10-1-2002

Summaries of Arkansas Cotton Research in Progress in 2001

Derrick M. Oosterhuis
University of Arkansas, Fayetteville

Summaries of Arkansas Cotton Research in Progress in 2001

Edited by Derrick M. Oosterhuis

ARKANSAS AGRICULTURAL EXPERIMENT STATION
Division of Agriculture | University of Arkansas
October 2002 | Research Series 497

This publication is available on the Internet at www.uark.edu/depts/agripub/publications

Additional printed copies of this publication can be obtained free of charge from Communication Services, 110 Agriculture Building, University of Arkansas, Fayetteville, AR 72701.

Layout and editing by Marci A. Milus

Technical editing and cover design by Cam Romund

Arkansas Agricultural Experiment Station, University of Arkansas Division of Agriculture, Fayetteville. Milc J. Shult, Vice President for Agriculture and Director; Gregory J. Weidemann, Dean, Dale Bumpers College o Agricultural, Food and Life Sciences and Associate Vice President for Agriculture–Research, University of Arkansas Division of Agriculture. PB1150/QX5. The University of Arkansas Division of Agriculture follows nondiscriminatory policy in programs and employment.
ISSN:1051-3140 CODEN:AKAMA6

SUMMARIES OF ARKANSAS COTTON RESEARCH 2001

Edited by Derrick M. Oosterhuis

Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701

CONTRIBUTORS

Agudelo, Paula, Graduate Assistant, Plant Pathology Department, Fayetteville

Ahrendsen, Bruce L., Associate Professor, Agricultural Economics and Agribusiness Department, Fayetteville

Baker, William H., Associate Professor, Arkansas State University, Jonesboro

Barrentine, James L., Professor and Head, Crop, Soil, and Environmental Sciences Department, Fayetteville

Bateman, Ronnie J., Pest Management Associate, Southwest Research and Extension Center, Hope

Benson, Ray, Research Associate, Northeast Research and Extension Center, Keiser

Bierlen, Ralph W., Former Research Associate, Agricultural Economics and Agribusiness Department, Fayetteville

Bourland, Fred M., Director, Northeast Research and Extension Center, Keiser

Branson, Jeffrey W., Weed Science Associate, Southeast Research and Extension Center, Monticello

Brown, Robert S., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville

Bryant, Kelly J., Area Extension Specialist - Farm Management, Southeast Research and Extension Center, Monticello

Capps, Chuck, Pest Management Technical Support Specialist, Southeast Research and Extension Center, Monticello

Coker, Dennis L., Research Specialist, Crop, Soil, and Environmental Sciences Department, Fayetteville

Conway, Hugh E., Graduate Assistant, Entomology Department, Fayetteville

Coy, Steven, Research Specialist - Cotton Entomology, Arkansas State University, Jonesboro

Dighe, Nilesh, Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville

Dixon, Bruce L., Professor, Agricultural Economics and Agribusiness Department, Fayetteville

Feng, Chunda, Professional Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville

Fisher, April, Jefferson County Extension Agent - Agriculture, Cooperative Extension Service, Pine Bluff

French, Ned, Field Development Scientist, Eden Biosciences, Little Rock

Glover, Robert E., Research Specialist, Northeast Research and Extension Center, Keiser

Gomez, S. Karen, Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville

Greene, Jeremy, Extension Entomologist, Southeast Research and Extension Center, Monticello

