, Monticello, Arkansas. 386 pp.

CHARACTERIZATION AND UTILIZATION OF CGA 362622 FOR BROADLEAF WEED CONTROL IN COTTON

Jeffrey W. Branson and Kenneth L. Smith[1]

RESEARCH PROBLEM

It is hypothesized that CGA 362622 has potential weed control properties and has adequate crop safety that would benefit Arkansas cotton growers. The objectives of this research were: (1) to characterize crop safety, weed spectrum, and soil residual properties of CGA 362622; (2) to determine the fit of CGA 362622 in conventional, bromoxynil-resistant, and glyphosate-tolerant cotton programs; and (3) to determine the most efficacious rates and application timings for the control of weeds common to southeast Arkansas cotton production.

BACKGROUND INFORMATION

CGA 362622 (trifloxysulfuron sodium) is an ALS inhibitor currently being developed by Syngenta (formerly Novartis) for broad-spectrum weed control in both transgenic and conventional cotton (Wells, 2000). The formulation of CGA 362622 is a 75 % active wettable dispersible granular that has expected application rates ranging from 5 to15 g ai/ha in cotton production (Wells, 2000). This herbicide is effective on many difficult-to-control weeds in cotton, and is also effective on large weeds (Wells, 2000). Some yellowing of cotton leaves and, less often, stunting can occur from over-the-top applications, but the response dissipates quickly and does not affect yield (Holloway, 2000). Preliminary studies indicate that CGA 362622 provides activity on sicklepod (*Senna obtusifolia*), ivyleaf morningglory (*Ipomoea hederacea*), pitted morningglory (*Ipomoea lacunosa*), yellow nutsedge (*Cyperus esculentus*), purple nutsedge (*Cyperus rotundus*), redroot pigweed (*Amaranthus retroflexus*), hemp sesbania (*Sesbania exaltata*), common cocklebur (*Xanthium strumarium*), coffee senna (*Cassia occidentalis*), Florida beggarweed (*Desmodium tortuosum*), common lambsquarters (*Chenopodium album*), and johnsongrass (*Sorghum halepense*) (Wells, 2000).

---

[1] Weed Science Associate and Extension Weed Scientist, University of Arkansas, Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

Field studies were established in the 2000 growing season at the Southeast Research and Extension Center at Rohwer, Arkansas. In field studies DP 451 B/RR and BXN 47, (*Gossypium hirsutum* L.) varieties were planted on 17-18 May 2000 in conventional 96-cm rows. The experimental design was a randomized complete block with four replications. Cotton was grown under normal cultural practices and sprinkler-irrigated as needed. Preemergence and over-the-top herbicide applications were applied with a CO_2 backpack sprayer equipped with 8002 VS flat fan nozzles calibrated to deliver a 140 l/ha volume. Greenhouse studies were established on 31 October 2000 at the University of Arkansas Altheimer Laboratory at Fayetteville, Arkansas, to determine levels of injury from applications of CGA 362622 to cotton growing in soils with moisture levels at field capacity and under saturated conditions. A BXN variety was planted in 8 x 8.5-cm pots and watered as needed until 36 h prior to treatment. When plants reached the 4- to 6-leaf stage all treatments were flooded; however, when the soil was fully saturated the field capacity treatments were allowed to drain while saturated treatments remained flooded and were sprayed 36 h later. A flood was maintained in these treatments for 36 h after applications. All treatments were applied with a spray chamber calibrated to deliver a 140 l/ha. All evaluations were separated using analysis of variance.

RESULTS

In field studies, weed control with preemergence applications of CGA 362622 was greater than 80% across all species evaluated at 14 days after treatment (DAT). At 28 DAT, only the 11 g ai/ha treatments provided greater than 80% control of sicklepod, hemp sesbania, Palmer amaranth, and pitted morningglory. Prickly sida control at 28 DAT had decreased to 60%. Injury from preemergence applications ranged from 13 to 43 % at 14 DAT, but dissipated to less than 10% at 28 DAT with all rates. Early and mid-postemergence applications of CGA 362622 provided greater than 90% control of Palmer amaranth and pitted morningglory at all rates at 14 DAT; however, at 28 DAT control of Palmer amaranth with the low rate of 2.7 g ai/ha had decreased to less than 70%. Following postemergence applications there were no significant differences in hemp sesbania or sicklepod control between CGA 362622 rates; however, sicklepod control with the low rate of 2.7 g ai/ha did decrease at 28 DAT to less than 50%. There was no control of prickly sida with postemergence applications of CGA 362622. Glyphosate at 0.85 kg ai/ha applied postemergence provided greater than 85% control of Palmer amaranth and hemp sesbania at all application timings; however, sicklepod and pitted morningglory control was less than 85% at all timings. CGA 362622 applied in combination with glyphosate provided greater than 90% control of all species at 2- to 4-leaf and 4- to 6-leaf application timings. Injury was observed in over-the-top applications that combined glyphosate and CGA 362622 at 2- to 4-leaf applications; however, injury dissipated quickly and was not visible at 21 DAT. Bromoxynil at 0.56 kg ai/ha provided excellent control of pitted morningglory and hemp sesbania at all application timings; however, sicklepod and Palmer amaranth control was less than 50% when bromoxynil was applied alone. When bromoxynil was combined with CGA 362622, control of sicklepod and Palmer amaranth was increased to 90% or greater at all application timings.

In greenhouse trials, rates of CGA 362622 were applied ranging from 2.7 to 11 g ai/ha to evaluate differences in visual injury symptomology and shoot dry weight after postemergence applications. A significant difference in shoot dry weight was observed between the treated and untreated plants; however, there were no differences in dry weights between rates of CGA 362622. Visually confirmed injury did occur with all rates and did increase as rate increased.

PRACTICAL APPLICATION

The yield loss due to weed pressure in Arkansas was over 1.3 million bales in 1997 (Webster, 1998). Some of the most troublesome weeds in cotton are yellow nutsedge, Palmer amaranth, prickly sida, entireleaf morningglory, pitted morningglory and hemp sesbania. Initial observations indicate that CGA 362622 has the potential to offer growers a tool to control these troublesome weeds while complementing the glyphosate-tolerant and bromoxynil-resistant cotton programs. Research will provide more conclusive data on crop safety, weed spectrum, and soil residual properties of CGA 362622. These data will be used to advise producers on proper use patterns and provide data for other university scientists to facilitate better recommendations to producers.

LITERATURE CITED

Anonymous. 1998. Weed Survey-Southern States. Southern Weed Science Society Proc. 51:299-313.

Holloway, J.C. 2000. CGA 362622 performance in cotton and sugarcane. Proc. Beltwide Cotton Conference. National Cotton Council, Memphis, TN. 1:1459-1460.

Webster, E.P. 1998. Report of the 1997 cotton weed loss committee. 1998 Proc. Beltwide Cotton Conference. National Cotton Council, Memphis, TN. 1:837.

Wells, J.W. 2000. Introduction to CGA 362622, a new postemergence herbicide. Proc. Beltwide Cotton Conference. National Cotton Council, Memphis, TN. 1:1459.

RESPONSES OF COTTON IN 2000 TO STRESS ASSOCIATED WITH TREATMENT LEVELS OF INSECT CONTROL, IRRIGATION, AND GLYPHOSATE

Jim L. Barrentine, Tina G. Teague, N. Philip Tugwell,
Diana M. Danforth, Oscar C. Sparks, and Marilyn R. McClelland[1]

RESEARCH PROBLEM

Glyphosate has become an important postemergence herbicide option since the introduction of Roundup Ready (glyphosate-resistant) cotton. However, glyphosate can reduce yield or delay maturity by affecting early-season fruit retention when applied past the four-leaf stage of growth. Data on how cotton fruiting is affected by glyphosate throughout the season are needed so a high-yielding crop can be grown without having to rely on late-season compensation to achieve that yield. The purpose of the two experiments described in this research was to evaluate cotton response to glyphosate applied up to maximum labeled rates (glyphosate selectivity experiment) and applied under different irrigation and insect management regimes with labeled and off-label applications (crop stress experiment).

BACKGROUND INFORMATION

Glyphosate is labeled for over-the-top application to tolerant cotton cultivars through the four-leaf stage and must be carefully post-directed after that. Total in-crop applications from cracking to layby should not exceed 4 lb ai/acre. Although glyphosate causes very few to no visible injury symptoms, it can reduce yield or delay maturity of glyphosate-tolerant cotton by affecting early-season fruit retention if applied over-the-top after the four-leaf stage of development (Jones and Snipes, 1999; Baughman *et al.*, 1999; Kalaher *et al.*, 1997). Baughman *et al.* (1999) reported yield reduction from 9- and 12-node applications at one location in Louisiana, but not at another. In Tennessee, yield was not reduced with applications at 4, 6, 8, 10, and 12 leaves (Matthews *et al.*, 1997), and Voth *et al.* (1997) reported no yield reduction or boll shed with labeled

[1] Professor/Head, Department of Crop, Soil, and Environmental Sciences, Fayetteville; Associate Professor of Entomology, Arkansas State University, Jonesboro; Professor, Department of Entomology, Fayetteville; Senior Research Associate, Department of Agricultural Economics and Agribusiness, Fayetteville; Graduate Research Specialist and Senior Research Associate, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

treatments unless the bottom 25% of the plant was sprayed at the 10- to 14-leaf stage. However, Kalaher *et al.* (1999) in North Carolina reported yield reduction with applications at the 8-leaf and first-flower stage of cotton growth. Number of bolls at the lower nodes were reduced, and although more squares were produced at higher positions, maturity was delayed and yields were often reduced because later-set bolls were not harvestable.

As is evident from these studies, yield is not always an accurate indicator of effect of glyphosate on the development of the cotton plant. The ability of cotton to compensate for stress, whether environmental or chemical, may mask effects of potential yield-reducing stresses. Reynolds *et al.* (1999), for example, indicated that favorable late-season weather allowed plants to compensate for early-season fruit losses caused by glyphosate, although unfavorable late-season conditions might result in an inability to compensate for fruit loss, and significant yield reduction could occur.

RESEARCH DESCRIPTION

Two experiments were conducted at Marianna, Arkansas, in 2000. In the glyphosate selectivity experiment, five treatments of glyphosate were applied, all within the label: 1 and 2 lb ai/acre at the cotyledon (cot.) to 1-leaf (lf) stage and 3- to 4-lf stage and 1 lb/acre at cot. to 1-lf followed by (*fb*) 3- to 4-lf *fb* 8-lf *fb* 13-lf (cot. to 1-lf and 3- to 4-lf treatments were applied over-the-top; 8- and 13-lf treatments were post-directed). An untreated check was included. Cotton cultivar DP 451BR was planted 24 May in 13- by 24-ft plots with four replications, and glyphosate was applied 5 June (cot. to 1-lf); 19 June (3- to 4-lf); 28 June (8-lf); and 8 July (13-lf) at 15 gal/acre carrier volume.

The glyphosate/crop stress experiment was conducted as a split-split plot design with main plots of insect control (full-season and no control before first flower); subplots of irrigation (irrigated full-season and to first flower only); and sub-subplots of five glyphosate treatments [1, 2, and 4 lb ai/acre over-the-top at 3- to 4-lf cotton; 2 lb/acre over-the-top at 7- to 8-lf cotton (‘off-label’ treatment); and untreated]. Cultivar SG 125 BG/RR was planted 10 May in 25- by 40-ft plots with three replications. Insecticides (Leverage, Karate, or Baythroid) were applied 23 June through 13 July on full-season control plots only and 19 July through 28 August (after first flower) on all plots. All plots were irrigated 8 July (before first flower), and plots with full-season irrigation were irrigated 19 July through 28 August.

Cotton stands, heights, and yields were recorded for each experiment. Cotton growth and development were monitored using COTMAN (COTton MANagement monitoring system) (Danforth and O’Leary, 1998) for in-season nodal development. COTMAP (Bourland and Watson, 1990) was used for final plant mapping to evaluate treatment effects on plant structure, fruiting pattern, and fruit retention. Data were analyzed by analysis of variance, and means were separated with LSD at 0.05.

RESULTS

Glyphosate applied within the label in the glyphosate selectivity experiment did not reduce cotton yield, although boll retention at first position sympodia and early boll retention were reduced by 1 and 2 lb/acre glyphosate applied at 3- to 4-lf cotton and by sequential applications totaling 4 lb/acre throughout the season, which included a 3- to 4-lf application (Table 1). Slight visual injury (<14%), expressed as “water soak” spots on leaves, was observed from glyphosate applied at 2 lb/acre to cot. to 1-lf cotton.

No immediate visual injury or pre-flower differences from glyphosate were evident in the crop stress experiment; however, differences in boll retention became apparent after first flower. Plants treated with off-label glyphosate (2 lb/acre over-the-top at 7- to 8-lf cotton) shed more large bolls (>9 days old) than plants treated at the 2- to 3-lf stage (Fig. 1). The relative effect on boll shed of glyphosate rates and application times was more apparent with full-season insect control than with no early insect control (Table 2). The off-label glyphosate treatment was apparent regardless of level of insect control. Where shedding occurred on the first two positions of the lower five sympodia, a higher percentage of bolls was retained on the 3rd and outer positions. Higher levels of square shedding (no early insecticide) plus boll shedding (glyphosate) were associated with later continued terminal growth (higher NAWF) (Fig. 2a). Higher boll shedding (insects controlled) was expressed by a still later surge in growth (Fig. 2b). Late continued growth was also expressed in a significant maturity delay when glyphosate was applied off-label (data not shown). Only glyphosate applied at the 7- to 8-lf stage reduced lint yields (421 lb/acre vs. 609 to 675 lb/acre for other treatments).

In summary, glyphosate applied within the label did not reduce yield, although boll retention was reduced by 3- to 4-lf applications and a total of 4 lb/acre during the season. Glyphosate applied ‘off-label’ at 2 lb/acre over-the-top at 7- to 8-lf cotton affected structural development of cotton by causing greater NAWF, especially with no early insect control, although pre-flower square shed and cotton stand were not affected. The off-label treatment increased shed of large bolls (>9 days old) but not of small bolls (<9 days old), indicating that glyphosate applied early in the season may evoke a response in the cotton plant much later. Cotton yield was reduced with the off-label treatment, regardless of level of irrigation or insect control. COTMAN was effective for detecting the effects of glyphosate and discriminating among treatments.

PRACTICAL APPLICATION

These experiments confirm that glyphosate should not be applied over-the-top after the four-leaf stage to current glyphosate-tolerant cotton cultivars, regardless of irrigation and insect control practices. Glyphosate may exert a stress on the cotton plant even when applied at the four-leaf stage (decline in boll retention), so good crop management practices should be followed to allow for optimal compensation by the cotton plant. Interactions of glyphosate and other crop stresses, such as insects, need to be further evaluated.

LITERATURE CITED

Baughman, T.A., E.P. Webster, J.W. Sij, Jr., and D.G. Bordovsky. 1999. Effect of postemergence topical applications of Roundup on Roundup Ready cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Vol. 1. p. 731.

Bourland, F.M. and C.E. Watson. 1990. COTMAP, a technique for evaluating structure and yield of cotton plants. Crop Sci. 30:224-226.

Danforth, D.M. and P.F. O'Leary (eds). 1998. COTMAN expert system 5.0. University of Arkansas, Agricultural Experiment Station, Fayetteville; and Cotton Incorporated, Raleigh, NC.

Jones, M.A. and C.E. Snipes. 1999. Tolerance of transgenic cotton to topical applications of glyphosate. J. Cotton Sci. 3:19-26.

Kalaher, C.J., H.D. Coble, and A.C. York. 1997. Morphological effects of Roundup application timings on Roundup Ready cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Vol. 1. p. 780.

Matthews, S.G., P. Brawley, T.C. Mueller, and R.M. Hayes. 1997. What happens when Roundup Ready cotton is sprayed with Roundup after the four-leaf stage? Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN. Vol. 1. p. 779.

Reynolds, D.B., S.L. File, R.E. Blackley, and C.E. Snipes. 1999. The effect of Roundup on Roundup Ready cotton. Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN. Vol. 1. p. 732.

Voth, R.D., J.A. Mills, and P.R. Rahn. 1997. Roundup Ready cotton tolerance to Roundup Ultra (glyphosate) herbicide. Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN. Vol. 1. p. 779.

Table 1. Effect of glyphosate rate and timing on cotton yield and fruiting, Marianna, Arkansas, 2000.[z]

Application stage[y]	Glyphosate rate	Seed cotton yield	BR[x] 1st posit.	EBR[w]	NAWF[v]
	(lb ai/acre)	(lb/acre)	------------ (%)	----------	(days)
Untreated		2979 a	38 a	47 a	75 a
Cot - 1 lf	1	2954 a	39 a	44 a	74 a
	2	3185 a	37 a	40 ab	75 a
3 - 4 lf	1	2635 a	24 b	29 bc	74 a
	2	2438 a	25 b	27 bc	72 a
Cot - 1lf + 3 - 4 lf + 8 lf + 13 lf	1	2728 a	22 b	24 c	80 a

[z] Means followed by the same letter do not differ by LSD (0.05).
[y] Cot to 1-lf and 3- to 4-lf applied over-the-top; 8 and 13 lf post-directed.
[x] Boll retention at first sympodia fruiting position.
[w] Early boll retention at first and second position on five lowest fruiting branches.
[v] Projected days to physiological cutout (nodes above white flower = 5).

Table 2. Interaction of glyphosate treatment and insect control on large-boll (>9 days old) shed, averaged over irrigation (2 August). Marianna, 2000.

	Large boll shed[z]	
Glyph. OT[y] rate/stage	Full-season insecticide	No insecticide pre-flower
(lb ai/acre)	------------------------------------ (%[x])	-----------------------------
Untreated	18 c	51 b
1, 2-3 lf	23 bc	52 b
2, 2-3 lf	17 c	61 ab
4, 2-3 lf	40 b	59 b
2, 7-8 lf	81 a	80 a

[z] Means within each column followed by the same letter do not differ according to LSD (0.05) = 19.5.

[y] OT = over-the-top.

[x] Percentages include insect-induced square shed and boll shed associated with glyphosate.

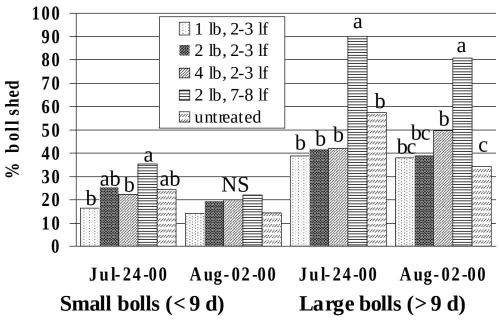


Fig. 1. Percent shed of small (<9 days old) and large (>9days old) bolls as affected by glyphosate applied over-the-top, averaged over irrigation and insect control. Means in each date and boll size group with the same letter do not differ.

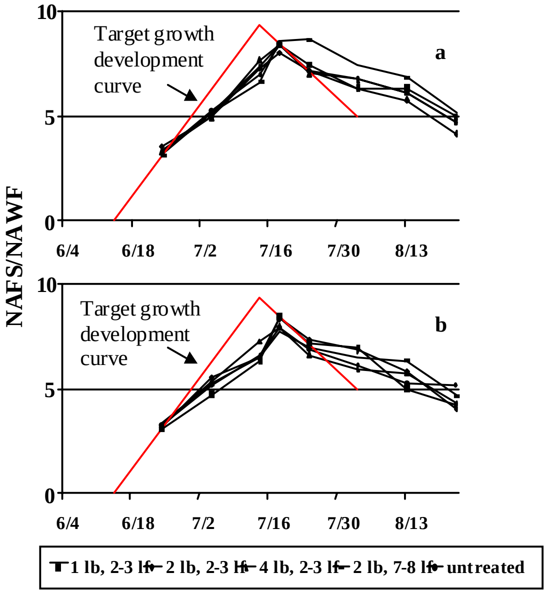


Fig. 2. Growth patterns for irrigated cotton treated with glyphosate applied over-the-top. a = no insect control before first flower; b = full-season insect control. NAFS/NAWF = nodes above first square (until after first flower at 7-14), then nodes above white flower.

VALOR™ (FLUMIOXAZIN) HERBICIDE APPLIED LAYBY IN COTTON

Marilyn R. McClelland, Jim L. Barrentine, Oscar C. Sparks, Kenneth L. Smith, and Jeffrey L. Branson[1]

RESEARCH PROBLEM

One of the primary herbicides used post-directed at layby in cotton has been Bladex™ (cyanazine). It gives rapid control of weeds present and provides enough residual control to prevent new infestations before harvest. Bladex, however, has been withdrawn from the market, and other herbicides must be used to replace it. The objective of this research was to evaluate Valor™ (flumioxazin) applied layby following a standard, early-season herbicide program.

BACKGROUND INFORMATION

Valor was evaluated a decade ago as V-53482 on cotton and soybean in Arkansas (Jordan *et al.*, 1990). Experiments on soybean were continued, but preemergence use in cotton was abandoned because of severe cotton injury. In the past few years, Valent USA Corp. has been developing Valor as a preemergence herbicide for soybean, peanut, and sugarcane (Cranmer *et al.*, 2000). It is also being evaluated preplant and postemergence in cotton (Guy and Carey, 2000; Wilcut *et al.*, 2000).

Flumioxazin is an N-phenylphthalimide herbicide that degrades rapidly in water and soil and has low carryover potential to rotational crops. Because its mode of action differs from other cotton herbicides, it offers a resistance management tool for a broad spectrum of weeds, including ALS- and triazine-resistant weeds (Altom *et al.*, 2000). It is of special interest as a cotton layby treatment since we are losing the option of cyanazine for post-directed use. However, because of potential cotton injury, Valor application is restricted to cotton at least 12 inches tall. The spectrum of activity of Valor at 0.063 to 0.094 lb ai/acre includes morningglory species (*Ipomoea* spp.), prickly sida (*Sida spinosa* L.), pigweed species (*Amaranthus* spp.), and several other broadleaf species common to cotton grown in the mid-South.

---

[1] Research Associate, Professor/Head, and Graduate Research Specialist, Department of Crop, Soil, and Environmental Sciences, Fayetteville; Extension Weed Scientist and Graduate Research Specialist, Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

Experiments were conducted in 1999 and 2000 at Fayetteville and Marianna, Arkansas, and in 2000 at Rohwer (all silt loam soils). Cotton was planted 3 June and 22 May at Fayetteville, 19 May and 11 May at Marianna (1999 and 2000, respectively), and 24 May at Rohwer. Each experiment was a randomized complete block design with four replications. Plot size at Marianna and Rohwer was four 38-in. rows by 27 ft., and Fayetteville plots were one 40-in. row by 27 ft. All plots were treated with standard PRE (preemergence) and POST (postemergence) treatments to suppress weeds until layby: trifluralin PPI (preplant incorporated) *fb* (followed by) fluometuron PRE *fb* fluometuron + MSMA DIR (post-directed) at 3- to 6-in. cotton at Fayetteville (1999 only) and Marianna; Roundup Ultra at 1-leaf over-the-top and 6-leaf DIR at Fayetteville in 2000; and trifluralin PPI at Rohwer. Valor at 0.063 was applied at layby alone or with MSMA at 2.0 lb ai/acre or Roundup Ultra at 1.0 lb ai/acre. Layby treatments were applied 29 July and 13 July at Fayetteville (1999 and 2000, respectively); 12 July and 5 July at Marianna; and 11 July at Rohwer. Valor treatments were applied with 1% crop-oil concentrate in 1999 and 0.25% non-ionic surfactant in 2000. Herbicides were applied in a water carrier at 15 gal/acre output. Visual weed control and cotton injury ratings were collected 1 to 4 weeks after layby treatments (WAT). Two-week ratings are discussed. Cotton yield was harvested only at Rohwer. Data were analyzed by analysis of variance, and means were separated by LSD (0.05).

RESULTS

Annual grass control, primarily broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] at Fayetteville and Marianna and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] at Rohwer, ranged from 80 to 100% (Fig. 1). Control with Valor plus glyphosate was better than with Valor alone or mixed with MSMA at Rohwer. Control of smooth pigweed (*Amaranthus hybridus* L.) and pitted morningglory (*Ipomoea lacunosa* L.) was good to excellent (90 to 100%) with all treatments (Figs. 2 and 3). As with annual grasses, prickly sida, was controlled better with Valor plus glyphosate than with Valor alone at Rohwer (Fig. 4). Control of several other species is presented in Table 1. Velvetleaf (*Abutilon theophrasti* Medicus) control depended on good spray coverage that included the terminal of the plants. Yellow nutsedge (*Cyperus esculentus* L.) was suppressed by Valor alone (66%) and control was increased with the addition of MSMA and glyphosate (84% and 85%, respectively). Cotton tolerance to Valor treatments was good, with only 3 to 14 % injury at 1 and 2 WAT, manifested as leaf desiccation and slight stem discoloration where contacted by spray (data not shown). Yield at Rohwer was not affected (data not shown).

PRACTICAL APPLICATION

Valor is promising as a layby treatment in cotton for its contact and residual activity. It is a viable replacement for cyanazine at layby. However, because of potential cotton injury, Valor cannot be applied on cotton less than 12 inches tall therefore cannot replace cyanazine as a mid-season post-directed application. Glyphosate and MSMA are good tank-mix companions for Valor.

LITERATURE CITED

Altom, J.V., J.R. Cranmer, and F.A. Pawlak. 2000. Valor herbicide - the new standard for layby applications in cotton. Proc. South. Weed Sci. Soc. 53:159.

Cranmer, J.R., F.V. Altom, J.C. Braun, and J.A Pawlak. 2000. Valor herbicide: A new herbicide for weed control in cotton, peanuts, soybeans, and sugarcane. Proc. South. Weed Sci. Soc. 53:158.

Guy, C. and F. Carey. 2000. Evaluation of Valor (flumioxazin) for preplant and in-season weed control in cotton. Abst. Ark. Crop Protection Assoc. 4:6.

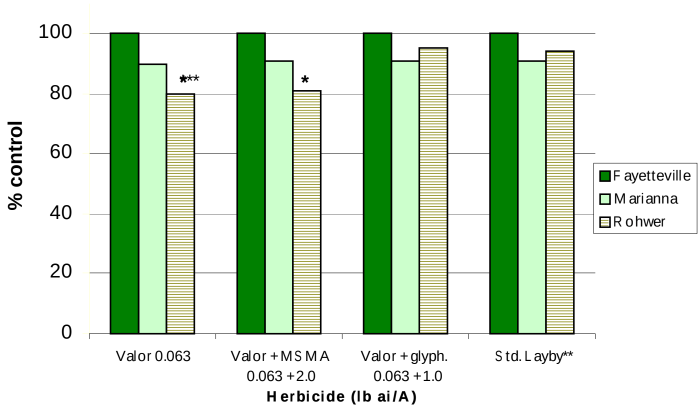
Jordan, D.L., R.E. Frans, M.R. McClelland, and W.G. Johnson. 1990. Spectrum of activity of V-53482. Proc. South. Weed Sci. Soc. 43:158.

Wilcut, J.W., S.D. Askew, A.J. Price, G.H. Scott, and J. Cranmer. 2000. Valor: A new weed management option for cotton. Proc. South. Weed Sci. Soc. 53:159.

Table 1. Control of velvetleaf in 1999 and hemp sesbania in 2000 at Fayetteville, Arkansas, and yellow nutsedge in 1999 at Marianna, Arkansas, with Valor treatments applied layby following standard early-season practices.

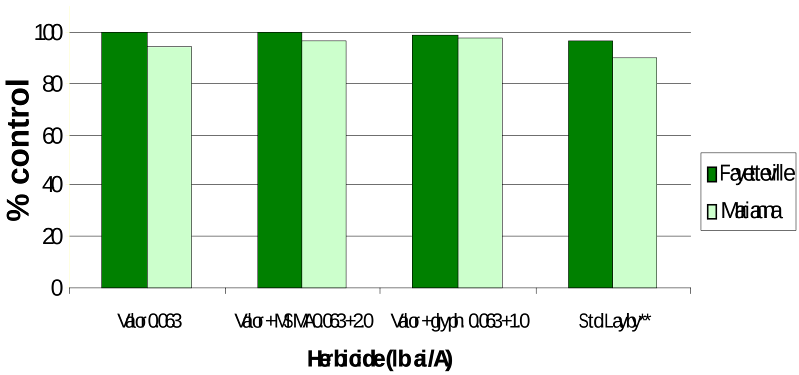
Herbicide	Rate	Velvetleaf	Hemp sesbania	Yellow nutsedge
	(lb ai/acre)	(%)		
Valor	0.063	94	97	66
Valor + MSMA	0.063 + 2.0	90	100	84
Valor + glyphosate	0.063 + 1.0	84	97	85
Std. layby	--[z]	90	100	80
LSD (0.05)		NS	NS	11

[z] Prometryn (Caparol) or cyanazine + MSMA.



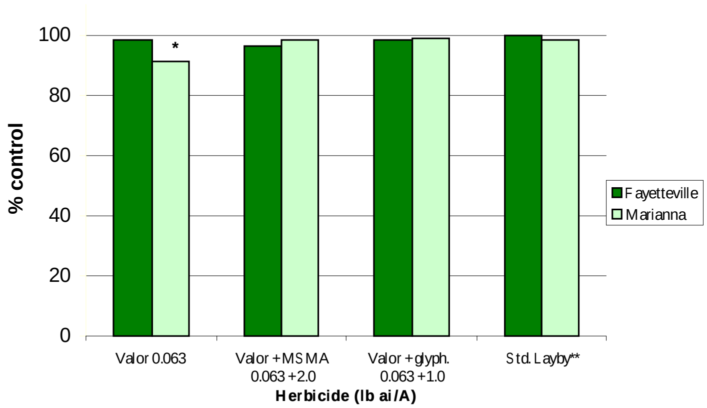
* significantly different by LSD (0.05)
** prometryn or cyanazine + MSMA

Fig. 1. Percent control 2 WAT of annual grasses (primarily broadleaf signalgrass at Fayetteville and Marianna, Arkansas, and barnyardgrass at Rohwer, Arkansas) 1999-2000 with Valor treatments applied at layby following standard early-season practices.



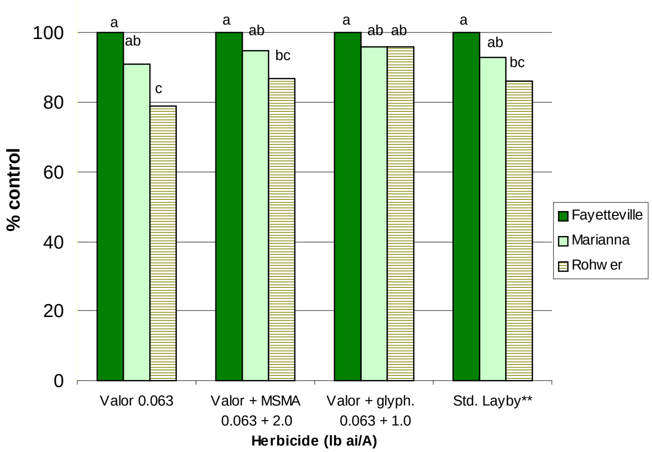
** prometryn or cyanazine + MSMA

Fig. 2. Percent control 2 WAT of smooth pigweed 1999-2000 with Valor treatments applied at layby following standard early-season practices.



* significantly different by LSD (0.05)
** prometryn or cyanazine + MSMA

Fig. 3. Percent control 2 WAT of pitted morningglory 1999-2000 with Valor treatments applied at layby following standard early-season practices.



* means with the same letter do not differ significantly [LSD (0.05)]
** prometryn or cyanazine + MSMA

Fig. 4. Percent control 2 WAT of prickly sida 1999-2000 with Valor treatments applied at layby following early-season practices.

THE EFFECT OF DIFFERENT HERBICIDE PROGRAMS AND ROW SPACINGS FOR CONTROL OF WEEDS IN TRANSGENIC COTTON

Michelle L. Mobley, Nilda R. Burgos, and Marilyn R. McClelland[1]

RESEARCH PROBLEM

The technology of cultivars resistant to postemergence (POST) herbicides provides the possibility of eliminating soil-applied herbicides, reducing the number of herbicide applications, and facilitating planting cotton in a conservation-tillage program and in ultra-narrow-row (UNR) spacing. Cotton grows very slowly early in the season, and a weed-free period of 8 to 10 weeks after planting is necessary to prevent yield reduction (McWhorter and Abernathy, 1992). This research was designed to determine if a soil-applied herbicide is necessary in weed control programs for transgenic cotton planted in UNR and conventional row spacing.

BACKGROUND INFORMATION

UNR cotton is defined as cotton planted in 19- to 38-cm row spacing (Jost and Cothren, 1999). Research has shown UNR production is economically feasible on marginal land (Reeves *et al.*, 1998). Planting UNR cotton entails investment in different machinery and presents different management challenges. Weed control used to be a major challenge in UNR cotton because of the unavailability of herbicides that could be sprayed over-the-top of cotton. In-season application of herbicides for broadleaf weeds used to be impossible in UNR cotton; however, with the commercialization of pyrithiobac (Staple®) and herbicide-resistant cotton, producers now have a choice of three herbicides (other than selective grass killers) that can be applied over-the-top of cotton.

MATERIALS AND METHODS

Studies were conducted at Fayetteville and Marianna in 2000. The study design at both locations was a split plot, with row spacing as the main plot and herbicide

[1] Graduate Assistant, Assistant Professor, and Senior Research Associate, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

programs and cultivars in a factorial arrangement as subplots. At Fayetteville, subplots were 4 by 6 meters and were irrigated. At Marianna, subplots were 2 by 9 meters in UNR main plots and 4 by 9 meters in conventional-row main plots, and irrigation was not available. The study was planted 24 May 2000 at Fayetteville and 15 May at Marianna. Plots with UNR spacing were rotary hoed and replanted 2 June at Fayetteville because of a poor stand (less than two plants/meter in many areas). Plots were overseeded with pitted morningglory, entireleaf morningglory, prickly sida, large crabgrass, and Palmer amaranth to insure adequate weed pressure was present. A natural infestation of goosegrass was present at Marianna. Treatments included transgenic cultivars of glyphosate-resistant (PM1218 BG/RR) and bromoxynil-resistant (BXN47) cotton in conventional (102 cm) and UNR spacing (19 to 25 cm) with or without preemergence herbicides. Weed control ratings at both locations were taken before the first postemergence (POST) application and at 2, 4, and 8 weeks after the last POST application.

All UNR cotton was planted on unbedded ground with a drill (19-cm row spacing) at Fayetteville and a tractor-mounted, box-type Planet Jr. unit (25-cm row spacing) at Marianna. Conventional cotton was planted on raised beds. The population for UNR cotton was 7 to 10 plants/meter, and approximately 13 plants/meter for conventional row spacing.

At all locations, herbicide programs for the glyphosate-resistant cultivar, PM1218, included (a) preemergence (PRE) application of fluometuron and metolachlor followed by (*fb*) glyphosate at the one- to three-leaf and six- to eight-leaf cotton stage with pyrithiobac and clethodim applied as needed or (b) a total postemergence (POST) program of glyphosate at one to three and six to eight cotton leaves. Herbicide programs for bromoxynil-resistant cotton, BXN47, included (a) fluometuron and metolachlor applied PRE *fb* bromoxynil and pyrithiobac at one-to three-leaf cotton and clethodim as needed or (b) a total POST application of bromoxynil and pyrithiobac one- to three-leaf cotton and clethodim as needed.

RESULTS

At Marianna, applying a PRE herbicide program increased control for all weed species except goosegrass and prickly sida, which did not respond differently to the PRE *fb* POSTand the total POST herbicide programs. Palmer amaranth control was better in UNR spacing (99%) than in conventional row spacing (78%). Row spacing, averaged over herbicide programs, did not influence control of the other weed species. Pitted morningglory control at Fayetteville was equal with the PRE *fb* POST and total POST programs (95 and 96%). For Palmer amaranth, the PRE *fb* POST program provided the same control as the total POST program (95 and 100%). This was also true for entireleaf morningglory and prickly sida (93 to 96% control). Row spacing did not influence control for any of the weed species at Fayetteville.

PRACTICAL APPLICATION

When weed pressure is high, a PRE herbicide increases the efficacy of most weed control programs. Culpepper and York (1999) and McWhorter and Abernathy (1992) found significant improvement in weed control by POST herbicides when soil-applied herbicides were also used. For heavy weed infestations, such as Palmer amaranth at Marianna, UNR spacing provides better control due to shading and quicker canopy closure.

ACKNOWLEDGMENTS

We thank the staff at the Cotton Branch Station in Marianna for their assistance and Vaughn Skinner for facilitating field operations at Fayetteville. Scott Payne, Oscar Sparks, Erin Cable, Satyendra Rajguru, and Dennis Coker also assisted throughout the season.

LITERATURE CITED

Culpepper, A.S. and A.C. York. 1999. Weed management and net returns with transgenic, herbicide-resistant, and nontransgenic cotton (*Gossypium hirsutum*). Weed Technol. 13:411-420.

Jost, P.H. and J.T. Cothren. 1999. Is ultra-narrow row earlier than conventionally-spaced cotton? Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 640.

McWhorter, C. and J. Abernathy (eds.). 1992. Weeds of cotton: characterization and control. Memphis, TN: The Cotton Foundation.

Reeves, D., P. Bauer, C. Monks, P. Delaney, C. Burmester, and R. Goodman. 1998. Ultra-narrow row cotton: tillage, cover crops and nitrogen. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 623.

TWO-SPOTTED SPIDER MITE MANAGEMENT IN COTTON

Jack Reaper, III, John D. Hopkins, Donald R. Johnson,
Gus M. Lorenz, III, Donald C. Steinkraus, and M. Chad Norton[1]

RESEARCH PROBLEM

The two-spotted spider mite, *Tetranychus urticae*, is an economic threat to cotton acreage in Arkansas. Damage from this pest will likely increase with the implementation of the Boll Weevil Eradication Program in southeast Arkansas. Frequent evaluation of the performance of commercial miticides is necessary to maintain up-to-date extension recommendations for mite control and to effectively implement resistance management strategies.

BACKGROUND INFORMATION

Damage caused by the two-spotted spider mite, *Tetranychus urticae*, can result in significant economic damage to cotton in Arkansas as well as in the entire U.S. Cotton Belt. In 1999, spider mites caused yield losses greater than 1,000 bales in Arkansas and 30,000 bales nationwide (Williams, 1999). Hot, dry conditions across the mid-South during the past few growing seasons created a favorable environment for this pest. Although some cultural practices help in preventing infestation in cotton, chemical control with miticides remains the most effective method.

Spider mites usually feed on the underside of leaves, removing vital chloropyll that causes a reduction in photosynthetic activity (Bondada *et al.*, 1995). This reduction in photosynthesis causes yellow speckling on the leaves that may turn red in color with increasing levels of infestation. Spider mite infestations usually begin on field borders and can increase with insecticide applications due to the removal of natural enemies (Gonzales *et al.*, 1982). Some weed species serve as hosts to spider mites (Steinkraus and Zawislak, 1999); therefore, control of weeds in cotton can be effective in suppressing spider mite populations.

---

[1] Entomology Extension Specialist and Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Extension Entomologist-Pest Management Section Leader, Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Professor, Department of Entomology, Fayetteville; and Staff Chair, Lincoln County Extension Office, Cooperative Extension Service, Star City.

The implementation of the Boll Weevil Eradication Program in southeast Arkansas will result in programmed insecticide applications throughout the area. This could increase the occurrence of spider mite infestations in cotton (Gonzales *et al.*, 1982). It is necessary to frequently monitor the performance of miticides in controlling the two-spotted spider mite as it becomes a potentially greater threat to Arkansas cotton production.

Experiments were conducted in Lonoke County, Arkansas, and Lincoln County, Arkansas, in 1999 and 2000, respectively, to evaluate the performance of currently available miticides for two-spotted spider mite management in cotton.

RESEARCH DESCRIPTION

The 1999 experiment was conducted on the James Ray Farm in Lonoke County. The cotton variety BXN 47 was conventionally sown in 38-inch rows on 11 May. Plot size was eight rows 75 ft in length. Treatments were arranged in a randomized complete block design with four replications. Insecticide treatments were initiated based upon state recommendations of 50% spider mite infestation. A John Deere 6000 hi-cycle sprayer equipped with a compressed air delivery system was used for treatment application. Total volume was 12 gal/acre at 45 psi using conejet TX6 nozzles with 20-inch spacing. The treatments listed in Table 1 were applied on 28 July. The center two rows of each plot were evaluated for spider mite infestation on 30 July (2 DAT) and 2 August (5 DAT). Ten leaves were randomly chosen from each plot and spider mites were counted in a 1-inch^2 area.

The Randy Eagle Farm in Lincoln County was the location of the 2000 experiment. The field was located within the boll weevil eradication zone and received programmed applications of ULV malathion throughout the growing season, which may have attributed to the spider mite infestation. BXN 47 was conventionally sown in 38-inch rows on 22 April. Plot size was eight rows 50 ft in length with a treatment design identical to the 1999 test. Application was similar to 1999 except a volume of 8.6 gal/acre was used. The treatments tested in 2000 were different from those tested in 1999 (Table 2). The application date was 13 July and spider mite populations were evaluated on 17 July (4 DAT), 20 July (7 DAT), and 28 July (15 DAT). The same methods used to evaluate spider mites in 1999 were used in 2000. Egg populations were evaluated in the same manner as live spider mites. Percentage spider mite control was determined from the number of spider mites present in the control treatment for the respective replication. Cotton yields were not evaluated in either year. Data were processed using Agriculture Research Manager Ver. 6.01. Means from both years were subjected to analysis of variance and 5% significance was determined using the Student-Newman-Keuls Test (1999) and Duncan’s New Multiple Range Test (2000).