Groves, Frank, Research Specialist, Southeast Branch Experiment Station, Rohwer

Hackman, George, Agronomic Systems Manager, Monsanto Co., Tumbling Shoals
Hammack, Jason, undergraduate, Crop, Soil, and Environmental Sciences Department, Fayetteville
Hendrix, Bill, Technical Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Hopkins, John D., Entomology Associate Specialist, Cooperative Extension Service, Little Rock
Hornbeck, Jimmy, Research Specialist, Cotton Branch Station, Marianna
Ihring, Rob, Roundup Cotton Specialist, Monsanto, Collierville, TN
Johnson, Donald R., Pest Management Section Leader and IPM Coordinator, Cooperative Extension Service, Little Rock
Kelly, Steven R., County Extension Agent, Desha County, Cooperative Extension Service, McGehee
Kennedy, Claude, Resident Director, Cotton Branch Station, Marianna
Kirkpatrick, Terry L., Plant Pathologist, Southwest Research and Extension Center, Hope
Kirst, Robert C., Jr., Research Specialist, Southeast Research and Extension Center, Monticello
Kring, Timothy J., Professor, Entomology Department, Fayetteville
Lorenz, Gus M., III, Extension Entomologist, Cooperative Extension Service, Little Rock
McClelland, Maryilyn R., Senior Research Associate, Crop, Soil, and Environmental Sciences Department, Fayetteville
McConnell, J. Scott, Associate Professor, Crop, Soil, and Environmental Sciences Department, Southeast Research and Extension Center, Monticello
Meek, Cassandra R., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Mutondo, Joao E., Graduate Research Assistant, Agricultural Economics and Agribusiness Department, Fayetteville
Namenek, Robin C., Research Specialist, Southeast Research and Extension Center, Monticello
Norton, M. Chad, Staff Chair, Lincoln County Extension Office, Cooperative Extension Service, Star City
Oosterhuis, Derrick M., Distinguished Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Paling, Joseph J., Research Associate, Southwest Research and Extension Center, Hope
Parsch, Lucas D., Associate Professor, Agricultural Economics and Agribusiness Department, Fayetteville
Plunkett, Donald E., Cotton Verification Coordinator, Cooperative Extension Service, Little Rock
Rajguru, Satyendra N., Research Associate, Crop, Soil, and Environmental Sciences Department, Fayetteville

Reaper, Jack D., III, Entomology Extension Specialist, Cooperative Extension Service, Little Rock
Robbins, Robert T., Professor, Plant Pathology Department, Fayetteville
Robertson, William C. Extension Agronomist - Cotton, Cooperative Extension Service, Little Rock
Robinson, Rodrick, Agriculture Student, Arkansas State University, Jonesboro
Smith, Kenneth L., Extension Weed Scientist, Southeast Research and Extension Center, Monticello
Sparks, Oscar C., Graduate Assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville
Steinkraus, Donald, Professor, Entomology Department, Fayetteville
Stewart, James M., Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville
Studebaker, Glenn, Entomologist, Northeast Research and Extension Center, Keiser
Tacker, Phil L., Agricultural Engineer, Cooperative Extension Service, Little Rock
Teague, Tina G., Professor, Arkansas State University, Jonesboro
Tingle, Chris, Agronomist, Northeast Research and Extension Center, Keiser
Tugwell, N. Philip, Professor, Entomology Department, Fayetteville
Villavaso, Eric J., Research Scientist, ARS-USDA, Mississippi State, MS
Vories, Earl D., Professor, Department of Biological and Agricultural Engineering, Northeast Research and Extension Center, Keiser
Yates, Chuck, Graduate Assistant, Entomology Department, Fayetteville
Zhang, Jinfa, Research Associate, Crop, Soil, and Environmental Sciences Department, Fayetteville

CONTENTS

SUMMARIES OF COTTON RESEARCH IN PROGRESS IN 2001

PREFACE

The 2001 cropping season was by comparison with previous years a very good year as far as yields went, but extremely disappointing with regard to cotton prices. The relatively mild temperatures and good rainfall experienced during the boll development period (Fig. 1) resulted in an average state yield of 823 lb lint/acre from 1,065,500 acres harvested, for a total production of 1,825,000 bales. The season average price was $0.33/lb for a production value of $428,541,000. It is interesting that the total production in 2001 represents the most bales produced in Arkansas since 1948 when 2,375,000 acres were planted, although the season average price in 1948 was only $0.03 lower! By the end of July the cotton crop in Arkansas showed promise of an exceptionally high yield. However, some deterioration of the crop occurred due to an excessively wet period in late August resulting in boll rot, some sprouting of seed in the boll in southeast Arkansas, and lower yields. The boll weevil eradication program appears to be working successfully, although the boll weevil is not going down without a fight. The 2001 season experienced higher populations of tarnished plant bugs than normal.

Cotton yields in Arkansas increased steadily during the eighties, but in recent years there has been a leveling off. Of more significance, however, is that extreme year-to-year variability in yields has occurred in the last decade, which is a major point of concern with cotton producers. It has been suggested that this may be related to extreme weather conditions during the boll development period in July and August. Average maximum temperatures in the 2001 season were a few degrees above normal. Recent research in Arkansas has indicated that elevated night temperatures during boll development may be a major contributory factor to low and variable yields. There is also evidence that yield variability in stressful seasons may be related to genotypic changes in the components of yield, seed number, and fiber per seed, over the last 30 years. Yield stability for Arkansas cotton producers has become a major focus for new in-state collaborative research projects.