RESULTS AND DISCUSSION

No statistical differences occurred among any treatments in 1999 for either evaluation date (Table 1), although there were differences in spider mite populations on a numeric basis. Trends in the data for both evaluation dates indicated miticides that resulted in the best overall control for the testing period. On a numerical basis only, Capture™ (0.06 lb ai/acre), Lorsban™ (1 lb ai/acre), Curacron™ (1 lb ai/acre), and Zephyr™ (0.0093 lb ai/acre) were the most effective miticides in reducing spider mite populations.

In 2000, pre-treatment evaluation of the test area was implemented to determine the initial spider mite population. The overall average egg population was 156 per 10 leaves in addition to 65 live spider mites. Of the miticides tested, Lorsban, Zephyr, Capture, Capture + Ovasyn™, Comite™, and Denim™ significantly reduced egg populations below that of the untreated check 4 and 7 DAT (Table 2). Only the Comite treatment caused an increase in population of 33.3 eggs 15 DAT. All other treatments were significantly below this level. The Kelthane™ and Ovasyn treatments did not reduce spider mite egg populations in a timely manner.

Based on live spider mite counts, Capture, Lorsban, and Capture + Ovasyn provided the best initial suppression of mites (Table 3). However, these were not significantly higher than the Denim, Ovasyn, Zephyr, or Kelthane (1 lb ai/acre) treatments. Only the untreated check and Kelthane (0.75 lb ai/acre) did not reduce mite numbers lower than the 65 pre-treatment count. Fewer treatment differences were observed by 7 DAT. Only the Kelthane (1 lb ai/acre), Zephyr, and Comite treatments had significantly less spider mites than the control. All treatments maintained mite populations lower than the initial 65 per 10 leaves, indicating there was no rebound in spider mite population. By 15 DAT there were no treatment differences with respect to spider mite population. The life cycle of the spider mite usually lasts 10 to 15 days; therefore, the lack of difference could be attributed to a natural population decline. The percentage of spider mite control based upon live counts is displayed in Table 4. Capture provided the highest percent control 4 DAT with 77.8%; however, this level was only significantly different from the untreated check and Kelthane (0.75 lb ai/acre) treatments. All treatments with the exception of Kelthane and Zephyr provided significantly higher control (>50%) than the untreated check 4 DAT. The addition of Ovasyn to Capture did not increase spider mite control. All treatments, with the exception of Capture + Ovasyn, provided significantly greater spider mite control than the untreated check at 7 DAT. By 15 DAT, no differences among treatments with respect to spider mite control were observed.

Based upon the data collected from both studies, Capture (0.06 lb ai/acre), Lorsban (1 lb ai/acre), and Zephyr (0.0093 lb ai/acre) provided the most consistent and timely suppression of spider mites over the test period. Although it was not included in the 2000 experiment, Curacron (1 lb ai/acre) provided favorable spider mite control in 1999.

PRACTICAL APPLICATION

As the two-spotted spider mite becomes an increasing threat in Arkansas cotton production, miticides will be implemented in integrated pest management programs. Two years of data showed Capture, Lorsban, and Zephyr to be effective miticides. Curacron, Comite, and Ovasyn provided reasonable suppression. Selective use of these miticides can prevent the development of resistance in areas where spider mite infestations are common on a yearly basis.

ACKNOWLEDGMENTS

The authors would like to thank Mr. James Ray, Mr. Randy Eagle, AgrEvo, Bayer Corporation, Dow AgroSciences, FMC Corporation, Helena Chemical, Novartis Crop Protection, Uniroyal Chemical Company, Zeneca, and Rohm and Haas for providing the resources necessary to conduct this research.

REFERENCES

Bondada, B.R., D.M. Oosterhuis, N.P. Tugwell, and K.S. Kim. 1995. Physiological and cytological studies of two spotted spider mite (*Tetranychus urticae* K.) injury in cotton (*Gossypium hirsutum* L.). Southwest Entomologist 20(2):171-180.

Cotton Pest Management Scouting Manual: EC 561. University of Arkansas Cooperative Extension Service.

Gonzales, D., B.R. Patterson, T.F. Leigh, and L.T. Wilson. 1982. Mites, a primary food source for two predators in San Joaquin Valley cotton. Calif. Agric. 36:18-20.

Steinkraus, D. and J. Zawislak. 2000. Spider mites on Arkansas cotton: wild host plants and chemical control. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1255-1258.

Williams, M.R. 2000. Cotton insect losses 1999. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 887-913.

Table 1. Two-spotted spider mite total mite counts in 1999.

Treatment		Rate	Total mites	
			2 DAT	5 DAT
		(lb ai/acre)	(No./10 1-inch^2 samples)	
1	Untreated		72 a	60 a
2	Denim	0.01	18 a[z]	69 a
3	Capture	0.06	5 a	5 a
4	Karate	0.028	49 a	41 a
5	Baythroid	0.03	82 a	43 a
6	Decis	0.02	86 a	72 a
7	Lorsban	1.0	15 a	16 a
8	Curacron	1.0	5 a	10 a
9	Comite	1.5	60 a	44 a
10	Zephyr	0.0093	27 a	18 a
11	Zephyr	0.005	49 a	57 a
12	Dimethoate	1.0	64 a	66 a
13	Dimethoate	0.5	100 a	64 a

[z] Means followed by the same letter do not significantly differ (P=0.05, Student-Newman-Keuls).

Table 2. Two-spotted spider mite egg suppression in 2000.

Treatment		Rate	Eggs		
			4 DAT	7 DAT	15 DAT
		(lb ai/acre)	-------------- (No./10 1-inch^2 samples) -------------		
1	Untreated		94.0 a[z]	24.5 bc	3.0 b
2	Kelthane MF	0.75	95.8 a	44.0 a	1.0 b
3	Kelthane MF	1.0	82.0 ab	40.5 ab	1.5 b
4	Lorsban 4E	1.0	7.5 c	5.3 d	5.0 b
5	Zephyr 0.15EC	0.0093	12.8 c	4.5 d	3.3 b
6	Capture 2EC	0.06	4.0 c	6.0 cd	4.5 b
7	Capture 2EC + Ovasyn 1.5EC	0.06 + 0.125	10.3 c	4.0 d	12.0 ab
8	Ovasyn 1.5EC	0.5	57.8 abc	5.8 d	1.3 b
9	Comite 6.55EC	1.6375	10.3 c	5.8 d	33.3 a
10	Denim 0.16EC	0.01	18.8 bc	5.8 d	2.5 b

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

Table 3. Two-spotted spider mite suppression in 2000.

	Treatment	Rate	Mites		
			4 DAT	7 DAT	15 DAT
		(lb ai/acre)	-------------- (No./10 1-inch^2 samples) -------------		
1	Untreated		62.3 ab	27.8 a	2.3 a
2	Kelthane MF	0.75	78.5 a[z]	10.5 ab	1.0 a
3	Kelthane MF	1.0	39.3 abc	6.0 b	2.3 a
4	Lorsban 4E	1.0	14.3 c	10.0 ab	2.5 a
5	Zephyr 0.15EC	0.0093	28.0 bc	3.0 b	3.3 a
6	Capture 2EC	0.06	7.8 c	14.5 ab	2.3 a
7	Capture 2EC + Ovasyn 1.5EC	0.06 + 0.125	18.0 bc	15.3 ab	4.3 a
8	Ovasyn 1.5EC	0.5	23.8 bc	11.5 ab	2.3 a
9	Comite 6.55EC	1.6375	17.0 c	5.5 b	2.8 a
10	Denim 0.16EC	0.01	25.3 bc	14.8 ab	3.0 a

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

Table 4. Percentage of two-spotted spider mite control in 2000.

	Treatment	Rate	Control[z]		
			4 DAT	7 DAT	15 DAT
		(lb ai/acre)	--------------------------- (%) --------------------------		
1	Kelthane MF	0.75	17.3 bc[y]	48.5 a	33.3 a
2	Kelthane MF	1.0	37.2 abc	69.5 a	25.0 a
3	Lorsban 4E	1.0	53.0 ab	68.7 a	50.0 a
4	Zephyr 0.15EC	0.0093	37.4 abc	81.0 a	25.0 a
5	Capture 2EC	0.06	77.8 a	65.1 a	41.7 a
6	Capture 2EC + Ovasyn 1.5EC	0.06 + 0.125	66.7 a	36.5 ab	25.0 a
7	Ovasyn 1.5EC	0.5	60.0 ab	57.0 a	41.7 a
8	Comite 6.55EC	1.6375	69.9 a	69.6 a	30.0 a
9	Denim 0.16EC	0.01	50.6 ab	57.8 a	25.0 a

[z] Control calculated as percentage of live mites in untreated check.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

TARNISHED PLANT BUG, *LYGUS LINEOLARIS*, MANAGEMENT IN COTTON

Donald R. Johnson, Gus M. Lorenz III, Jack D. Reaper III, John D. Hopkins, Glenn Studebaker, and Richard Edmund[1]

RESEARCH PROBLEM

The decreased use of insecticides in many cotton integrated pest management programs could potentially increase tarnished plant bug damage in Arkansas cotton. Experiments were conducted in Jefferson County and Mississippi County, Arkansas, in 1999 and 2000, respectively, to evaluate the performance of conventional and new insecticides in controlling tarnished plant bugs in cotton.

BACKGROUND INFORMATION

The tarnished plant bug is a pest of cotton production in Arkansas that requires attention each year. The damage is normally inflicted on the youngest squares in the terminal area of the plant. Prolonged infestations will cause substantial damage and subsequent loss of yield. In Arkansas, treatment is recommended when infestations are around 1 tarnished plant bug per row foot or when infestations are present and square set is starting to decline below 75 to 80% set. An average of 0.68 applications per acre was utilized to control tarnished plant bugs in 1992 and 0.73 applications in 1993 (Johnson *et al.*, 1999).

The tarnished plant bug (*Lygus lineolaris*), herinafter plant bug, is one of the most polyphagus insects that has hundreds of hosts (Young, 1986). Tarnished plant bugs overwinter as adults in and around host plant areas. The availability of host plants is an important factor of population expansion in the spring. When the early host plants begin to senesce and decline in abundance, the plant bug starts migrating into areas where favorable host plants occur, and in many areas of Arkansas that host plant is cotton. Plant bugs have also been found on other host plants in the Mississippi River Delta region including soybean, but cotton is the most important crop that

---

[1] Extension Entomologist-Pest Management Section Leader, Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Entomology Extension Specialist and Entomology Associate Specialist, Cooperative Extension Service, Lonoke; and Technical Representative, DuPont Agricultural Products, Little Rock.

is directly affected by plant bugs. In cotton, a generation may be produced in approximately 30 days. As a result, two or more generations may develop in cotton.

The introduction and adoption of the transgenic cotton containing the *Bacillus thuringiensis* gene has reduced the overall requirements for insecticide in the cotton production system. Furthermore, the success of the boll weevil eradication program is eliminating the need for insecticide use to control boll weevil. The evolution of cotton insecticides has also shifted toward the newer insecticides emamectin benzoate (Denim), spinosad (Tracer), and indoxacarb (Steward). Spinosad has not shown activity in the control of plant bugs but the use of indoxacarb has shown some efficacy against plant bugs activity. Overall, the trend in insecticide development is to develop products that are not as broad-spectrum and more specific in activity. As a result, the potential for plant bug population increases in cotton fields may be a larger problem in the future than in the past.

In the mid-South cotton producing region, entomologists have been concerned about the plant bug for many years and have conducted numerous studies on this insect. Scott *et al.* (1985) reported plots with significant yield losses that were attributed to the tarnished plant bug. The standard approach to solving the problem has been to apply one of a wide range of insecticides that would control plant bugs. In the mid 1980s, county agents and consultants started reporting failures of insecticides to control plant bugs. In 1998, Holloway *et al.* reported that tarnished plant bug resistance to oxamyl, acephate, and cypermethrin increased with time during the 1995 and 1996 growing seasons. Resistance of the tarnished plant bug seemed to be associated with the use of the pyrethroid insecticides (Luttrell *et al.*, 1998). The development of insecticide resistance in the tarnished plant bug is of major concern because of the potentially expanding pest status of the plant bug. The control of tarnished plant bug using acephate, dicrotophos, and several new insecticides gave excellent control in central Arkansas, indicating the resistance was not present in all areas of the Delta nor at all periods of time in the growing season.

RESEARCH DESCRIPTION

The field experiment in 1999 was conducted on a producer farm in Jefferson County and in 2000 on a farm in Mississippi County. The research was moved into the Mississippi County location because the boll weevil eradication program was in progress in Jefferson County and malathion applications had drastically reduced plant bug populations. In 1999, the treatments were applied using a John Deere 6000 sprayer equipped with a CO_2-powered spraying system with 12 spraying booms. Treatments were applied at 45 PSI in 10 gal/acre total solution. Plots were 8 rows wide and 75 feet long. Treatments were applied on 4 August and evaluated 3 days after treatment. In 2000, treatments were applied with a backpack CO_2-powered sprayer. Plots were 4 rows wide by 50 feet long. The first 3 rows of each plot were sprayed. Plots were sprayed on 3 August and evaluated 4 days after treatment. In both tests, the treatments were evaluated using a drop sheet to count adult and immature plant bugs. In 1999, the sample size was 12 row-feet, and 24 row-feet in 2000.

RESULTS AND DISCUSSION

Tarnished plant bug experiments indicated varying degrees of control in 1999 (Tables 1 and 2) and 2000 (Table 3) with the control ranging from 52% to 97%. The older insecticides Bidrin™ (dicrotophos), Orthene™ (acephate), and Vydate™ (oxamyl) gave control ranging from 72% to 97%. Bidrin gave the best overall control of plant bugs in both 1999 and 2000. In 1999, Bidrin had an average of 1.6 plant bugs per sample compared to 17.6 in the untreated check or 90%. Similarly in 2000, Bidrin achieved 92 to 97% control in the 0.5 and 0.33 lb active ingredient per acre (ai/acre) treatments. The plant bug counts averaged 0.8 in the 0.33-lb treatment and 2.3 in the 0.5-lb treatment compared to 27.8 in the untreated check. Orthene averaged 5.5 plant bugs at the 0.25-lb rate and 4.5 at the 0.5-lb rate or 72% and 77% control in 1999. In 2000, the plant bug counts for Orthene at the 0.5-lb rate were 2.3 plant bugs or 92% control. Vydate treatment resulted in 4.0 plant bugs per sample in 1999 and 7.8 plant bugs in 2000 or 79% and 72% control, respectively. Overall, these insecticides gave good control of plant bugs in these experiments. The test conducted in 1999 was in south Arkansas where insecticide use is greater and in 2000 in north Arkansas where insecticide use is less. The insecticide use pattern may have an influence on the degree of control since insecticide resistance is more apparent in areas where insecticide use is greater. Plant bug control using Bidrin and Orthene was less in 1999 compared to 2000, indicating that the resistance detected in other regions of the Delta using these older insecticides, is probably causing the decreased control.

The pyrethroid insecticides Karate™ (lambda-cyhalothrin) and Asana™ (esfenvalerate) were also evaluated in 2000 and gave 77% and 85% control, respectively. Karate averaged 6.5 plant bugs per sample and Asana 4 plant bugs per sample. Both of these treatments were significantly different from the untreated check. Leverage™ (imadacloprid plus cyfluthrin) provided improved control of plant bugs (compared to Provado™ alone), giving an 88% reduction or averaging 2.1 plant bugs per sample.

The control of plant bugs using several new insecticides was also evaluated in the experiments. Steward™ (indoxacarb) has recently received registration and currently is recommended to control most lepidopterous pests in Arkansas cotton. Steward was evaluated in both years for control of plant bugs. Plant bug control in 1999 averaged 74% for Steward across all rates and 70% in 2000. Steward averaged 2.9 plant bugs at 0.065-lb rate, 4.5 at the 0.09-lb rate, and 5.8 at another 0.09 rate in 1999 (Table 1). In another test, plant bug counts were 3.25 and 7.5 in the 0.09- and 0.11-lb treatments, respectively (Table 2). In 2000, plant bugs in the Steward treatments averaged 9.5 at the 0.65-lb rate, 9.5 at the 0.09-lb rate and 9.0 at the 0.11-lb rate. Steward does not have an obvious rate response but may be expected to deliver fair plant bug control of approximately 70%.

Regent (fipronil) was only evaluated in 1999. Regent averaged 7.5 plant bugs at the 0.038 rate and 4.0 plant bugs in the 0.05 treatments in one test (Table 1). In another test (Table 2), Regent tested at the same rates had a slip in control, averaging 16.25 plant bugs in the lower rate, not significantly different from the untreated check, and 5.5 at the next higher rate. Denim (emamectin benzoate) was also evaluated at the 0.01-lb rate and had 8.5 plant bugs per sample, around 52% control. This treatment was not significantly different from the untreated check. Another new insecticide, Actara™, averaged 9.5 plant bugs per sample or 48% control, not significantly different from the check. Provado (imadicloprid) was evaluated both years. Provado treatments averaged 55% control in 1999 and 66% control in 2000. The plant bugs averaged 8.0 per sample in 1999 and 9.5 in 2000.

Overall, the conventional insecticides Bidrin and Orthene provided the highest level of control in these tests. Steward performed well compared to other new insecticides and should be in an excellent position to assist in future pest management.

PRACTICAL APPLICATION

Growers in Arkansas can expect insecticide inputs to be reduced due to the adoption of Bollgard cotton and completion of the Boll Weevil Eradication Program. This in turn will probably result in an increase in pest status for the tarnished plant bug. The new insecticides evaluated in this research will play a large role in controlling plant bugs as older classes of insecticides are phased out.

LITERATURE CITED

Holloway, J.W., B.R. Leonard, J.A. Ottea, J.H. Pankey, and J.B. Graves. 1998. Insecticide resistance and synergism of pyrethroid toxicity in the tarnished plant bug, *Lygus linolaris*. Proc. Beltwide Cotton Conf., National Cotton Coucil, Memphis, TN. Vol. 2:947-950.

Johnson, D.R., J. Dearworth, H.B. Myers, and C.D. Klein. 1999. Survey of cotton pesticide use in Arkansas. MP 416, 80 pp. University of Arkansas Cooperative Extension Service.

Lorenz III, G.M., D.R. Johnson, R. Edmond, A. Fisher, L. Page, and J.D. Hopkins. 2000. Management of the tarnished plant bug, *Lygus linolaris*, with traditional and new insecticides. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Vol. 4.

Luttrell, R.G., G.L. Snodgrass, and S.D. Stewart. 1998. Susceptibility management of tarnished plant bug in the South. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Vol. 2:951-955.

Scott, W.P., J.W. Smith, and G.L. Snodgass. 1985. The tarnished plant bug (Hemiptera: Miridae): A key pest of cotton in the Mississippi Delta. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 164-167.

Young, O.P. 1986. Host plants of the tarnished plant bug, *Lygus linolaris* (Heteroptera: miridae). Ann. Entomol. Soc. Am. 79:747-762.

Table 1. Performance of insecticides in control of tarnished plant bugs during 1999.[z] Jefferson County, Arkansas.

Treatment/rate	Immature plant bugs 3 DAT	Adult plant bugs 3 DAT	Total plant bugs 3 DAT
(lb ai/acre)			
Untreated	16.3 a	1.3 a	17.6 a
Regent / 0.038	6.5 ab	1.0 a	7.5 ab
Regent / 0.05	4.0 ab	0.0 a	4.0 ab
Bidrin / 0.5	1.3 b	0.3 a	1.6 b
Provado / 0.047	7.0 ab	1.0 a	8.0 ab
Leverage 3.75 oz/acre	1.8 b	0.3 a	2.1 b
Actara / 0.062	7.3 ab	1.8 a	9.1 ab
Steward / 0.065[y]	2.3 b	0.3 a	2.6 b
Steward / 0.09[y]	3.5 ab	1.0 a	4.5 ab
Untreated	16.0 a	1.3 a	17.3 a
Steward / 0.09[y]	5.5 ab	0.3 a	5.8 ab
Denim / 0.01	8.0 ab	0.5 a	8.5 ab

[z] Means followed by the same letter are not significantly different (P=0.05).
[y] All Steward treatments had surfactant Dyne-Amic added at 0.5% v/v.

Table 2. Performance of insecticides in control of tarnished plant bugs during 1999.[z] Jefferson County, Arkansas.

Treatment/rate	Immature plant bugs 3 DAT	Adult plant bugs 3 DAT	Total plant bugs 3 DAT
(lb ai/acre)			
Untreated	16.75 a	2.25 a	19.00 a
Regent / 0.038	15.00 a	1.25 a	16.25 ab
Regent / 0.05	3.75 b	1.75 a	5.50 bc
Provado / 0.047	5.25 b	1.25 a	6.50 bc
Steward / 0.09[y]	2.50 b	0.75 a	3.25 c
Steward / 0.11[y]	6.75 b	0.75 a	7.50 bc
Vydate / 0.33	4.00 b	0.00 a	4.00 c
Orthene / 97 0.25	4.75 b	0.75 a	5.50 bc
Orthene / 97 0.5	4.25 b	0.25 a	4.50 c

[z] Means followed by the same letter are not significantly different (P=0.05).
[y] All Steward treatments had surfactant Dyne-Amic added at 0.5% v/v.