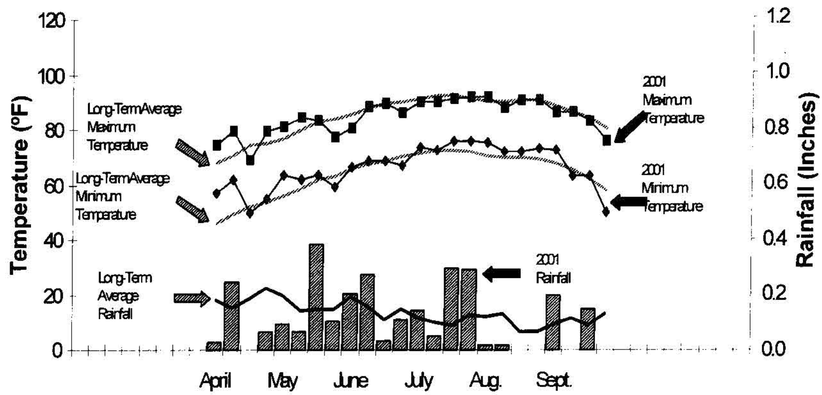


Fig. 1. Weekly maximum and minimum termperatures and rainfall for 2001 compared with the long-term 31-year averages at West Memphis, Arkansas.

ARKANSAS COTTON RESEARCH GROUP

2001/2002

The University of Arkansas Cotton Group is composed of a steering committee and three sub-committees representing production, genetics, and pest management. The group contains the appropriate representatives in all the major disciplines as well as representatives from the Cooperative Extension Service, the Farm Bureau, the Agricultural Council of Arkansas, and the State Cotton Support Committee.

The objective of the Arkansas Cotton Group is to coordinate efforts to improve cotton production and keep Arkansas producers abreast of all new developments in research.

Steering Committee: Fred Bourland, Gus Lorenz, Gene Martin, Keith Martin, Robert McGinnis, Derrick Oosterhuis (Chm.), Don Plunkett, Bill Robertson, Craig Rothrock, Mac Stewart, Cecil Williams, David Wildy, Jerry Williams

Pest Management: Jeremy Greene, Don Johnson, Terry Kirkpatrick, Tim Kring, Gus Lorenz, Bill Robertson, Craig Rothrock (Chm.), Ken Smith, Don Steinkraus, Glen Studebaker, Tina Teague, Chris Tingle, Phil Tugwell, Seth Young

Production: Morteza Mozaffari, Leo Espinoza, Mark Cochran, Dennis Gardisser, Gus Lorenz, Scott McConnell, Derrick Oosterhuis (Chm.), Lucas Parsch, Don Plunkett, Bill Robertson, Phil Tacker, Chris Tingle, Earl Vories

Genetics: Fred Bourland, Hal Lewis, Bill Robertson, Mac Stewart (Chm.)

ACKNOWLEDGMENTS

The organizing committee would like to express its appreciation to Marci Milus for help in typing this special report and getting it ready for publication.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The Summaries of Cotton Research in Progress in 2001 has been published with funds supplied by the Arkansas State Support Committee through Cotton Incorporated.

The principal purpose of Cotton Incorporated is to increase the profitability of cotton production by building demand for U.S. cotton. The Arkansas State Support Committee of Cotton Incorporated is a board whose voting members are cotton growers from Arkansas. Advisory members include representatives of Arkansas' certified producer organizations, the University of Arkansas, the Cotton Board, and Cotton Incorporated. Five percent of Cotton Incorporated's total budget is allocated for research and promotional activities, as determined by the State Support Committees of the cotton-producing states. The sum allotted to Arkansas' State Support Committee is proportional to Arkansas' contribution to the total U.S. cotton fiber production and value in the five years previous to the budget.

The Cotton Research and Promotion Act is a federal marketing law. The objective of the act is to develop a program for building demand and markets for U.S. cotton. The Cotton Board, based in Memphis, Tennessee, was created to administer the act and is empowered to contract with an organization with the capacity to develop such a program. Cotton Incorporated, with its main offices in New York, New York, the center of the U.S. clothing merchandising industry, and its research offices in Raleigh, North Carolina, the center of the U.S. textile industry, is the contracting agency. Cotton Incorporated also maintains offices in Osaka, Japan; Mexico City, Mexico; Shanghai, China; and Singapore, Malaysia to foster international sales. Both the Cotton Board and Cotton Incorporated are non-profit entities with governing boards comprised of cotton growers and cotton importers. The budgets of both organizations are annually reviewed and approved by the U.S. Secretary of Agriculture.