Table 3. Performance of insecticides in control of tarnished plant bugs during 2000. Mississippi County, Arkansas.[z]

Treatment / rate	Total plant bugs 4 DAT
(lb ai/acre)	
Untreated check	27.8 a
Steward / 0.065[y]	9.5 b
Steward / 0.075	9.5 b
Steward / 0.09	9.0 b
Steward / 0.11	5.5 bcd
Vydate C-LV / 0.33	7.8 bcd
Karate Z / 0.028	6.5 bcd
Orthene / 0.5	2.3 cd
Asana XL / 0.04	4.3 bcd
Bidrin / 0.33	0.8 d
Bidrin / 0.5	2.3 cd
Provado / 0.047	9.5 b

[z] Means followed by the same letter are not significantly different (P=0.05).
[y] All Steward treatments had surfactant Dyne-Amic added at 0.5% v/v.

LARGE BLOCK TEMIK (ALDICARB) SIDEDRESS STUDIES IN ARKANSAS, 1998-2000

Gus M. Lorenz III, Terry Kirkpatrick, Cliff Coker, John Hopkins, Don Johnson, Robert T. Robbins, April Fisher, Steve Rodery, Michael Hamilton, Jerry Sites, Claude Bonner, and Jack Reaper[1]

RESEARCH PROBLEM

Large-plot studies were conducted on typical grower farms, with root-knot nematode, reniform nematode, or no nematodes, to evaluate the impact of Temik™ sidedress applications over a three-year period. Results indicated a significant yield increase in 1998 and 1999 for sidedressed plots compared to the untreated plots even in the absence of nematodes in some fields. However, in 2000 there was only one location with a significant yield increase attributed to sidedress applications.

BACKGROUND INFORMATION

Nematode severity in Arkansas has been increasing throughout the state in recent years. The root-knot nematode (RKN), *Meloidogyne incognita*, and reniform nematode, *Rotylenchulus reniformis*, are the most important nematode pests of cotton in the state. Cotton yields have been reduced throughout much of the state due to environmental stress and nematodes have made a bad situation worse for many growers. The objectives of these studies were to evaluate various rates and timings of selected nematicides for suppression of root-knot and reniform nematode in typical grower fields.

---

[1] Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Professor, Southwest Research and Extension Center, Hope; Plant Pathology Specialist, University of Arkansas, Monticello; Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Professor, Department of Plant Pathology, Fayetteville; Jefferson County Extension Agent - Agriculture, Cooperative Extension Service, Pine Bluff; Crittenden County Extension Agent, Cooperative Extension Service, Marion; Poinsett County Extension Agent, Cooperative Extension Service; Harrisburg; Drew County Extension Agent, Cooperative Extension Service, Monticello; Consultant, Cotton Specialists of Arkansas, Inc., Little Rock; and Entomology Extension Specialist, Cooperative Extension Service, Lonoke.

RSEARCH DESCRIPTION

Large-Block Study 1998-1999

Eight large-block studies were conducted in five counties to evaluate the effect of Temik (aldicarb) sidedressed to cotton. Of the eight locations, the Cornerstone #1 (Jefferson Co.), Crittenden, Jefferson, and Mississippi Co. fields were known to have root-knot nematode infestations. The Cornerstone #2 field (Jefferson Co.) represented the only field with a reniform infestation. Desha #1 and Desha #2 as well as the Poinsett Co. fields had no nematode infestation. Fields designated as non-nematode fields all had in-furrow applications of Temik at 3.5 lb of product per acre. All nematode infested fields had an in-furrow application of Temik at 5.0 lb of product per acre. At pinhead to match-head square stage, plots were set out in a simple paired comparison design with treated plots receiving 7.5 lb of product per acre on non-nematode fields and 5.0 lb of product per acre on nematode fields. Each location had four replications of treated and untreated plots. Each plot was sampled for nematodes prior to application, 2 to 4 weeks post application and at harvest. Each plot was machine harvested for yield comparisons. Yields were subjected to analysis and mean separation for each location. All locations were then pooled and analyzed.

RESULTS AND DISCUSSION

Large-Block Study

In 1998 both trials resulted in numerical yield increases with a Temik sidedress (compared to the untreated check). However, only the Pulaski County location was significantly higher (Table 1).

In 1999, of the eight locations, Cornerstone #2 (reniform); Crittenden (RKN); Desha #2; Mississippi (RKN); and Poinsett (no nematodes) showed significant yield increases at various confidence intervals with a sidedress application of Temik (Table 2). The Cornerstone #1 (RKN); Desha #2 (no nematodes); and Jefferson (RKN) locations indicated no significant yield difference between the treated and untreated plots. When all locations were pooled, the treated plots averaged 911.5 lb of lint cotton per acre compared to the untreated plots, which averaged 869.6 lb of lint cotton per acre, resulting in a significant yield increase of 41.9 lb of lint per acre for the sidedress treatment.

In 2000, only the Chicot County location had significantly higher yields with the addition of a sidedress Temik application. No differences were indicated by the different rates (Table 3). When all locations were pooled, untreated plots averaged 892 lb of lint cotton per acre compared to 887, 950, and 891 lbs of lint per acre for 5, 7, and 10 lb of Temik sidedressed per acre, respectively.

In both 1998 and 1999, Temik sidedress applications were shown to increase yields over an untreated check. However, in 2000 only one location out of seven had significantly higher yields with an additional application of Temik. These studies indicate that more work is needed to refine and define the situations and timing of applications to elicit a significant yield response with sidedress applications of a nematicide.

PRACTICAL APPLICATION

The use of Temik as a sidedress application in root-knot or reniform nematode infested cotton has generally resulted in increased yields. However, additional research to refine application timings is warranted.

Table 1. Large-block study of Temik sidedressed at pinhead to match-head square. Arkansas. 1998.

Location (nematode[z])	Treatment[y]	Seedcotton yield[x]
		(lb/acre)
Lonoke (RKN)	7.5 lb/acre	2014 a
	Untreated	1745 a
Pulaski (RKN)	7.5 lb/acre	1857 a
	Untreated	1641 b

[z] RKN = root-knot nematode.

[y] All fields were treated with Temik at 3.5 lb/acre in-furrow at planting and an additional application of 7.5 lb/acre at pinhead to match head square stage.

[x] Means within a location and column followed by the same letter are not significantly different (LSD=0.05).

Table 2. Large-block study of Temik sidedressed at pinhead to match-head square, Arkansas, 1999.

Location (nematode)[z]	Treatment[y]	Lint yield[x]	LSD	α Level
Cornerstone #1 (RKN)	Treated	927.8 a	110.45	NS[w]
	Untreated	899.8 a		
Cornerstone #2 (RNF)	Treated	1011.5 a	13.36	0.20
	Untreated	993.5 b		
Crittenden (RKN)	Treated	577.2 a	86.86	0.10
	Untreated	487.9 b		
Desha #1 (None)	Treated	1142.8 a	71.67	0.20
	Untreated	1069.2		
Desha #2 (None)	Treated	1228.8 a	97.49	NS
	Untreated	1234.9 a		
Jefferson (RKN)	Treated	1064.9 a	37.81	NS
	Untreated	1079.2 a		
Mississippi (RKN)	Treated	846.9 a	84.53	0.20
	Untreated	751.9 b		
Poinsett (None)	Treated	492.3 a	28.70	0.05
	Untreated	440.3 b		
Means for all locations	Treated	911.5 a	23.61	0.05
	Untreated	869.6 b		

[z] RKN = root-knot nematode; RNF = reniform nematode; none = no nematodes.

[y] All fields with nematodes received 5.0 lb of Temik in-furrow at planting and treated plots received a sidedress application of an additional 5.0 lb/ of Temik at pinhead to match-head square stage. Fields with no nematodes were treated with Temik at 3.5 lb/acre in-furrow at planting and an additional application of 6.5 lb/acre at pinhead to match-head square stage.

[x] Means within a location and column followed by the same letter are not significantly different at α levels of 0.05, 0.1, and 0.2.

[w] NS = not significantly different at all alpha (α) levels tested.

Table 3. Large-block study of Temik sidedressed at pinhead to match-head square, Arkansas, 2000.

Location (nematode[z])	Treatment[y]	Lint yield[x]
Chicot (RKN)	UTC[w]	871 b
	5 lb	958 a
	7 lb	948 a
	10 lb	938 a
Crittenden (RKN)	UTC	998 a
	7 lb	1026 a
Desha (None)	UTC	781
	5 lb	810 a
	10 lb	822 a
Jefferson (RKN)	UTC	1069 a
	5 lb	1020 a
	10 lb	1039 a
Lonoke #1 (RKN)	UTC	876 a
	5 lb	875 a
	10 lb	883 a
Lonoke #2 (RKN)	UTC	874 a
	7 lb	874 a
Poinsett (None)	UTC	778 s
	5 lb	773 a
	10 lb	774 a
Average	UTC	892 a
	5 lb	887 a
	7 lb	950 a
	10 lb	891 a

[z] RKN = root-knot nematode; RNF = reniform nematode; and none = no nematodes.
[y] All fields with nematodes received 5.0 lb of Temik in-furrow at planting and treated plots received a sidedress application of an additional 5.0 lb of Temik at pinhead to match-head square stage. Fields with no nematodes were treated with Temik at 3.5 lb/acre in-furrow at planting and an additional application of 7 and/or 10 lb/acre at pinhead to match-head square stage.
[x] Means within a location and column followed by the same letter are not significantly different (LSD = 0.05).
[w] UTC = untreated check.

BOLLGARD II PERFORMANCE IN ARKANSAS

*Gus Lorenz, Don Johnson, John Hopkins,
Jack Reaper, April Fisher, and Chad Norton*[1]

RESEARCH PROBLEM

Bollgard II, Monsanto line DPX-9C985-EB, was compared to Bollgard and conventional cotton in two field trials to determine efficacy against the Heliothine complex in cotton.

BACKGROUND INFORMATION

Bollgard cotton (*Gossypium hirsutum* L.), containing the CryIAc endotoxin of *Bacillus thuringiensis* Berliner, became commercially available to cotton producers in 1996. Bollgard varieties since that time have provided excellent control of the tobacco budworm *(Heliothis virescens* F.) for growers in Arkansas. Control of bollworm (*Helicoverpa zea* Boddie), and other lepidopterous pests has been less dependable thus foliar insecticide applications are sometimes needed for control.

Bollgard II was developed to contain an additional toxin, CryX , to enhance the control of lepidopterous pests in cotton and hinder the development of resistance. Previous studies have shown Bollgard II to have increased efficacy for bollworm and soybean looper (Allen *et al.*, 2000; Stewart *et al.*, 2000; Ridge *et al.*, 2000).

The purpose of this study was to compare the efficacy of Bollgard II to Bollgard and conventional cotton for control of lepidopterous pests. Observations were also made to compare agronomic characteristics of these varieties.

RESEARCH DESCRIPTION

Studies were conducted on the Fratesi Farm in Jefferson County, Arkansas, and on the McGraw Farm in Lincoln County, Arkansas. Both studies were planted on 25 May 2000 and the same plan was used at both locations. The test consisted of a

[1] Extension Entomologist-IPM Coordinator and Extension Entomologist-Pest Management Section Leader, Cooperative Extension Service, Little Rock; Entomology Associate Specialist and Entomology Extension Specialist, Cooperative Extension Service, Lonoke; and Jefferson County Extension Agent, Cooperative Extension Service, Pine Bluff; Staff Chair, Lincoln County Extension Office, Cooperative Extension Service, Star City.

randomized complete split block design with four replications. The three main treatments were the varieties: DPL 50, DPL 50 BG, and DPX-9C985-EB. Each plot was 8 rows by 50 feet at Jefferson County and 4 rows by 50 ft at Lincoln County. The subtreatment consisted of unsprayed or sprayed with a foliar larvicide. Larvicides used in the study were cyfluthrin (Baythroid 2E) and spinosad (Tracer 4E). Applications were based on weekly samples taken from mid-June to early-August. Application dates at the Jefferson County location using Baythroid were 6 July, 20 July, 27 July, and 3 Aug, and one application of Tracer on 14 Aug. Application dates at Lincoln County were 3 July, 26 July, and 4 Aug using Baythroid and 14 Aug using Tracer. Scouting data taken included damaged fruit counts and larval counts. Plots were machine picked 13 Oct (Jefferson County) or 20 October (Lincoln County). All data were analyzed using analysis of variance and LSD (P=0.05).

RESULTS AND DISCUSSION

Heliothine pressure was considerably greater at the Jefferson County location compared to Lincoln County and probably gives a better indication of the efficacy of Bollgard II compared to Bollgard and conventional cotton.

At the Jefferson County location, seasonal averages of the percent damaged squares and larval counts (Table 1) showed significantly higher damage and larval counts in both sprayed and unsprayed conventional compared to Bollgard II. However, no significant difference was observed between Bollgard and Bollgard II regardless of whether or not they were sprayed. Also, Bollgard and Bollgard II had significantly higher yields than sprayed conventional, which yielded significantly higher than unsprayed conventional (Table 2). Results were not as conclusive at the Lincoln County site although trends were somewhat similar to those seen in Jefferson County.

These results indicate that both Bollgard and Bollgard II were effective in controlling Heliothine larvae. However, we still have much to learn about the value of Bollgard in cotton production, particularly with Bollgard II in terms of where it will fit in the production scheme for Arkansas growers.

SUMMARY

In the Jefferson County trial where insect pressure was greatest, results indicated that there were significantly fewer damaged squares, less live larvae, and increased yield in Bollgard and Bollgard II plots compared to conventional cotton, whether or not it was sprayed. The same trend was shown in the Lincoln County trial although significant differences were not shown.

ACKNOWLEDGMENTS

We would like to thank Monsanto for supporting this work by providing the seed and grant support. Also, we would like to thank Bobby Fratesi and Johnny McGraw for allowing us to do this research on their farms.

REFERENCES

Allen, C.T., M.S. Kharboutli, C. Capps, and L.D. Earnest. 2000. Effectiveness of Bollgard II cotton varieties against foliage and fruit feeding caterpillars in Arkansas. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1093-1094.

Ridge, R.L., S.G. Turnipseed, and M.J. Sullivan. 2000. Field comparison of genetically modified cottons containing one strain (Bollgard) and two strains (Bollgard II) of *Bacillus thuringiensis kurstaki.* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1057-1058.

Steward, S.D. and K.S. Knighten. 2000. Efficacy of BT cotton expressing two insecticidal proteins of *Bacillus thuringiensis* Berliner on selected caterpillar pests. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1043-1048.

Table 1. Seasonal average of percent damaged squares and live larval counts in conventional, Bollgard, and Bollgard II cotton. Jefferson County, Arkansas. 2000.

	Damaged squares[z]		Larval counts[z]	
Variety / Treatment[y]	Jefferson	Lincoln	Jefferson	Lincoln
	------------ (%) -----------			
DPL 50 U	11.9 a	4.0 a	29.5 a	4.0 a
DPL 50 S	5.4 b	1.0 b	16.8 b	1.0 b
DPL 50 BG U	1.8 c	1.0 b	8.8 bc	1.0 b
DPL 50 BG S	1.6 c	1.0 b	5.5 c	1.0 b
DPX-9C985-EB U	1.2 c	0.0 b	2.5 c	1.0 b
DPX-9C985-EB S	1.5 c	0.0 b	0.8 c	0.0 b

[z] Means within a column followed by the same letter are not significantly different (LSD=0.05).

[y] U=unsprayed or no larvicide; S=sprayed as needed indicated by scouting.

Table 2. Lint yield in conventional, Bollgard, and Bollgard II cotton. Jefferson County, Arkansas. 2000.

Variety/treatment[y]	Lint yield[z]	
	Jefferson	Lincoln
	------------------(lb/acre) --------------	
DPL 50 U	413 c	799 ab
DPL 50 S	774 b	763 b
DPL 50 BG U	1091 a	820 ab
DPL 50 BG S	1119 a	826 ab
DPX-9C985-EB U	1058 a	823 ab
DPX-9C985-EB S	1037 a	911 a

[z] Means within a column followed by the same letter are not significantly different (LSD=0.05).

[y] U=unsprayed or no larvicide; S=sprayed as needed indicated by scouting.

HELIOTHINE CONTROL IN COTTON WITH NEW CHEMISTRY

Jack Reaper III, John D. Hopkins, Donald R. Johnson, and Gus M. Lorenz, III[1]

RESEARCH PROBLEM

The development and evaluation of new insecticides is necessary to maintain acceptable control levels of the Heliothine species in cotton. Performances of new and traditional insecticides were evaluated with three field experiments in Jefferson Co., Arkansas, in 2000. The objective of these experiments was to compare new and traditional insecticides in addition to determining efficacy of combinations of each for Heliothine control in cotton.

BACKGROUND INFORMATION

Resistance of the tobacco budworm (*Heliothis virescens*) to currently available insecticides has demanded the development of new chemistry for effective Heliothine control in cotton. Some recently developed compounds for use in cotton include Tracer™ (spinosad) by Dow AgroSciences, Intrepid™ (RH-2485) by Rohm & Haas, Denim™ (emamectin benzoate) by Novartis, and S-1812™ by Valent. Of these compounds, only Tracer is recommended for Heliothine control in Arkansas cotton.

Tracer is a biologically based insect control product with many favorable characteristics. The organism *Saccharopolyspora spinosa*, a bacterium, produces the secondary metabolite spinosad, which is the active ingredient in Tracer. Tracer has a high efficacy on target insects, including Heliothine species, while maintaining little effect on beneficial insects.

Intrepid is a molt-accelerating compound that mimics an insect molting hormone when ingested. Like Tracer, Intrepid has little effect on beneficial insects. Intrepid has provided excellent control of foliage feeding insects, such as cotton bollworm and loopers, while demonstrating activity on tobacco budworm as well (Harrison *et al.*, 1997).

Denim provides control of many Lepidopteran species including tobacco budworm, cotton bollworm, armyworms, and loopers (Dunbar *et al.*, 1998). While emamectin

---

[1] Entomology Extension Specialist and Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Extension Entomologist-Pest Management Section Leader, Extension Entomologist-IPM Coordinator, University of Arkansas Cooperative Extension Service, Little Rock.

benzoate is susceptible to photodegradation, reservoirs of the compound develop in cotton leaf tissue resulting in long residual activity under field conditions. Low use rates (0.0075-0.015 lb ai/acre) have been shown to effectively control Heliothine species (Dunbar *et al.*, 1998).

S-1812 is a new compound currently in the developmental stages. While its mode of action is not completely understood, previous research has shown efficient control of Heliothine species at the 0.15 lb ai/acre. S-1812 has also exhibited good levels of selectivity, indicating little effect on beneficial insects.

RESEARCH DESCRIPTION

The cultivar DP5415RR was planted on 1 May 2000 and treatments were evaluated in small plots (eight 40-inch rows x 50 ft) arranged in a randomized complete block design with 4 replications. Applications were made with a hi-cycle sprayer equipped with a compressed air delivery system using conejet TXVS 6 nozzles on a 20-inch spacing. Operating pressure was 45 psi with a final spray volume of 8.6 gpa. Treatments were applied as foliar sprays on 6 July, 20 July, 27 July, and 3 August. Insect counts and damage ratings were made on 10 July, 24 July, 31 July, and 7 August. Data were collected by examining 50 squares and 50 terminals selected at random from the center of each plot. Seasonal averages of percentage square damage and total number of live larvae were calculated from the rating dates. The center two rows of each plot were machine harvested on 13 October (165DAP) and lint yields were determined based on a 36% gin turnout. Data were processed using Agriculture Research Manager Ver. 6.0.1. Analysis of variance was conducted and Duncan's New Multiple Range Test (P=0.05) was used to separate means only when AOV Treatment P(F) was significant at the 5% level.

RESULTS AND DISCUSSION

In Arkansas, the tobacco budworm populations are greatest the last part of July and the first part of August. Based upon pheromone trap catches, this trend held true for the year 2000. Heliothine pressure was highest around 31 July (or around the third insecticide application).

Heliothine control in cotton using new products S-1812 and Tracer was compared to and used in combination with traditional insecticides Orthene™, Asana XL™, Baythroid™, Leverage™, and Capture™. All treatments resulted in less seasonal percentage square damage than the untreated check (Table 1). Tracer provided the least amount of seasonal average square damage (3.9%) and live larvae (0.3); however, these figures were not significantly different from all other treatments. Leverage plus Tracer did not significantly increase Heliothine control or lint yield when compared to Tracer alone. The lint yield of the Leverage plus Tracer treatment was greater than all other treatments. S-1812 at the 0.15 lb ai/ac rate did not differ from the Tracer treatment with respect to seasonal Heliothine control and lint yield.

New insecticides Tracer, Intrepid, Denim, and S-1812 were compared to pyrethroid insecticides Karate Z™, Decis™, Fury™, Leverage, and Baythroid. Only Tracer (0.67 lb ai/acre), Denim (0.01 lb ai/acre), and Decis (0.02 lb ai/acre) provided increased Heliothine control and lint yield over the untreated check (Table 2). All treatments with the exception of Decis (0.01 lb ai/acre) had significantly greater yields than the untreated check. No yield difference was observed between Tracer and S-1812. In general, new products Tracer, Intrepid, Denim, and S-1812 provided greater seasonal Heliothine control and yield when compared to the pyrethroid insecticides.

The efficacy of Tracer and Denim used in combination with Lorsban™ and Karate was also evaluated. In general, combinations of the new products with old resulted in better Heliothine control than using the older products alone (Table 3). For example, all treatments provided less seasonal square damage when compared to the control except for the Karate and Lorsban treatments. Tracer (0.033 lb ai/acre) combined with Karate and with Lorsban provided greater Heliothine control and yield. However, Tracer used alone (0.67 lb ai/acre) had the same level of control as the Tracer (0.033 lb ai/acre) + Karate combination. The activity of Denim was not enhanced by the addition of a wetting agent alone. Heliothine control and lint yield were increased, however, by adding Karate (0.03 lb ai/acre) and Latron CS-7 (0.25% v/v) to Denim (0.0075 lb ai/acre). Denim used alone did not provide Heliothine control comparable to the Tracer treatments.

SUMMARY

The continuing occurrence of Heliothine resistance to recommended insecticides will increase the demand for the development and implementation of new products for future Heliothine control. The performance of Tracer, S-1812, Intrepid, and Denim provided improved Heliothine control compared to traditional insecticides. Selective use of these products with traditional insecticides can minimize Heliothine resistance, thus resulting in an effective pest management program and profitable cotton crop.

LITERATURE CITED

Dunbar, D.M., D.S. Lawson, S.M. White, and N. Ngo. 1998. Ememectin benzoate: control of the Heliothine complex and impact on beneficial arthropods. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1116-1119.

Harrison, W.E., L.C. Walton, and A.E. Duttle. 1997. Control of Lepidoptera pests in cotton with Intrepid™ experimental insecticide. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1091-1093.

Table 1. Seasonal average Heliothine control in cotton from various insecticide treatments. Jefferson County, Arkansas. 2000.

Treatment		Rate	Heliothine damaged squares[z]	Total live Heliothine larvae[z]	Lint yield
			(%)		(lb/acre)
1	Untreated check	--	18.0 a	4.4 a	633 e
2	S-1812 35WP	0.075 lb ai/acre	10.6 b[y]	2.1 cde	909 cd
3	S-1812 35WP	0.15 lb ai/acre	8.5 bcd	1.6 c-f	968 bc
4	S-1812 35WP	0.075 lb ai/acre	8.1 bcd	1.3 def	888 cd
	Orthene 90S	0.5 lb ai/acre			
5	S-1812 35WP	0.075 lb ai/acre	9.1 bc	2.0 cde	946 bc
	Asana XL 0.66EC	0.02 lb ai/acre			
6	Asana XL 0.66EC	0.02 lb ai/acre	11.9 b	3.3 abc	816 cd
7	Orthene 90S	0.5 lb ai/acre	8.9 bc	1.4 def	752 de
8	Tracer 4SC	0.067 lb ai/acre	3.9 d	0.3 f	1093 ab
9	Baythroid 2EC	0.033 lb ai/acre	7.8 bcd	1.9 c-f	936 bcd
10	Leverage 2.7SE	3 fl oz/acre	11.8 b	3.8 ab	827 cd
11	Leverage 2.7SE	3 fl oz/acre	5.1 cd	1.0 ef	1168 a
	Tracer 4SC	0.033 lb ai/acre			
12	Capture 2EC	0.05 lb ai/acre	10.9 b	2.7 bcd	889 cd

[z] Damage based upon samples of 50 squares and 50 terminals per plot.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

Table 2. Comparison of new chemistry and pyrethroids for seasonal average Heliothine control in cotton. Jefferson County, Arkansas. 2000.

Treatment		Rate	Heliothine damaged squares[z]	Total live Heliothine larvae[z]	Lint yield
		(lb ai/acre)	(%)		(lb/acre)
1	Untreated check	--	--	17.8 a[y]	562 e
2	Tracer 4SC	0.067	4.3 d	0.6 e	1196 a
3	Intrepid 2SC	0.15	14.0 ab	4.1 a	944 bc
4	Denim 0.16EC	0.01	9.8 bc	1.6 cde	966 bc
5	Karate Z 2.09CS	0.025	13.5 ab	3.3 ab	823 bcd
6	Decis 1.5EC	0.01	14.0 ab	4.0 ab	719 de
7	Decis 1.5EC	0.02	11.8 bc	2.4 bcd	924 bcd
8	Fury 1.5EC	0.0375	10.8 bc	3.6 ab	777 cd
9	Leverage 2.7SE	0.079	12.8 abc	3.1 abc	840 bcd
10	Baythroid 2EC	0.03	13.0 ab	3.3 ab	892 bcd
11	S-1812 35WP	0.15	10.0 bc	2.6 a-d	1040 ab

[z] Damage based upon samples of 50 square and 50 terminals per plots.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

Table 3. Efficacy of Tracer and Denim combinations with traditional insecticides for seasonal average Heliothine control in cotton. Jefferson County, Arkansas. 2000.

	Treatment	Rate	Heliothine damaged squares[z]	Total live Heliothine larvae[z]	Lint yield
			(%)		(lb/acre)
1	Untreated check	--	13.3 a[y]	2.4 a	669 g
2	Lorsban 4E + Tracer 4SC	0.5 lb ai/acre 0.033 lb ai/acre	8.1 bcd	1.2 bc	976 de
3	Lorsban 4E + Karate Z 2.09CS	0.5 lb ai/acre 0.015 lb ai/acre	8.6 bc	2.0 ab	954 e
4	Tracer 4SC + Karate Z 2.09CS	0.033 lb ai/acre 0.015 lb ai/acre	4.5 d	0.6 c	1228 a
5	Lorsban 4E	1.0 lb ai/acre	10.0 ab	1.6 abc	786 f
6	Karate Z 2.09CS	0.03 lb ai/acre	10.0 ab	1.3 bc	1047 cde
7	Tracer 4SC	0.067 lb ai/acre	4.4 d	0.8 c	1126 abc
8	Denim 0.16EC + Latron CS-7	0.01 lb ai/acre 0.25 % v/v	7.6 bcd	1.3 bc	1049 cde
9	Denim 0.16EC	0.01 lb ai/acre	5.4 cd	1.1 bc	1023 cde
10	Denim 0.16EC + Latron CS-7	0.0075 lb ai/acre 0.25 % v/v	6.4 bcd	0.8 c	1082 bcd
11	Denim 0.16EC + Karate Z 2.09CS + Latron CS-7	0.0075 lb ai/acre 0.03 lb ai/acre 0.25 % v/v	4.9 cd	0.8 c	1184 ab

[z] Damage based upon samples of 50 squares and 50 terminals per plot.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT).

INTERNET INFORMATION DELIVERY SYSTEM FOR REPORTING HELIOTHINE MOTH TRAP CATCHES IN ARKANSAS

Rebecca L. Bridges, Donald R. Johnson, Gus M. Lorenz III, and John D. Hopkins[1]

RESEARCH PROBLEM

Realizing the importance of early detection of pests in the Arkansas cotton crop, and wanting to capitalize on the availability of the Internet and the technology that it provides, entomologists and computer specialists from the University of Arkansas Cooperative Extension Service have developed an on-line database system to allow cotton scouts from participating Arkansas counties to enter daily scout information and make statewide comparisons, thus allowing for trends in pest populations to be determined quickly. The focus of the program during the first year, during which 14 Arkansas counties participated by reporting 8060 observations, included the tobacco budworm, *Heliothis virescens* and the cotton bollworm, *Helicoverpa zea*.

BACKGROUND INFORMATION

Bollworm and budworm infestations have been taking their toll on Arkansas' cotton crop, being the most expensive pest to control over four of the previous five years (from 1995 - 1999). These pests have also caused an average reduction in yield of Arkansas cotton of 3.056% for the previous five years (Williams, 1999).

Increased resistance to insecticides has made control of these pests more difficult (Allen *et al.*, 1999). The early detection of any pest is of prime importance in controlling the pests' effects on the host crop, and being able to accurately estimate the current population level is most beneficial to cotton producers. The placement of traps, the number of traps used, and continuous sampling of adult moth activity during the growing season are critical components in the Arkansas Integrated Pest Management program (Lorenz *et al.*, 1999). The Trap and Survey Summary System provided by the University of Arkansas Cooperative Extension Service provides this information, which is as close as the nearest computer with Internet access.

---

[1] Computer Specialist, Extension Entomologist, IPM Coordinator, and Assistant Specialist, University of Arkansas Cooperative Extension Service, Little Rock.

Previous versions of this program were MS-DOS based and did not provide a means for statewide data comparisons or compilations. The on-line concept of the current version of the program not only provides an ease of entry, but a quick and easy way to retrieve county and state summaries and comparisons while enabling quick program updates because of the central location of the main program. Data are entered on an actual count-per-trap basis. These actual counts are then calculated into a daily average per trap. Graphs are created using calculated averages (Figs. 1 and 2).

Future updates of this program for 2001 will use the species composition formula or ratio of tobacco budworm to bollworm in creating graphs, and additional graph types will be used (Fig. 3). Additional surrounding states are also invited to participate in the program.

RESEARCH DESCRIPTION

This system consists of cooperator enrollment screen, trap enrollment screen, and daily scout screens to allow for daily entry of trap counts on seven types of species: tobacco budworm (*Heliothis virescens*); cotton bollworm (*Heliocoverpa zea*); boll weevil (*Anthonomus grandis*); armyworm (*Pseudaletia unipuncta)*; fall armyworm (*Spodoptera frugiperda*); beet armyworm (*Spodoptera exigua*); southwestern corn borer; and European corn borer. Counts for tobacco budworm and cotton bollworm were entered daily, or as scouted. Data could be accumulated immediately to provide the user with a graph reflecting trap counts and averages with a user-specified range from one to seven days. Data could also be downloaded in a comma-delimited format to allow for importation into a spreadsheet. This is useful when creating county-specific graphs or when needing to customize graphs for a specific purpose.

The Texas cone pheromone trap designed by Hartstack *et al.* (1979) is used throughout Arkansas for most moth species. The total trapping system involves around 500 traps distributed throughout the counties that are involved with crop production. Traps are monitored each week from 1 to 5 times depending on the species. Typically, the armyworm traps are monitored weekly and others from 2 to 5 times weekly. County extension agents with the University of Arkansas Cooperative Extension Service coordinate the monitoring of pheromone traps. Scouts, county agents, cooperating consultants, and agri-business personnel conduct monitoring. Pheromone is purchased from Hercon Inc. and Great Lakes IPM Inc.

Data entry began on 7 June 2000 by designated users in the cotton producing counties of Ashley, Clay, Crittenden, Drew, Jefferson, Lafayette, Lee, Lincoln, Lonoke, Monroe, Phillips, St. Francis, White, and Woodruff in Arkansas. Each county could enroll their traps by individual cooperators, or a “cooperator” could become identified with an actual trap type, which enabled users to read graphs in a more descriptive manner. Information for each entrolled trap included the trap type, location description, longitude, and latitude. Daily trap count data recorded included beginning date of scouting period (usually the previous day); ending date (the day the count was made); the actual count; and whether or not the trap was actually scouted. Traps that were not scouted were not included in the daily trap average so as not to skew the data.

RESULTS AND DISCUSSION

The Trap and Survey Summary System provides an easy method to summarize pheromone trap data collected throughout the state. Data is collected on several species of pests that commonly occur in Arkansas. The most commonly surveyed insect species are the tobacco budworm and cotton bollworm. These species are economically important to cotton in Arkansas and the data collected are used to aid cotton producers in the selection of insecticides.

The Trap and Survey Summary System is hosted on a Gateway 7210 server running Windows NT with 512 Meg of RAM. The system consists of two access points. The first is located at http://apps.uaex.edu/TrapPublic/trap_home.asp and allows for public access so that anyone can review a graph for a given Arkansas county for a particular species. This page is also accessible from the IPM home page at http://ipm.uaex.edu. The second access point is used only by registered users of the system, and is located at http://apps.uaex.edu/Trap2000/Trap_Home.asp. Users are required to obtain a login and password, and may then enter information as needed into the system. Users only have direct access to data that they have entered, although they can see graphs of any and all information entered into the system.

Entomologists from surrounding states who are interested in participating in our program are encouraged to contact us at bbridges@uaex.edu or djohnson@uaex.edu for additional information, or visit our home page of the University of Arkansas Cooperative Extension Service at http://www.uaex.edu.

PRACTICAL APPLICATION

The ability to have daily statewide information on adult moth activity leads to improved decision-making capabilities and response times for producers and consultants when evaluating pest management strategies for cotton.

LITERATURE CITED

Allen, C. T., M.S. Kharboutli, and K.R. Williams. 1999. Insecticide resistance in tobacco budworm and cotton bollworm in southeast Arkansas. *In:* Oosterhuis, D.M. (ed.). Proc. 1999 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 193:223-227, Fayetteville.

Hartstack, A.W., J.A Witz, and D.R. Buck. 1979. Moth traps for the tobacco budworm. J. Econ. Entomol. 72:519-22.

Lorenz, G., D.R. Johnson, C. Allen, and G. Studebaker. 1999. Using moth traps in cotton IPM programs. FSA 7050. University of Arkansas Cooperative Extension Service.

Williams, M.R. 2000. Cotton insect losses 1999. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 887-913.

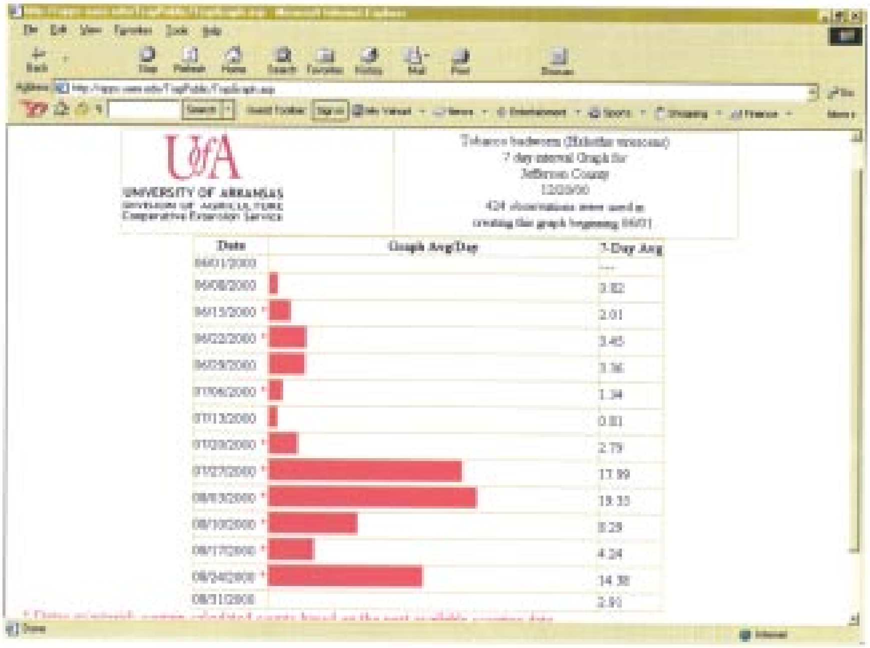


Fig. 1. Tobacco budworm (*Heliothis virescens*) 7-day interval graph for Jefferson County, Arkansas, 2000.

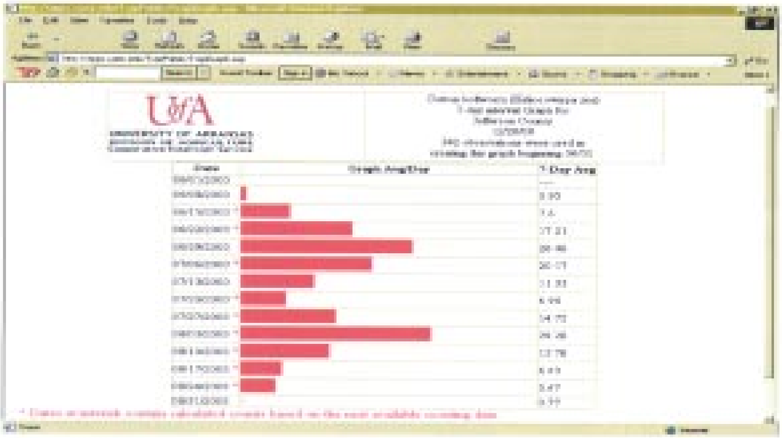


Fig. 2. Cotton bollworm *(Heliocoverpa zea*)
7-day interval graph for Jefferson County, Arkansas, 2000.

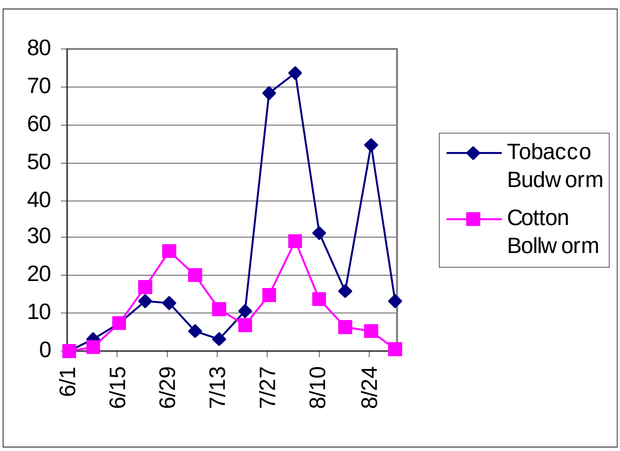


Fig. 3. Bollworm and tobacco budworm trap
count averages for Jefferson County, Arkansas. 2000.

STEWARD™ (INDOXACARB) PERFORMANCE IN COTTON

John D. Hopkins, Donald R. Johnson, Gus M. Lorenz, III, and Jack D. Reaper, III[1]

RESEARCH PROBLEM

Continued reliance on pyrethroid insecticides as the major control measure for the Heliothine complex has resulted in increased levels of resistance in both species (Bagwell *et al.*, 1999; Brown *et al.*, 1998; Sparks *et al.*, 1993). Continued discovery of new pest control technology is essential to maintain a viable cotton production industry in Arkansas.

BACKGROUND INFORMATION

The Heliothine complex, composed of the bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (Fab.), occurs each year at damaging levels in Arkansas cotton. In Arkansas, during the 1999 growing season, all of the 970,000 planted cotton acres were infested by the Heliothine complex. Half of this acreage required insecticide treatment for Heliothine control. Of all the cotton pests impacting the 1999 cotton crop in Arkansas, damage caused by the Heliothine complex resulted in the greatest yield reduction at 1.3% (Williams, 2000a; Williams 2000b). Steward™ (indoxacarb) is a new insecticide that received EPA registration for use on cotton on 30 October 2000 (Edmund, 2000, personal communication). This material exhibits broad-spectrum activity against lepidopterous pests (Bierman, 1998). Ingestion is the primary route of entry into target species, although absorption through the cuticle also occurs. Steward's novel mode of action acts to block sodium ion entry into nerve cells, resulting in paralysis and death of the pest. When pest species are exposed to a toxic dose of Steward, there is a rapid cessation of feeding (within 1-4 hours) and knockdown occurs within 1-2 days (Mitchell, 1999). The objective of these studies was to evaluate the efficacy of Steward, alone and with tankmix partners, for Heliothine control compared to traditional pyrethroids and other new insecticides.

---

[1] Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Extension Entomologist-Pest Management Section Leader, Cooperative Extension Service, Little Rock; Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Entomology Extension Specialist, Cooperative Extension Service, Lonoke.

RESEARCH DESCRIPTION

Two trials were conducted on the Robert Fratesi Farm in Jefferson County, Arkansas, in 2000 to evaluate Steward for the control of the Heliothine complex in non-*Bt* cotton. This farm was located within the boll weevil eradication zone and received programmed sprays of ULV malathion that greatly reduced boll weevil and plant bug pressure.