Cotton production research is supported in Arkansas both by Cotton Incorporated directly from its national budget and by the Arkansas State Support Committee from its formula funds. Several of the projects described in this research summaries publication, including publication costs, are supported wholly or in part by these means.

Arkansas Cotton State Support Committee / Cotton Incorporated funding 2001.

Project	Principal investigator	Amount funded 2001	2002
Proceedings annual Arkansas research meeting	Oosterhuis	5,000	6,500
Cottonseed pool — Arkansas	Cotton Inc.	8,520	5,520
Control of reniform nematodes	Kirkpatrick	19,118	19,118
Cotton graduate student award	Oosterhuis	500	--
New stress index	Tugwell	10,000	10,000
New petiole sampling	Oosterhuis	6,370	6,370
Plant bug feeding	Greene	8,000	8,000
Transgenic evaluation	Tingle	15,000	15,000
Insecticide termination	Greene	10,000	10,000
Bollworm/budworm studies	Johnson	13,934	13,934
Carbohydrate partitioning and stress	Oosterhuis	18,650	18,650
Defoliation	Robertson	9,486	9,486
Fungicide decisions	Rothrock	13,946	13,946
Aphid fungus	Steinkraus	15,927	15,927
New irrigation	Vories	23,188	23,188
Herbicide systems	Savage	16,000	16,000
Mapping PGRs	Robertson	15,304	15,304
Sidedress Temik	Lorenz	11,990	11,990
Herbicide drift	Robertson	12,091	12,091
Smaller bracts	Bourland	15,227	15,228 *
Plant breeding: yield and quality	Bourland	25,935	25,935
Campaign for Agriculture	Welch	--	1,000
Stink bug thresholds	Greene	--	15,500
Large-scale variety evaluations	Guy	--	10,000
Aphid thresholds	Kring	--	5,541
Totals:		274,186	304,228

* this amount was carried over from 2001.

SUMMARIES OF
ARKANSAS COTTON RESEARCH
2001

UNIVERSITY OF ARKANSAS COTTON BREEDING PROGRAM - 2001 PROGRESS REPORT

Fred M. Bourland[1]

RESEARCH PROBLEM

The University of Arkansas Cotton Breeding Program attempts to develop cotton genotypes that are improved with respect to yield, host plant resistance, fiber quality, and adaptation to Arkansas environments. Such genotypes would be expected to provide higher, more consistent yields with fewer inputs. To maintain a strong breeding program, continued research is needed to develop techniques that will identify genotypes with favorable genes, combine those genes into adapted lines, then select and test derived lines.

BACKGROUND INFORMATION

Cotton-breeding programs have existed at the University of Arkansas since the 1920s (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and possess good host-plant resistance traits. Bourland (2001) provided the most recent update of the current program.

RESEARCH DESCRIPTION

Each year, breeding lines and strains are tested in the University of Arkansas Cotton Breeding Program. The breeding lines are developed and evaluated in non-replicated tests, which include initial crossing of parents, individual plant selections from segregating populations, and evaluation of the progeny grown from seed of the individual plants. Once the segregating populations are established, each sequential test provides screening of genotypes to identify ones with specific host-plant resistance and agronomic performance capabilities. Selected progeny are carried forward

[1] Director and plant breeder, University of Arkansas, Northeast Research and Extension Center, Keiser.

and evaluated in replicated strain tests at multiple Arkansas locations to determine their yield, quality, and adaptative properties. Superior strains are subsequently evaluated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm or cultivars. In 2001, modifications were made to accommodate second-cycle individual plant selections prior to testing as strains.

RESULTS

Breeding Lines

Crosses made in 2001 were primarily focused on improving basic yield components, reducing bract trichomes, enhancing thrips and root knot nematode resistance, and improving seedling vigor. The F_1 seed were advanced to F_2 generation during the winter. In 2001, all F_2 populations were hot-water (65C) treated, then sequentially selected for resistance to seed deterioration and bacterial blight, morphological traits and visual performance. Seed from 577 individual selected plants will be evaluated in first cycle progeny rows in 2002. In addition, 900 plants were selected from 90 advanced progeny in 2001. These will be tested as second-cycle progeny rows in 2002. From 830 second-cycle progeny in 2001, 72 were selected and will be evaluated in replicated strain tests in 2002.