In Test 1, Steward was compared to various pyrethroids and other new cotton insecticides. In Test 2, Steward was evaluated alone and in combination with tank-mix partners. Treatments were evaluated in small plots (eight 40-inch rows x 50 ft) arranged in a randomized complete block design with 4 replications. The cotton variety used was Deltapine 5415RR, planted on 1 May 2000. The crop was furrow-irrigated on an as-needed basis. Insecticide treatments were initiated based on state recommendations of one Heliothine-damaged square per row foot with eggs and small larvae present. Applications were made with a John Deere 6000 hi-cycle equipped with a compressed air delivery system. The boom was equipped with conejet TXVS 6 nozzles on a 20 inch spacing. Operating pressure was 45 psi with a final spray volume of 8.6 gpa. Treatments evaluated in Test 1 as shown in Table 1 were: an untreated check; Tracer™ 4SC (0.067 lb ai/acre or 2.1 fl oz/acre); Steward 1.25SC (0.11 lb ai/acre or 11.3 fl oz/acre); Intrepid™ 2SC (0.15 lb ai/acre or 9.6 fl oz/acre); Denim™ 0.126EC (0.01 lb ai/acre or 8.0 fl oz/acre); Karate Z™ 2.09CS (0.025 lb ai/acre or 1.5 fl oz/acre); Decis™ 1.5EC (0.01 lb ai/acre or 0.9 fl oz/acre); Decis 1.5EC (0.02 lb ai/acre or 1.7 fl oz/acre); Fury™ 1.5EC (0.037 lb ai/acre or 3.2 fl oz/acre); Leverage™ 2.7SE (0.079 lb ai/acre or 3.8 fl oz/acre); Baythroid™ 2EC (0.03 lb ai/acre or 1.9 fl oz/acre); and S-1812™ 35WP (0.15 lb ai/acre or 0.43 oz/acre). Treatments evaluated in Test 2 were: an untreated check; Steward 1.25SC (0.11 lb ai/acre or 11.3 fl oz/acre); Steward 1.25SC (0.075 lb ai/acre or 7.7 fl oz/acre); Asana XL™ 0.66EC (0.032 lb ai/acre or 6.2 fl oz/acre); Asana XL 0.66EC (0.04 lb ai/acre or 7.8 fl oz/acre); Curacron™ 8E (0.5 lb ai/are or 8.0 fl oz/acre); Orthene™ 90S (0.5 lb ai/acre or 0.55 oz/acre); Asana XL 0.66EC + Steward 1.25SC (0.032 + 0.075 lb ai/acre or 6.2 + 7.7 fl oz/acre); Asana SL 0.66EC + Steward 1.25SC (0.04 + 0.075 lb ai/acre or 7.8 + 7.7 fl oz/acre); Curacron 8E + Steward 1.25SC (0.5 + 0.075 lb ai/acre or 0.55 oz/acre + 7.7 fl oz/acre); and Orthene 90S + Steward 1.25SC (0.5 + 0.075 lb ai/acre or 0.55 oz/acre + 7.7 fl oz/acre).

Treatments were applied as foliar sprays on 6 July, 20 July, 27 July, and 3 August. Insect counts and damage ratings were made on 10 July (4DAT#1), 24 July (4DAT#2), 31 July (4DAT#3), and 7 August (4DAT#4). Data were collected by examining 50 squares and 50 terminals at random from the center of each plot for the presence of live larvae (<1/4 + >1/4 inch) and square damage. The center two rows of each plot were machine harvested with a commercial two-row John Deere cotton picker on 13 October (165DAP) and lint yields were determined based on a 36% gin turnout. Data were processed using Agriculture Research Manager Ver. 6.0.1. Analysis of variance was run and Duncan's New Multiple Range Test (P=0.05) was used to separate means only when AOV Treatment P(F) was significant at the 5% level.

RESULTS AND DISCUSSION

At the site for Test 1 and Test 2, the Heliothine population mix was approximately 75% cotton bollworm / 25% tobacco budworm during the initial portion of these trials. The Heliothine population shifted to approximately 20% cotton bollworm/80% tobacco budworm at about the time of the second treatment application. During the remainder of the test period, the population mix averaged 27% cotton bollworm / 73% tobacco budworm (Fig. 1). The seasonal average for % Heliothine damaged squares and total live Heliothine larvae per 50 squares and 50 terminals was obtained by averaging the data across the four rating dates.

Test 1

Intrepid (0.15 lb ai/acre), Karate (0.025), Decis (0.01), Leverage (0.079), and Baythroid (0.03) failed to differ significantly from the untreated control with respect to percent Heliothine square damage. Denim (0.01), Decis (0.02), Fury (0.0375), and S-1812 (0.15) were intermediate in their ability to reduce Heliothine square damage. Tracer (0.067) and Steward (0.11) significantly reduced the level of Heliothine square damage compared to the other treatments (Table 1). Intrepid (0.15), Karate (0.025), Decis (0.01), Fury (0.0375), Leverage (0.079), Baythroid (0.03), and S-1812 (0.15) failed to differ significantly from the untreated control with respect to the live Heliothine larvae count. Denim (0.01) and Decis (0.02) were intermediate in reducing the live larvae count. Tracer (0.067) and Steward (0.11) significantly outperformed the other treatments with respect to the live larvae count (Table 1). Decis (0.01) was the only treatment that failed to significantly out-yield the untreated control. The pyrethroid treatments, while out-yielding the untreated control, tended to yield less than Intrepid (0.15), Denim (0.01) Steward (0.11), and S-1812 (0.15). Tracer significantly out-yielded all other treatments except Steward (0.11) and S-1812 (0.15) (Fig. 2). Under predominantly budworm pressure, the pyrethroids tested were the least effective in controlling the Heliothine complex. Intrepid, Denim, and S-1812 provided a higher level of control, while Tracer and Steward provided the highest level of control along with high yields. Similar results indicating Steward efficacy against the Heliothine complex have been shown by Kharboutli *et al.* (1999a and 1999b)

Test 2

In this test, Orthene (0.5 lb ai/acre), Asana XL (0.032), Asana XL (0.04), Steward (0.075), and Curacron (0.5) failed to differ significantly from the untreated control with respect to percent Heliothine square damage. Steward alone at 0.11 lb ai/acre along with the following tank mixtures: Asana XL + Steward (0.04 + 0.075); Curacron + Steward (0.5 + 0.075); Orthene + Steward (0.5 + 0.075); and Asana XL + Steward (0.032 + 0.075) provided the greatest reduction in Heliothine square damage compared to the untreated control (Table 2). Asana XL (0.032); Asana XL (0.04); and Orthene (0.5) failed to differ significantly from the untreated control with respect to the live Heliothine larvae count. Curacron (0.5); Steward (0.075); Orthene + Steward (0.5 + 0.075); and Asana XL + Steward (0.032 + 0.075) were intermediate in reducing the live larvae count. Steward (0.11); Curacron + Steward (0.5 + 0.075); and Asana XL + Steward (0.04 + 0.075) provided the best performance with respect to reducing the live larvae count (Table 2). Orthene (0.5) was the only treatment that failed to significantly out-yield the untreated control. The low rate (0.032) of the pyrethroid Asana XL resulted in an intermediate yield. Orthene + Steward (0.5 + 0.075); Steward (0.11); Asana XL (0.04); Curacron + Steward (0.5 + 0.075); Curacron (0.5); Asana XL + Steward (0.04 + 0.075); Steward (0.075); and Asana XL + Steward (0.032 + 0.075) were statistically the highest yielding treatments in the test (Fig. 3). In this test, Steward alone at 0.11 lb ai/acre provided excellent control of the Heliothine complex and was among the treatments producing the highest yields. Steward alone at 0.075 lb ai/acre, Orthene alone, Asana XL alone, and Curacron alone were less effective. When these materials were tank-mixed with Steward (0.075), efficacy of the tank mixture was similar to that of Steward alone at the high rate (0.11).

PRACTICAL APPLICATION

These studies were conducted to evaluate Steward alone and in combination with tank-mix partners for Heliothine control in conventional cotton. Based on these results, Steward at 0.11 lb ai/acre provided Heliothine control comparable to Tracer, which is becoming the new standard in cotton for lepidopterous pest control. It also outperformed the traditional pyrethroid standards. In addition, Steward at the reduced rate of 0.075 lb ai/acre in combination with standard rates of Orthene, Curacron, or Asana XL provided Heliothine control comparable to Steward at 0.11 lb ai/acre (its recommended labeled rate).

ACKNOWLEDGMENTS

Tracer is a registered trademark of Dow AgroSciences LLC. Steward and Asana XL are registered trademarks of E.I. duPont de Nemours & Co., Inc. Intrepid is a registered trademark of Rohm and Haas Company. Denim and Curacron are registered trademarks of Novartis. Karate is a registered trademark of Zeneca Company. Decis is a registered trademark of Hoechst Schering AgrEvo S.A. de C.V. Fury is a registered trademark of FMC Corporation. Leverage and Baythroid are registered trademarks of Bayer Corp. Orthene is a registered trademark of OMS Investments, Inc.

LITERATURE CITED

Bagwell, R.D., D.C. Cook, J.J. Adamczyk, B.R. Leonard, and S. Micinski. 1999. Status of insecticide resistance in tobacco budworm and bollworm in Louisiana during 1998. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 872-878.

Bierman, R.H. 1998. Results of DPX-MP062 efficacy trials on cotton bollworm (*Helicoverpa zea*) and tobacco budworm (*Heliothis virescens*) in Texas. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1167-1170.

Brown, T.M., P.K. Bryson, D.S. Brickle, S. Pimprale, F. Arnette, M.E. Roof, J.T. Walker, and M.J. Sullivan. 1998. Pyrethroid-resistant *Helicoverpa zea* and transgenic cotton in South Carolina. Crop Protection 17:441-445.

Kharboutli, M.S., C.T. Allen, C. Capps, and L. Earnest. 1999a. Outlook for Steward insecticide in southeast Arkansas. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1092-1095.

Kharboutli, M.S., C.T. Allen, C. Capps, and L. Earnest. 1999b. 1998 bollworm and tobacco budworm control studies. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1186-1190.

Mitchell, W. 1999. Steward® – a new broad spectrum insect control agent from DuPont. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 73-74.

Sparks, T.C., J.B. Graves, and B.R. Leonard. 1993. Insecticide resistance and tobacco budworm: past, present, and future. Rev. Pestic. Toxicol. 2:149-183.

Williams, M.R. 2000a. Cotton insect loss estimates - 1999. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 884-887.

Williams, M.R. 2000b. Cotton insect losses – 1999. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 887-913.

Table 1. Test 1-Seasonal average for percent Heliothine-damaged squares and live Heliothine larvae count: Steward versus alternative insecticides for Heliothine control in cotton. Arkansas. 2000.

Treatment	Rate	Seasonal average % Heliothine-damaged squares	Seasonal average total live Heliothine larvae / 50 sq & 50 term
	(lb ai/acre)		
Untreated check	--	17.8 a[z]	4.2 a
Tracer 4SC	0.067	4.3 d	0.6 e
Steward 1.25SC	0.11	7.3 cd	1.3 de
Intrepid 2SC	0.15	14.0 ab	4.1 a
Denim 0.16EC	0.01	9.8 bc	1.6 cde
Karate Z 2.09CS	0.025	13.5 ab	3.3 ab
Decis 1.5EC	0.01	14.0 ab	4.0 ab
Decis 1.5EC	0.02	11.8 bc	2.4 bcd
Fury 1.5EC	0.0375	10.8 bc	3.6 ab
Leverage 2.7SE	0.079	12.8 abc	3.1 abc
Baythroid 2EC	0.03	13.0 ab	3.3 ab
S-1812 35WP	0.15	10.0 bc	2.6 a-d
$LSD_{(P=0.05)}$		4.93	1.45

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT)

Table 2. Test 2-Seasonal average for percent Heliothine-damaged squares and live Heliothine larvae count: Steward alone and in combination for Heliothine control in cotton. Arkansas, 2000.

Treatment	Rate	Seasonal average % Heliothine damaged squares	Seasonal average total live Heliothine larvae / 50 sq & 50 term
	(lb ai/acre)		
Untreated check	--	9.4 a	2.6 a
Steward 1.25SC	0.11	4.5 bc[z]	0.4 c
Steward 1.25SC	0.075	7.0 abc	1.3 bc
Asana XL 0.66EC	0.032	8.3 ab	2.2 ab
Asana XL 0.66EC	0.04	9.0 a	2.9 a
Curacron 8E	0.5	6.5 abc	1.4 bc
Orthene 90S	0.5	10.3 a	2.6 a
Asana XL 0.66EC + Steward 1.25SC	0.032 + 0.075	4.9 bc	1.0 bc
Asana XL 0.66EC + Steward 1.25SC	0.04 + 0.075	3.6 c	0.9 c
Curacron 8E + Steward 1.25SC	0.5 + 0.075	4.3 c	0.7 c
Orthene 90S + Steward 1.25SC	0.5 + 0.075	4.8 bc	1.1 bc
$LSD_{(P=0.05)}$		3.49	1.12

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

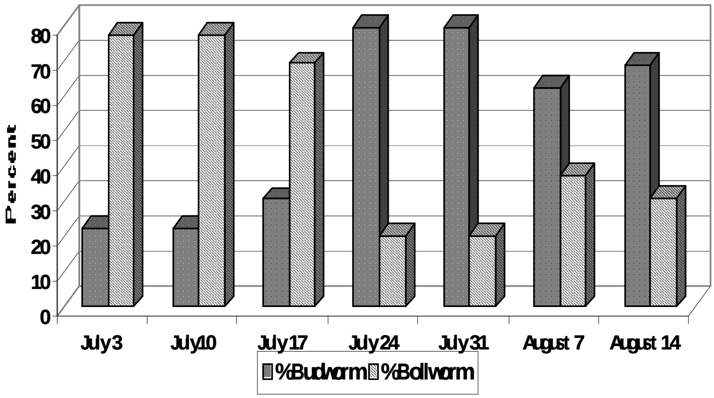


Fig. 1. Heliothine population density based on pheromone trap catches, July through mid-August. Jefferson County, Arkansas. 2000.

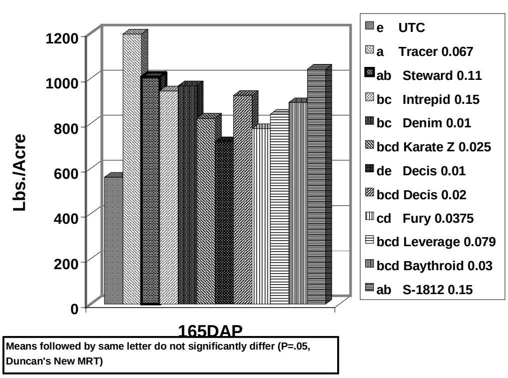


Fig. 2. Lint yield, Steward versus alternative insecticides for Heliothine control treatments in cotton. Arkansas. 2000.

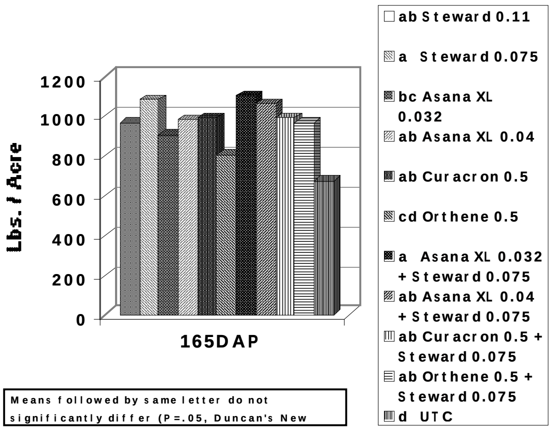


Fig. 3. Lint yield, Steward alone and in combination for Heliothine control treatments in cotton. Arkansas. 2000.

PERFORMANCE OF NEW AND CONVENTIONAL INSECTICIDES IN *Bt* COTTON

John D. Hopkins, Donald R. Johnson, Gus M. Lorenz, III, and Jack D. Reaper, III[1]

RESEARCH PROBLEM

Bollgard cotton provides exceptional control of the tobacco budworm, but the level of control provided for the cotton bollworm is somewhat less. In 2000, supplemental insecticide applications to the Bollgard cotton variety, Deltapine 451B/RR (contains a single gene for the production of CryIA(c) toxin), were evaluated to determine if improved Heliothine control could be demonstrated compared to untreated Deltapine 451B/RR.

BACKGROUND INFORMATION

The bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (Fab.), are perennial pests of cotton in Arkansas and growers must utilize control measures to prevent economic damage each year. The commercialization of transgenic cotton cultivars containing the insecticidal endotoxin of *Bacillus thurengiensis* introduced a new approach in managing the Heliothine complex in cotton (Deaton, 1995). This new management tactic for Heliothine control, the utilization of transgenic *Bt* cotton varieties, is gaining acceptance in Arkansas with approximately 35% of the 950,000 cotton acres in 2000 being planted to transgenic *Bt* varieties. Research is needed in Arkansas to help understand how best to integrate this new tactic with traditional methods of Heliothine control. *Bt* cotton alone has been shown to provide excellent mortality of the tobacco budworm but is less efficacious on the bollworm (Leonard *et al.*, 1997). In instances where bollworm pressure is high, the reliance on *Bt* cotton alone to provide control has been less than satisfactory. Improved Heliothine control in *Bt* cotton has been documented through the use of supplemental insecticide applications (Burd *et al.*, 1999; Johnson *et al.*, 2000). Resistance management is also a concern when deciding how best to employ *Bt* cotton. A selected colony of the bollworm exhibited 50-fold resistance to the CryIA(c) toxin after six

[1] Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Extension Entomologist-Pest Management Section Leader, Cooperative Extension Service, Little Rock; Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Entomology Extension Specialist, Cooperative Extension Service, Lonoke.

generations of selection and nearly 100-fold resistance after 10 generations of selection (Burd *et al.*, 2000). The use of supplemental insecticides when needed in *Bt* cotton can help reduce the potential for loss of *Bt* efficacy through resistance. The objective of this study was to document, under Arkansas conditions, the benefits of supplemental applications of traditional and new insecticides in *Bt* cotton to enhance Heliothine control.

RESEARCH DESCRIPTION

This trial was conducted on the Robert Fratesi Farm in Jefferson County, Arkansas, in 2000. This farm was located within the boll weevil eradication zone and received programmed sprays of ULV malathion that greatly reduced boll weevil and tarnished plant bug pressure. A combination of new and traditional chemistry was selected for evaluation. Treatments were evaluated in small plots (eight 40-inch rows x 50 ft) arranged in a randomized complete block design with four replications. The cotton variety used was Deltapine 451B/RR, which was planted on 1 May 2000. The crop was furrow-irrigated on an as-needed basis. Insecticide treatments were initiated based on state recommendations of one Heliothine-damaged square per row foot with eggs and small larvae present. Applications were made with a John Deere 6000 hi-cycle equipped with a compressed air delivery system. The boom was equipped with conejet TXVS 6 nozzles on a 20-inch spacing. Operating pressure was 45 psi with a final spray volume of 8.6 gal/acre. Treatments evaluated were: an untreated check; Stewart 1.25SC (0.075 lb ai/acre or 6.66 fl oz/acre); Steward 1.25SC (0.075 lb ai/acre or 7.68 fl oz/acre); Steward 1.25SC (0.09 lb ai/acre or 9.22 fl oz/acre); Tracer 4SC (0.067 lb ai/acre or 2.14 fl oz/acre); Karate Z 2.09E (0.028 lb ai/acre or 1.7 fl oz/acre); Karate Z 2.09E (0.033 lb ai/acre or 2.0 fl oz/acre); Asana XL 0.66EC (0.036 lb ai/acre or 7.0 fl oz/acre); Vydate C-LV 3.77SL + Asana XL 0.66EC (0.25 + 0.033 lf ai/acre or 8.5 + 6.4 fl oz/acre); Decis 1.5EC (0.025 lb ai/acre or 2.13 fl oz/acre); Decis 1.5EC (0.03 lb ai/acre or 2.56 fl oz/acre); Baythroid 2EC (0.03 lb ai/acre or 1.9 fl oz/acre).

Treatments were applied as foliar sprays on 6 July, 20 July, 27 July, and 3 August. Insect counts and damage ratings were made on 10 July (4DAT#1); 24 July (4DAT#2); 31 July (4DAT#3); and 7 August (4DAT#4). Data were collected by examining 50 squares, 50 terminals, and 50 blooms at random from the center of each plot for the presence of live larvae (<1/4 + >1/4 inch) and square damage. The center two rows of each plot were machine harvested with a commercial two-row John Deere cotton picker on 13 October (165DAP) and lint yields were determined based on a 36% gin turnout. Data were processed using Agriculture Research Manager Ver. 6.0.1. Analysis of variance was run and Duncan's New Multiple Range Test (P=0.05) was used to separate means only when AOV Treatment P(F) was significant at the 5% level.

RESULTS AND DISCUSSION

During the initial portion of this trial, the Heliothine population mix was approximately 75% cotton bollworm, 25% tobacco budworm. By the time the second treatment application was made, the population had shifted to 20% cotton bollworm, 80% tobacco budworm and averaged 27% cotton bollworm, 73% tobacco budworm during the remainder of the test period (Fig. 1). Heliothine pressure was high in the test area as indicated in the untreated control of an adjacent non-*Bt* test plot (cotton variety: Deltapine 5415RR) that had an identical 1 May planting date. Over the same evaluation period as mentioned above, the non-*Bt* plots averaged 18% square damage, 4.2 live larvae per 50 squares and 50 terminals, and yielded 562 lb lint/acre. Peak Heliothine pressure occurred at the test site around 31 July.

At four days after the first application (4DAT#1) when the Heliothine population was predominantly cotton bollworm, all treatments had significantly less Heliothine-damaged squares than the untreated control (*Bt* cotton alone). During the remaining three ratings (4DAT#2, 4DAT#3, and 4DAT#4) when the Heliothine population was predominantly tobacco budworm, there were no significant differences among treatments with respect to square damage (Table 1). When looking at the treatment seasonal averages for square damage (<1%), no significant differences among treatments were observed (Fig. 2).

There were no significant differences among treatments for total live Heliothine larvae / 50 squares, 50 terminals, & 50 blooms at any of the rating dates (Table 2). When looking at the treatment seasonal averages for live Heliothine larvae counts, all treatments remained below 0.5 larvae / 50 sq., 50 term., & 50 blm and again, treatment differences were non-significant (Fig. 3). Tracer at 0.067 lb ai/acre and Vydate + Asana XL at 0.25 + 0.033 lb ai/acre significantly out- yielded the untreated *Bt* cotton control by 182 and 158 lb lint/acre, respectively. All other treatments failed to significantly out-yield the *Bt* cotton untreated control. On a numerical basis only, all other treatments except Asana XL at 0.036 lb ai/acre out-yielded the control by an average of 75 lb lint/acre (Fig. 4).

PRACTICAL APPLICATION

This study was conducted to evaluate potential benefits from supplemental applications of insecticides for Heliothine control in *Bt* cotton. The results obtained in this study suggest that the appropriate use of selected supplemental insecticides, targeted at pests not adequately controlled by the CryIA(c) toxin in single gene *Bt* cotton, can be beneficial. The benefits derived from this improved bollworm control and increased yield can result in a substantial economic benefit to the producer.

ACKNOWLEDGMENTS

Tracer is a registered trademark of Dow AgroSciences LLC. Steward, Asana, and Vydate are registered trademarks of E.I. duPont de Nemours & Co., Inc. Karate is a registered trademark of Zeneca Company. Decis is a registered trademark of Hoechst Schering AgrEvo S.A. de C.V. Baythroid is a registered trademark of Bayer Corporation.

LITERATURE CITED

Burd, T., J.R. Bradley, Jr., and J.W. Van Duyn. 1999. Performance of selected *Bt* cotton genotypes against bollworm in North Carolina. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 931-934.

Burd, A.D., J. R. Bradley, Jr., J. W. Van Duyn and F. Gould. 2000. Resistance of Bollworm, *Helicoverpa zea,* to CryIA(c) Toxin. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 923-926.

Deaton, W.R. 1995. Bollgard™ gene for cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 37.

Johnson, D.R., G.M. Lorenz, III, J.D. Hopkins, and L.M. Page. 2000. Control of the Heliothine complex in Bollgard cotton cultivars, 1998-1999. *In:* Oosterhuis, D.M. (ed.). Proc. 2000 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas, Agricultural Experiment Station Special Report 198:245-248, Fayetteville.

Leonard, B.R., H. Fife, K. Torrey, J.B. Graves, and J. Holloway. 1997. Helicoverpa/ Heliothis management in Nucotn and conventional cotton cultivars in Louisiana. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 863-867.

Table 1. Percent Heliothine-damaged squares: Heliothine control with supplemental insecticide applications in *Bt* Cotton. Arkansas, 2000.

		Heliothine-damaged squares			
Treatment	Rate	4DAT#1	4DAT#2	4DAT#3	4DAT#4
	(lb ai/acre)	------- (%) -------			
Untreated check	--	2.0 a	0.0 a	1.0 a	0.5 a
Steward	0.065	0.0 b[z]	0.5 a	1.5 a	2.0 a
Steward	0.075	0.5 b	1.0 a	1.5 a	0.0 a
Steward	0.09	0.5 b	1.0 a	2.0 a	0.0 a
Tracer	0.067	0.0 b	0.5 a	1.5 a	0.0 a
Karate Z	0.028	0.0 b	0.0 a	3.0 a	0.0 a
Karate Z	0.033	0.5 b	0.0 a	3.0 a	0.0 a
Asana XL	0.036	0.0 b	0.5 a	1.5 a	0.0 a
Vydate + Asana XL	0.25 + 0.033	0.0 b	0.0 a	0.5 a	0.0 a
Decis	0.025	0.0 b	1.5 a	0.5 a	0.0 a
Decis	0.03	0.0 b	0.5 a	1.5 a	0.0 a
Baythroid	0.03	0.5 b	1.0 a	0.5 a	0.0 a

[z] Means followed by same letter do not significantly differ (P= 0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 2. Live Heliothine larval counts: Heliothine control with supplemental insecticide applications in *Bt* cotton. Arkansas. 2000.

Treatment	Rate	Total live Heliothine larvae			
		4DAT#1	4DAT#2	4DAT#3	4DAT#4
	(lb ai/acre)	----------------- (#/50 sq, 50 term, & 50 blm) -----------------			
Untreated check	--	1 a	0 a	0 a	1 a
Steward	0.065	0 a[z]	0 a	0 a	0 a
Steward	0.075	1 a	0 a	0 a	0 a
Steward	0.09	0 a	0 a	0 a	0 a
Tracer	0.067	0 a	0 a	1 a	0 a
Karate Z	0.028	0 a	0 a	0 a	0 a
Karate Z	0.033	0 a	0 a	1 a	0 a
Asana XL	0.036	0 a	0 a	1 a	1 a
Vydate + Asana XL	0.25 + 0.033	0 a	0 a	0 a	0 a
Decis	0.025	0 a	0 a	0 a	1 a
Decis	0.03	0 a	0 a	1 a	0 a
Baythroid	0.03	0 a	0 a	0 a	0 a

[z] Means followed by same letter do not significantly differ (P= 0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

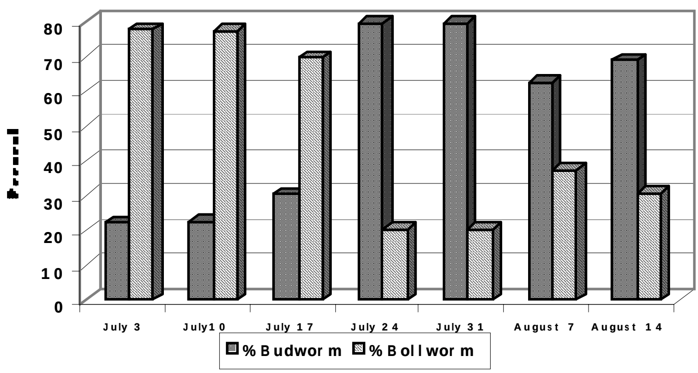


Fig. 1. Heliothine population density based on pheromone trap catches, July through mid-August. Jefferson County, Arkansas. 2000.

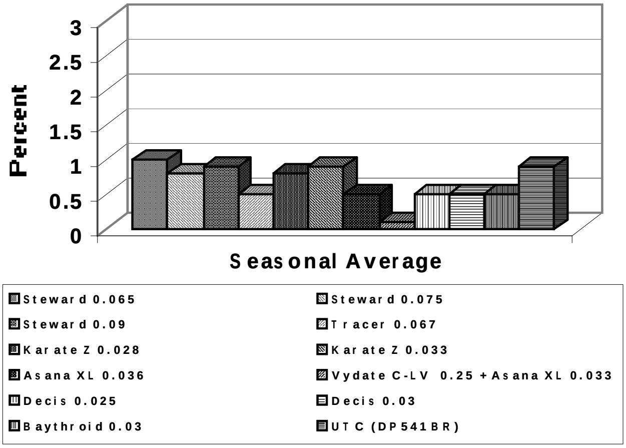


Fig. 2. Seasonal average percent Heliothine-damaged squares from Heliothine control treatments in *Bt* cotton, Arkansas, 2000.

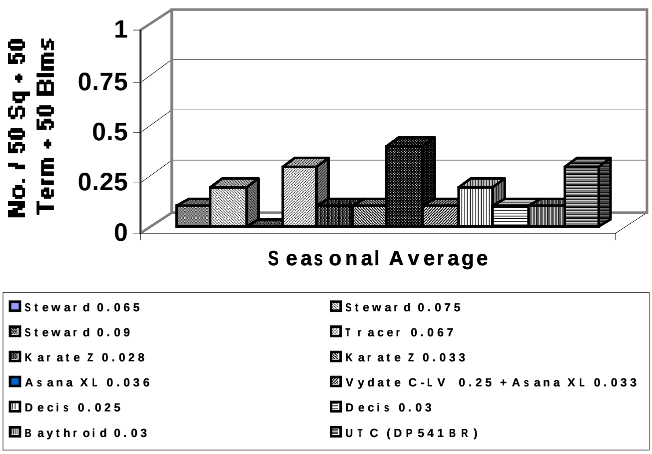


Fig. 3. Seasonal average live Heliothine larvae counts from Heliothine control treatments in *Bt* cotton. Arkansas. 2000.

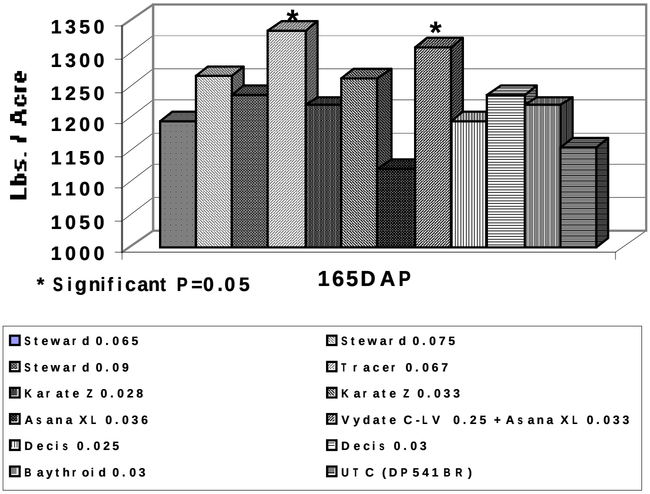


Fig. 4. Lint yield from Heliothine control treatments in *Bt* cotton. Arkansas. 2000.

TARNISHED PLANT BUG CONTROL IN COTTON AFTER APPLICATIONS OF CENTRIC™, ACTARA™, STEWARD™, CALYPSO™, AND LEVERAGE ™

Tina Gray Teague, N. Philip Tugwell, and Eric J. Villavaso[1]

RESEARCH PROBLEM

Evaluating insecticides for tarnished plant bug (TPB) [*Lygus lineolaris* (Palisot de Beauvois)] control remains a high priority research effort in Arkansas cotton research as new insecticides that have novel modes of action become commercially available. With these new products, performance evaluation criteria may require adjustment. For instance, crop protection activity of products such as the neonicotinoid, Provado™ (imidacloprid), includes anti-feeding effects against TPB (Teague and Tugwell, 1996; Teague *et al.*, 2000). While determination of percent mortality after a brief exposure time (24 hr) may be suitable for measuring performance of a fast-acting organophosphate insecticide such as Orthene™ (acephate), it would be inappropriate for an insecticide such as Provado.

RESEARCH DESCRIPTION

Cotton was planted 16 May in 8-row wide plots 50 ft long with 10 ft alleys. The experiment was arranged in a Randomized Complete Block Design with three replications. Insecticides were applied 20 Jul using a 4-row electrostatic, high-clearance sprayer calibrated to deliver 10 gpa at 28 psi with Turbo Teejet nozzles (TT1002-VP) set on 19-inch spacing to provide two nozzles per row. In the center two rows of each plot, six organdy sleeve cages, 6 inches diameter by 18 inches long, were secured to randomly selected individual plants. The lower end of each cage was tied around the plant approximately 1 ft from the terminal. The cages were rolled down to the tie and covered with aluminum foil, leaving plant terminals exposed. Immediately following the application while the foliage was still wet, the foil was removed, the cage pulled up, and five TPB nymphs (3rd instar) were placed into each cage. Cages were secured with twist ties. The TPB were obtained from a laboratory colony reared on an artificial diet at the USDA-ARS laboratory in Mississippi State, MS (Cohen *et al.*, 2000).

---

[1] Professor, Arkansas State University, Jonesboro; Professor, Department of Entomology, Fayetteville; and Research Scientist, ARS-USDA, Mississippi State, MS.

One day following application, three plants were cut below the cage and taken to the laboratory where TPB mortality was determined. The procedure was repeated for the remaining three cages at 4 days after treatment (DAT). Mortality data were analyzed with AOV, and means separated with LSD.

RESULTS

Significant differences between treatments were observed after 1 day exposure in cages (Table 1). Mortality of >85% was observed in the thiamethoxam treatments (Actara™ and Centric™). A longer exposure time appeared to be appropriate for evaluating the other compounds. At 4 days, mortality was >90% for all insecticides tested except the low rate of Steward and the Calypso™. The tank-mix of Calypso plus Steward did not significantly increase mortality over Steward alone. Benefits from a tank-mix might appear at a lower Steward rate, but further testing is needed.

PRACTICAL APPLICATION

The extended exposure time (4 days compared to 1 day) used in this cage study appears to be appropriate for insecticides that do not immediately result in insect death following exposure. Compounds that have repellent activity may require a longer testing period for evaluation because for the first few hours of the test, the insect may rest on the cage rather than the treated plant. Mortality from insecticides that act following ingestion or from those with anti-feeding properties also will be less rapid. Observations from similar 1999 cage work indicated that 3-day testing was not sufficient for evaluating such products, thus a 4-day evaluation interval was adopted (Teague *et al.*, 2000).

Growers and crop advisors should be aware that the perception of insecticide performance will differ with some new chemistry products compared to the organophosphate standards. Live insects may remain in the field in the first few days following application; however, crop injury may not be occurring. To assess crop protection provided by these insecticides, crop monitoring of new injury is required. Simply counting live insects may not suffice.

ACKNOWLEDGEMENTS

We thank Claude Kennedy, Director of the Cotton Branch Experiment Station, and his staff for their assistance in the study. We also acknowledge Dr. Bill McGovern of USDA-ARS for his support and Ms. Gay McCain, USDA-ARS, Mississippi State, MS for providing the tarnished plant bug nymphs. Special thanks to Mr. Alan Hopkins of Bayer for the use of his high-clearance sprayer.

LITERATURE CITED

Cohen, A.C. 2000. New oligidic production diet for *Lygus Hesperus* Knight and *L. lineolaris* (Palisot de Beauvois). J. Entomol. Sci. 35:301-310.

Teague, T.G. and N.P. Tugwell. 1996. Chemical control of tarnished plant bug: Results from field cage studies and laboratory bioassays. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 850-854.

Teague, T.G., N.P. Tugwell, S. Muthiah, and J.M. Hornbeck. 2000. New insecticides for control of tarnished plant bug – results from field and cage studies and laboratory bioassays. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1214-1217.

Table 1. Mortality of tarnished plant bug (TPB) nymphs observed one and four days after treatment (DAT) with insecticides in cage studies at the Cotton Branch Experiment Station, Marianna, Arkansas. 2000.

		TPB dead	
Treatment /formulation	Rate	1 DAT	4 DAT
	(lb ai/acre)	---------------- (%)	----------------
Untreated	--	10.87 d[z]	18.0 c
Steward 1.25 SC	0.0650	53.3 bc	74.2 b
Steward 1.25 SC	0.1100	48.5 dc	91.4 a
Centric 40 WG	0.0473	88.9 ab	97.8 a
Actara 25 WG	0.0473	93.3 a	91.1 a
Calypso 480 SC	0.0469	55.9 abc	62.2 b
Calypso 480SC + Steward 1.25SC	0.0469+0.11	60.0 abc	97.8 a
Leverage 2.7 EC	0.0634	12.8 d	93.3 a
P>F (AOV)		0.05	0.05
LSD (0.05)		37.8	12.64

[z] Numbers within a column followed by the same letter are not significantly different (P=0.05).

DEVELOPMENT OF COTTON APHID THRESHOLD THAT INCORPORATES NATURAL ENEMIES

Hugh E. Conway and Tim Kring[1]

RESEARCH PROBLEM

Two main objectives were identified to evaluate using field experimental conditions: (1) to design management methods that incorporate the action of biological control agents in establishing a threshold for the cotton aphid, *Aphis gossypii*; and (2) to evaluate pest management regimes in regard to natural enemies of the cotton aphid.

BACKGROUND INFORMATION

The primary means of managing the cotton aphid is through application of insecticides based on treatment thresholds that fail to take into account the pest's natural enemies. Currently, treatment thresholds in Arkansas rely only on the percentage of infested plants when aphid populations are increasing. This study incorporates the use of selected natural enemies and the entomopathogenic aphid fungus, *Neozygites fresenii,* into the decision-making process for applying insecticides.

MATERIALS AND METHOD

The Clarkedale, Arkansas, study field was subdivided into 16 plots, each about 0.75 acre in size (56 rows x 180 ft). Using a Latin Square Design, four treatments were made with four replicates: (1) untreated control, (2) fungicide treated, (3) conventional threshold, and (4) experimental threshold. The fungicide treatment was used in an attempt to disrupt the action of the aphid fungus (Wells *et al.*, 1997). Conventional threshold plots were treated when >50% of the plants were infested and aphid populations were increasing (Johnson, 2000). Experimental plots were treated when aphid populations were increasing, aphids were present on >50% of cotton plants, *and* aphid densities exceeded:

- 15 aphids/leaf if "no" fungus, parasitoids or coccinellids were present.
- 30 aphids/leaf if "no" fungus, 10% mummies, 0.3 coccinellid adults/row-ft, 0.2 coccinellid larvae/row-ft werepresent.

---

[1] Graduate Assistant and Professor of Entomology, Department of Entomology, Fayetteville.

- 50 aphids/leaf if 10% visible fungus, and no parasitoids or coccinellids were present.
- 70 aphids/leaf if 10% visible fungus, 10% mummies, 0.3 coccinellid adults/row-ft, or 0.2 coccinellid larvae/row-ft were present.

Twice weekly samples of aphid numbers and types (small, large, winged, and mummy) were taken from one terminal and one middle leaf from 20 randomly selected plants in each plot. Additionally, five aphid-infested terminal leaves and five aphid-infested middle leaves per plot were collected and placed in marked vials of 70% ethanol to analyze for the presence and percent infestation of the fungus *Neozygites fresenii* at Dr. Steinkraus's laboratory in Fayetteville, Arkansas (Steinkraus *et al.*, 1991; Hardee *et al.*, 1994).

Cages were placed on cotton plants in untreated, conventional, and experimental plots to partition the role of natural enemies on the cotton aphid. The exclusion cage methods involved a trio of cages: an open cage surrounding the leaf (allowing movement of insects in and out); a total exclusion or a closed cage (blocked on both ends); and a third no-cage-treatment (Kring *et al.*, 1985; Kerns and Gaylor, 1991). For both the open and enclosed cages, each leaf cage was a 16-oz clear plastic Solo cup with the bottom removed. A fine mesh sleeve was attached to the bottom to fit around the petiole and the sleeve was secured with a twist tie. The cage was held in place by a twist tie around flags. The top of the enclosed cage was sealed with a fine nylon mesh. Three leaves of similar size, with similar aphid densities and in close proximity to each other, were selected in a plot. The three cage treatments were then randomly assigned to these leaves. Cages were monitored daily for the number and type of aphids (small, large, winged, and mummies) and the presence and type of natural enemies.

Twice weekly samples of natural enemies were taken using a dislodgement method where the plants were struck on a wire mesh covering a wash basin (Elkassabany *et al.*, 1996). Density levels of beneficial insects were obtained by sampling 24 row-ft per plot (8 samples per plot, each sample 3 row-ft long). Beneficial insects collected using this method were: spiders, predaceous Heteroptera *(Geocoris* spp., *Orius insidious*, *Nabis* spp., *Scymnus* spp.); lady beetles (*Coccinella septempunctata*, *Harmonia axyridis*, *Hippodamia convergens*, *Coleomegilla maculata*); and lacewings *(Chrysopa* spp., *Hemerobius* spp.). Plant growth parameters were evaluated weekly using COTMAN. Two representatitve locations were selected to collect data for COTMAN.

RESULTS

The cotton aphid populations began increasing in late June, 2000 until reaching the conventional threshold (Conv) treatment levels on 28 June and again on 3 July (Fig. 1). The experimental threshold (Exp) was reached on 3 July. Treatment consisted of an application of 3 oz/acre of Provado. Aphid densities in untreated (Untr) plots continued to increase until mid-July when the fungus *Neozygites fresenii* rapidly killed the cotton aphid.

Lady beetle larvae numbers followed the cotton aphid population with a peak population near 12 July (Fig. 2). The plots treated with Provado reached a peak 3X to 4X lower than the untreated control.