Strain Evaluation

In 2001, 88 strains were evaluated in replicated strain tests at multiple locations in Arkansas. Within each test, strains were compared to standard cultivars (PSC 355 and Sure-Grow 747). Based on their performance, 36 of the strains were selected and entered into 2002 strain tests. The superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality. Also, eight strains were evaluated in the 2001 Arkansas Cotton Variety Test (Benson et al., 2002).

Selection Criteria

In 2001, work continued to establish selection criteria in four specific areas: Root-knot nematode resistance, thrips resistance, improved yield components, and reduced bract trichomes.

Root-Knot Nematode (RKN) Resistance

Advanced progeny and F_2 populations having RKN resistant parentage were planted in a field near Leachville, AR. High infestations of RKN and Fusarium wilt were identified in 2000. However, very low incidence of RKN injury in 2001 precluded selection for resistance. Mass selection was done in the populations, and plants will be inoculated and selected for resistance in the greenhouse.

Thrips Resistance

New and advanced strains were evaluated for yield in adjacent plots having thrips control (in-furrow insecticide) and no thrips control in 2001. Thrips infestations were relatively low, and infested plots yielded ca. 92% as much as control plots.

Yield Components

Strains were evaluated with regard to relative influence of basic yield components of seed per acre (SPA) and lint weight per seed (LPS). An additional index trait, LPS divided by seed weight, should standardize LPS for different sizes of seed. This index appeared to correlate (but the same measurement) with lint percentage. Work is continuing to determine the relationships among these traits.

Bract Trichomes

Trichomes on the teeth of bracts may influence the cleanability of cotton lint. Bract trichomes were found to be correlated with trichomes on leaves and stems, but independent assortment should be possible. Visual rating of bract trichomes was improved in 2001 by using a magnifying glass and a dark background. Environment does not appear to greatly influence the bract-trichome trait. Over three years, a cultivar-by-location interaction was only found one year when a severely stressed environment was included. In 2001 study, bract trichomes from three positions of three cultivars were counted over three dates. Trichomes declined with lower position (older bracts) on the plant, later sampling date, and as leaves of the cultivar had less trichomes. None of the 2-way or 3-way interactions were significant. These results suggest that bract trichomes of genotypes can be characterized by sampling one location (i.e., to avoid highly stressed environments) on one sampling date at one plant position. Variation in bract trichomes of breeding lines is being evaluated, and a genetic study of the trait has been initiated.

Release of Material

Six germplasm lines (Arkot 8606, Arkot 8710, Arkot 8717, Arkot 8727, Arkot 8918, Arkot 9103) were released in 2001 (Bourland and Benson, 2002a,b,c,d). Data are being summarized for additional releases in 2002.

PRACTICAL APPLICATION

Genotypes with improved host-plant resistance that are adaptable to Arkansas environments and possess good fiber quality are being developed. Improved host

plant resistance should decrease production costs and reduce production risks. Selection based on a higher reliance on lint per seed rather than seed per acre to produce yield may help to identify and develop lines having improved and more stable yield. Lines with fewer bract trichomes may reduce the amount of lint cleaning required to attain acceptable trash grades. These genotypes should be valuable as breeding material to commercial breeders or released as cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions.

LITERATURE CITED

Benson, N.R., F.M. Bourland, A.B. McFall, J.M. Hornbeck, and F.E. Groves. 2002. Arkansas Cotton Variety Test 2001. University of Arkansas Agricultural Experiment Station Research Series 491, Fayetteville, AR.

Bourland, F.M. 2001. University of Arkansas cotton breeding program - 2001 progress report. *In:* D.M. Oosterhuis (ed.) Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 204:29-34.

Bourland, F.M. and N.R. Benson. 2002a. Notice of release of Arkot 8606 germplasm line of cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (In press).

Bourland, F.M. and N.R. Benson. 2002b. Notice of release of Arkot 8710 and Arkot 8717 germplasm lines of cotton. Proc. Cotton Conf., National Cotton Council, Memphis, TN. (In press).

Bourland, F.M. and N.R. Benson. 2002c. Notice of release of Arkot 8727 germplasm line of cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (In press).

Bourland, F.M. and N.R. Benson. 2002d. Notice of release of Arkot 8918 and 9103 germplasm lines of cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (In press).

Bourland, F. M. and B.A. Waddle. 1988. Cotton research overview–breeding. Arkansas Farm Research. 37(4):7.