The lady beetle adults peaked a week after the lady beetle larvae (Fig. 3). There was not as noticeable a difference in the number of adult lady beetles occurring among treatments.

The lady beetle complex (adult and larvae) made up the majority of natural enemies present in the cotton field (Fig. 4).

Table 1 indicates that there was no significant difference in the overall yield between the insecticide treated cotton using the conventional threshold and the untreated control. There was a slight trend for yields to be higher in plots where the experimental threshold was applied when compared to the conventional threshold.

VALUE OF RESEARCH

Research results indicate that the inclusion of natural enemies of the cotton aphid into the treatment decision process would have the potential of helping the farmer by delaying the initial insecticide application and reducing the number of pesticide applications. There is a potential for maintaining yield and decreasing the chance of pesticide resistence in the cotton aphid with fewer applications of insecticides.

LITERATURE CITED

Elkassabany, N.E., J.R. Ruberson, and T.J. Kring. 1996. Seasonal distribution and overwintering of *Orius insidiosus* (Say) in Arkansas. J. Entomol. Sci. 31:76-88.

Hardee, D.D., M.T. Smith, A.A. Weathersbee III, and G.L. Snodgrass. 1994. Sampling of the cotton aphid (Homoptera: Aphididae) in cotton. Southwest. Entomol. 19: 33-44.

Johnson, D.R. 2000. MP 144 Insect Recommendations for Arkansas. University of Arkansas, United States Department of Agriculture, and County Government Cooperative Extension Service. 1-143.

Kerns, D.L., and M.J. Gaylor. 1993. Biotic control of cotton aphids (Homoptera: Aphididae) in cotton influenced by two insecticides. J. Econ. Entomol. 86: 1824-1834.

Kring, T.J., F.E. Gilstrap, and G.R. Michels Jr. 1985. Role of indigenous coccinellids in regulating greenbugs (Homoptera: Aphididae) on Texas grain sorghum. J. Econ. Entomol. 78: 269-273.

Steinkraus, D.C., T.J. Kring, and N.P. Tugwell. 1991. *Neozygites fresenii* in *Aphis gossypii* on cotton. Southwest. Entomol. 16: 118-123.

West, H.M. 1997. Influence of arbuscular mycorrihizal infection on competition between *Holcus lanatus* and *Dactylis glomerata*. J. Ecol. 84:429-438.

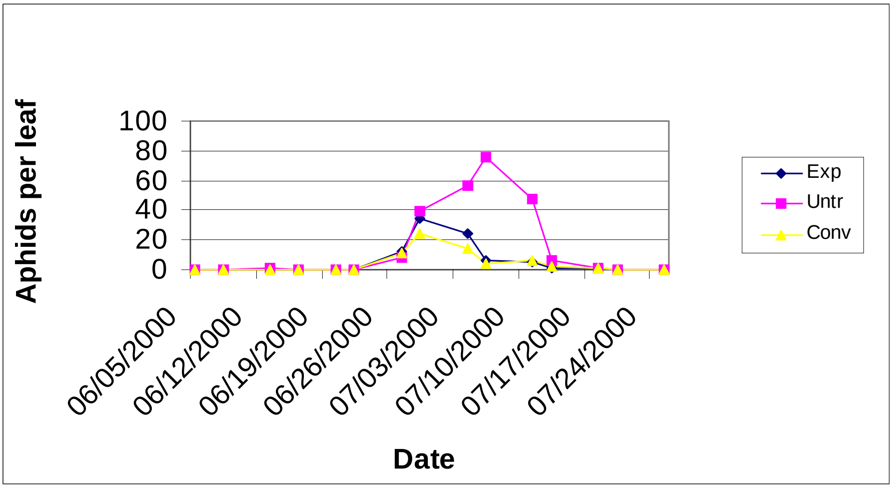


Fig. 1. Aphids per leaf from test plots at Clarkedale Experiment Station. Arkansas. 2000.

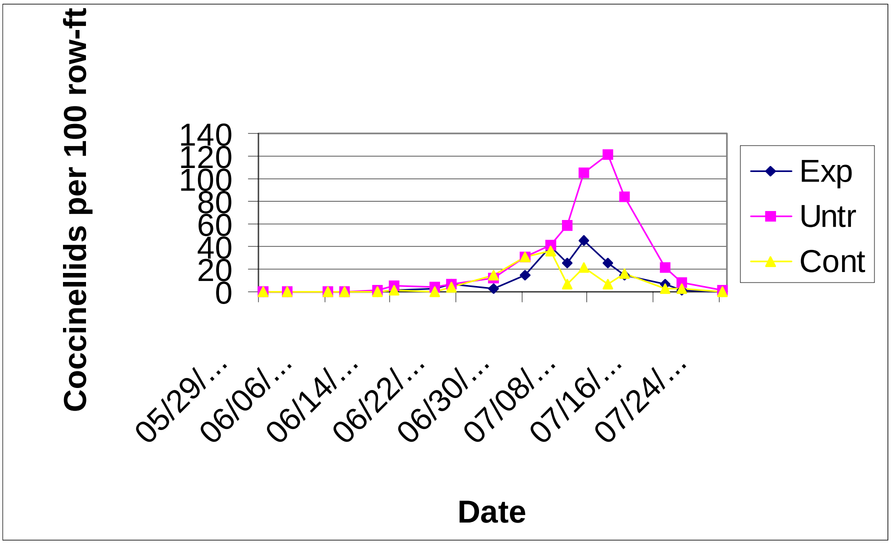


Fig. 2. Larval coccinellids from test plots at Clarkedale Experiment Station. Arkansas. 2000.

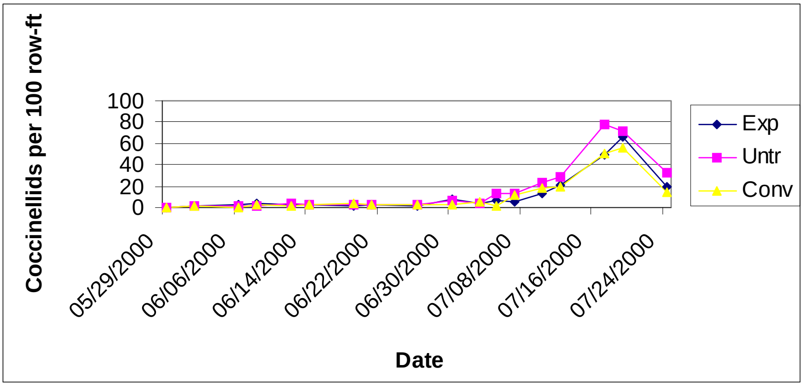


Fig. 3. Adult coccinellids from test plots at Clarkedale Experiment Station. Arkansas. 2000.

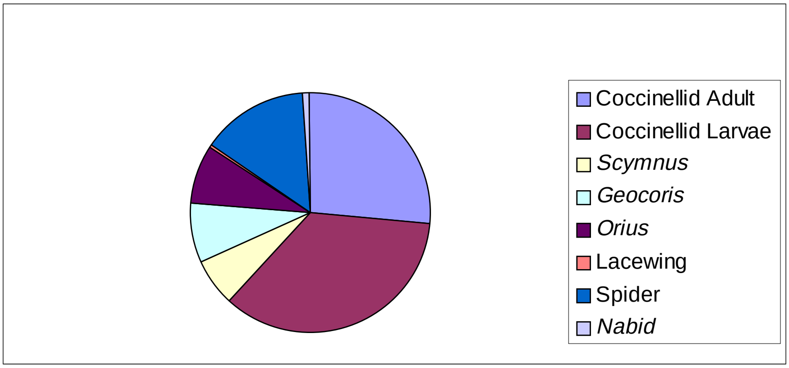


Fig. 4. Percent of beneficial insects from test plots at Clarkedale Experiment Station.

Table 1. Yield results from test plots at Clarkedale Research Station. Arkansas. 2000.

Treatment	Lint yield[z]
	(lb/acre)
Untreated	578.4 a
Experimental	574.3 a
Fungicide	545.7 a
Conventional	531.6 a

[z] Yields followed by the same letter are not significantly different (P=0.05).

EVALUATION OF THRIPS MANAGEMENT OPTIONS IN COTTON

Donald R. Johnson, John D. Hopkins, Gus M. Lorenz, III, and Jack D. Reaper, III[1]

RESEARCH PROBLEM

Thrips are early-season pests that have the potential of causing 50-60% yield reduction in Arkansas cotton with the level of damage varying from year to year. The objective of this experiment was to evaluate seed treatment, in-furrow granulars, and in-furrow sprays.

BACKGROUND INFORMATION

Thrips are an annual problem in cotton production. However, the thrips population varies in severity from year to year. The problem with controlling thrips is that you never know when they are going to be severe. As a result, most growers apply insecticides in-furrow or as seed treatments. Thrips build up in the spring on early wild host plants, most likely wheat. These hosts of thrips start to dry up from early May until mid June. As these hosts begin to dry, thrips start to migrate to more favorable food sources. Unfortunately, this is about the same time that cotton is starting to grow. The large host acreage for thrips and their reproductive capability create a situation, in most years, where young cotton sustains some level of damage from large thrips populations. In the mid-South production area, the tobacco thrips *Frankliniella fusca* is the predominant species that occurs on cotton. However, the western flower thrips, *Frankliniella occidentalis,* was quite common last year and caused a great deal of concern among Arkansas producers. Other species that have been reported in cotton include the flower thrips, *Frankliniella tritici;* the soybean thrips, *Neohydatothrips variables* (Burris *et al.*, 2000); and the onion thrips, *Thrips tabaci* (Eddy and Livingstone, 1931).

Thrips injure cotton by feeding in the terminal area of the plant. This terminal feeding disrupts normal growth of the plant leaf structure. The result is usually severely deformed leaves, aborted terminals, and greatly reduced leaf area. This general injury of the plant structure greatly reduces the photosynthetic capacity of the plant.

---

[1] Extension Entomologist-Pest Management Section Leader, Cooperative Extension Service, Little Rock; Entomology Associate Specialist, Cooperative Extension Service, Lonoke; Extension Entomologist-IPM Coordinator, Cooperative Extension Service, Little Rock; Entomology Extension Specialist, Cooperative Extension Service, Lonoke.

As a result, the general vigor of the plant is low, causing stunting, increased susceptibility to plant diseases, and, in the end, lower yields. If not controlled, thrips injury can reduce stands severely. In addition, yields can be reduced by up to 50 to 60% in a year when thrips are numerous and not controlled by insecticides either in-furrow, as seed treatments, or as foliar treatments.

RESEARCH DESCRIPTION

The test for 2000 was planted at the Cotton Branch Experiment Station at Marianna, Arkansas, and in Lonoke County in 1999. The test was arranged in a randomized complete block design with 4 replications. Plots consisted of four 38-inch rows 50 feet long. The variety was Paymaster 1218 BG/RR in 2000 and Paymaster 1560 BG in 1999. All insecticides for thrips control were applied at planting. Thrips samples and ratings were taken on 23 May, 31 May, 6 June, and 13 June in 2000. During 1999, samples were taken on 28 May, 3 June, 24 June, and 28 June. Five plants were randomly sampled per plot to determine the level of thrips infestation. Plants were processed using the wash procedure described by Burris *et al.* (1990). Samples were taken from the outside two rows of each plot to avoid influence on yield. Each plant was cut and immediately placed into a mason jar containing 70% ethyl alcohol. In the laboratory, plants were rinsed with alcohol to wash off thrips. To separate the thrips from alcohol, the solution was poured through coffee filters lining the inside of a buchner funnel. A vacuum pump was used to quickly evacuate the alcohol through the coffee filter. The thrips on the coffee filter were rinsed into a petri dish. Thrips were visually counted on the petri dish using a dissecting microscope.

Damage was also evaluated on each rating date using a 1 to 10 damage rating system with 1 equal to no damage, 5 equal to moderate damage, and 10 equal to extreme damage. Damage ratings were a composite of the overall appearance of the plots based on individual plant appearance. Plants with entire leaves without thrips damage in the terminal area were described as *no damage* and given a rating of 1. Plants with all leaves damaged and having damage along all leaf margins but still maintaining leaf form were described as *moderate damage* and given a rating of 5. The *extreme* damage rating of 10 was given to plots with plants having severe damage and leaves without form. Many times the severely damaged plots would have severe stand reduction. Plots were planted using a John Deere 7100 planter and maintained using standard agronomic practices. Yields were determined by harvesting the middle 2 rows of each plot.

RESULTS AND DISCUSSION

During 1999, the thrips pressure was higher than usual. All treatments in the test significantly improved thrips control compared to the untreated check (UTC) (Tables 1 and 2). The untreated check had significantly more thrips than all other treatments, averaging 58.8 thrips on the first evaluation compared to the lowest number of 0.8 in the Temik™ at 0.75 lb that was the best treatment on the 17 days after treatment (DAT) observation. The counts on the other treatments on the 17 DAT observations ranged from 1.5 to 10.5 thrips per 5 plants. On the 23 DAT observations the trend on the thrips numbers was for the Temik treatments to have a few less thrips. The Temik treatments averaged 3.0 to 4.5 total thrips compared to 6.8 to 8.5 thrips per sample in the Adage™, Admire™, and Gaucho™ treatments. In the next set of observations, the trend was significantly different. The Temik treatments averaged 20.8 to 36.0 significantly lower than the Adage, Admire, and Gaucho, which averaged 93.8, 49.5, and 86.8, respectively, and 80.8 for the untreated check. The trend continued into the 34 DAT observations but the numbers had declined significantly by this time. This information indicates that Temik will give longer residual control of thrips and may reduce the need of additional control measures in years when thrips infestations are high. The lowest damage ratings were also observed in the Temik treatments. The separation of thrips damage ratings was first observed 27 days after planting when the Temik had significantly lower damage ratings compared to other treatments. The damage rating for the untreated check was 8.3 or extremely damaged. Temik treatments averaged 2.8 for the Temik 0.5 treatment, 2.5 for the Temik 0.75 rate, and 2.8 for the highest rate of 1.05 pounds. Admire had a 5.5 damage rating, Adage a 5.3 rating, and Gaucho a 5.8 damage rating. The highest yield was also observed in the Temik treatment with 1036 lb lint per acre. All treatments were significantly higher in yield compared to the untreated check but treatments were not significantly different. The average yield did tend to be higher in the Temik treatments with an overall yield of 938 lb lint per acre compared with an average of 869 lb lint for non-Temik treatments and 604 lb lint for the untreated check.

The thrips pressure in 2000 was more intense in Arkansas in some locations but the pressure in the test location was lighter than in 1999. The control of thrips was similar for all products. Significant differences were found primarily on the first observation with Gaucho, Temik, and Adage providing control better than the untreated check. Temik treatments averaged 4 to 11 thrips per sample on the first observation with Adage and Gaucho 480 averaging 4.8 and 9 thrips, respectively. Gaucho 600FS and DiSyston™ were not significantly different from the untreated check, averaging 23 and 25 thrips per sample. The untreated check averaged 29 per sample. The overall difference among treatments for yield was not significant. However, the trends were similar to 1999 with the Temik treatment having the highest yield at 1471 lb lint per acre compared to the untreated control, which had the lowest yield at 1216 lb lint per acre. Similarly, Temik treatments overall averaged 1405 lb lint per acre compared to an average yield of 1321 for all other treatments (Tables 3 and 4). In Arkansas tests, Temik historically has been one of the best treatments for thrips control and the trend is similar for the trials reported here.

PRACTICAL APPLICATION

In 1999 and 2000, all treatments significantly improved thrips control above that of the untreated check. In 1999, the Temik treatments outperformed the others with respect to thrips suppression, visual damage rating, and cotton yield. While thrips suppression was not significant among treatments in 2000, the Temik treatments achieved higher yields. The data presented from these growing seasons indicate Temik to be one of the best treatments for thrips control in Arkansas cotton.

REFERENCES

Burris, E., C. Allen, R. Bagwell, D. Cook, B. Freeman, G. Herzog, G. Lentz, R. Leonard, and J. Reed. 2000. Thrips (Thysanoptera: Thripidae) A multi-state survey: Summary of observations for Arkansas, Alabama, Georgia, Louisiana, Mississippi, and Tennessee. Research Information Sheet 103. 6 pp. Louisiana State University.

Burris, E., A.M. Pavloff, B.R. Leonard, J.B. Graves, and G. Church. 1990. Evaluation of two procedures for monitoring populations of early season insect pests (Thysanoptera: Thripidae and Homoptera: Aphididae) in cotton under selected management strategies. J. Econ. Entomol. 83:1064-1068.

Eddy, C.O. and E.M. Livingstone. 1931. *Frankliniella fusca* (Hinds) thrips on seedling cotton. S. C. Agric. Exp. Stn Bull. B-113.

Table 1. Evaluation of insecticide treatment options on thrips population levels in cotton. Arkansas. 1999.

Treatment	Rate	Number of thrips			
		17 DAT	23 DAT	27 DAT	34 DAT
	(lb ai/acre)	(totals per 5 plants[z])			
Untreated check	--	58.8 a	11.8 a	80.8 a	7.5 a
Temik 15G IF	0.53	2.3 b	4.5 b	36.0 c	2.3 c
Temik 15G IF	0.75	0.8 b	4.0 b	34.1 c	1.5 c
Temik 15G IF	1.05	1.5 b	3.0 b	20.8 c	1.8 c
Admire	0.05	10.5 b	7.5 ab	93.8 b	5.8 b
Adage 200 ST	3.2[y]	6.5 b	8.5 ab	49.5 b	6.0 b
Gaucho 480 ST	8.0[y]	7.5 b	6.8 ab	86.8 b	5.0 b

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) was significant at mean comparison OSL.

[y] oz/cwt seed.

Table 2. Effect of different thrips control options in cotton on damage and yields in Arkansas. 1999.

Treatment	Rate	Thrips damage ratings 17 DAT	23 DAT	27 DAT	Lint yield
	(lb ai/acre)	---(1-10 scale)---			(lb/acre)
Untreated check	--	6.5 a[z]	7.3 a	8.3 a	604 b
Temik 15G IF	0.53	4.8 a	1.3 b	2.8 c	1036 a
Temik 15G IF	0.75	5.3 a	1.5 b	2.5 c	904 ab
Temik 15G IF	1.05	4.8 a	1.5 b	2.8 c	875 ab
Admire	0.05	5.8 a	3.5 b	5.5 b	861 ab
Adage 200 ST	3.2[y]	5.5 a	2.8 b	5.3 b	824 ab
Gaucho 480 ST	8.0[y]	6.8 a	2.8 b	5.8 b	922 ab

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) was significant at mean comparison OSL.

[y] oz / cwt seed.

Table 3. Evaluation of effects of different thrips control options on cotton in Arkansas. 2000.

Treatment	Rate	Number of thrips 17 DAT	23 DAT	27 DAT	34 DAT
	(lb ai/acre)	--- (totals per 5 plants[z]) ---			
Untreated check	--	29 a	142 a	101 a	135 a
Gaucho 600FS (ST)	6.4[y]	23 a	84 a	104 a	161 a
Gaucho 480 (ST)	8.0[x]	9 b	75 a	88 a	136 a
Temik 15G (IF)	0.50	4 b	44 a	94 a	127 a
Temik 15G (IF)	0.60	6 b	55 a	97 a	141 a
Temik 15G (IF)	0.75	11 b	57 a	124 a	154 a
Adage 300 (ST)	4.8[x]	6 b	75 a	149 a	146 a
DiSyston 15G (IF)	1.00	25 a	54 a	104 a	165 a

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) was significant at mean comparison OSL.

[y] fl oz / cwt seed.

[x] oz / cwt seed.

Table 4. Evaluation of thrips control options on cotton damage rating and yields in Arkansas, 2000.

Treatment	Rate	Thrips damage ratings				Lint yield
		13 DAT	21 DAT	28 DAT	34 DAT	
	(lb ai/acre)	---------------- (1-10 scale) --------------				(lb/acre)
Untreated check	--	4.0 a[z]	5.3 a	7.8 a	9.0 a	1215.92 a
Gaucho 600FS (ST)	6.4[y]	3.8 a	3.5 a	3.3 b	5.0 b	1348.14 a
Gaucho 480 (ST)	8.0[x]	1.8 b	3.8 a	3.5 b	3.8 b	1283.01 a
Temik 15G (IF)	0.50	1.3 b	2.5 a	4.0 b	5.5 b	1360.48 a
Temik 15G (IF)	0.60	1.8 b	3.8 a	3.8 b	5.3 b	1384.32 a
Temik 15G (IF)	0.75	2.5 ab	4.5 a	6.5 ab	5.0 b	1471.59 a
Adage 300 (ST)	4.8[x]	1.8 b	3.5 a	3.8 b	4.8 b	1390.14 a
DiSyston 15G	1.00	2.5 ab	4.3 a	4.3 b	5.3 b	1264.56 a

[z] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

[y] fl oz / cwt seed.

[x] oz / cwt seed.