TRANSGENIC AND CONVENTIONAL COTTON PRODUCTION SYSTEMS EVALUATION

Chris Tingle, Glenn Studebaker, Jeremy Greene, Kelly Bryant, and Kenneth L. Smith[1]

RESEARCH PROBLEM

The goal of state variety testing is to compare the agronomic potential of commercially available cotton cultivars. Due to the increasing number of both conventional and transgenic cultivars each year, uniform pest-management strategies are often utilized. Although these results are useful in making agronomic comparisons among cultivars, additional evaluations, involving their unique production systems, could allow for more realistic comparisons.

BACKGROUND INFORMATION

Transgenic cotton cultivars have been developed to provide growers with additional management options for weed and insect control. Growers now have the option to plant cultivars that express a toxin from the bacterium *Bacillus thuringiensis* (*Bt*). These *Bt* cultivars express a toxin in the foliage of the plant that is active against some lepidopteran pests once the foliage is eaten (Benedict, 1996). Additional cultivars have been developed with the ability to withstand non-selective herbicides such as glyphosate (Roundup Ready) or bromoxynil (BXN) (Collins, 1996; Stewart, 1996). Newer cultivars have incorporated both the herbicide and *Bt* expressions in order to optimize pest-management strategies.

These newly transformed cultivars have been widely accepted by producers. In 2000, the USDA-AMS Cotton Division reported that 65.8% of the cotton acreage in the south central region of the United States was planted to transgenic cultivars (Anonymous, 2000). More specifically, in Arkansas, 23.8% was planted to *Bt*, 21.9% was planted

[1] Agronomist and entomologist, University of Arkansas, Northeast Research and Extension Center, Keiser; extension agronomist, area extension specialist - farm management, and extension weed scientist, University of Arkansas, Southeast Research and Extension Center, Monticello.

to BXN, 6.3% was planted to Roundup Ready, and 36.3% was planted to *Bt* + Roundup Ready cultivars in 2000.

Although these cultivars are widely adapted among growers, they have undergone only limited university research in evaluating their overall agronomic performance (Bourland et al., 1997). Thus, early research evaluating *Bt* cotton primarily had an entomological focus. This scenario was also observed with BXN and Roundup Ready cultivars for which previous work consisted mainly of weed control and crop tolerance evaluations. There is a current need for systems-level research evaluating how these cultivars will perform under a wide variety of pest complexes and cultural methods. Due to this limited research, many companies are encouraging the continual and sometimes sole use of a single pest-management strategy.

RESEARCH DESCRIPTION

Field studies were initiated in 2001 at the Northeast Research and Extension Center (NEREC) and the Southeast Branch Experiment Station (SEBES). Cotton was planted on 15 May at NEREC and 10 May at SEBES. Due to an early-season hail storm at SEBES, cotton was replanted on 7 June. Plot size was four rows (102 cm) by 15 m long. The experimental design was a randomized complete block with four replications.

Cultivars, consisting of conventional, Roundup Ready, BXN, *Bt*, and Roundup Ready/*Bt*, were chosen based on performance in the 2000 University of Arkansas Official Variety Tests (Benson et al., 2000) and percentage of acreage planted to each management type in Arkansas (Anonymous, 2000). These included: Stoneville ST 474, Stoneville ST 4793R, Stoneville ST 4892 BR, Stoneville, ST 4691 B, Stoneville, BXN 47, FiberMax FM 966, PhytoGen PSC 355, Suregrow SG 215 BR, Paymaster PM 1199 R, and Deltapine 20 B (Table 1).

Pest Management Inputs

All plots were managed to maximize yields according to University of Arkansas Cooperative Extension Service recommendations. Herbicide systems were chosen based on the genetic capabilities for each cultivar. For example, Roundup UltraMax was the primary herbicide for Roundup Ready and Roundup Ready/*Bt* cultivars, Buctril herbicide was used for BXN 47, and conventional herbicides were used for conventional cultivars. After emergence, plots were scouted weekly for insects. As with the herbicide systems, insecticide applications were based on the genetic capabilities of each cotton cultivar.

Data Collection

After first square, COTMAN data were collected weekly as described by Tugwell et al. (1998) and continued until all plots reached cutout (NAWF=5). At both locations,

the two center rows of each plot were machine harvested. At NEREC, seed cotton samples were ginned to determine percent gin turnout and fiber-quality data were determined using HVI analysis. In addition, 5 plants per plot were box-mapped in order to determine individual boll number and corresponding weights for each cultivar.

Economic Analysis

Production input expenses such as seed, technology fees, herbicide, insecticide, and application costs were determined for each cultivar. These expenses, in combination with yield values and appropriate loan values, were used to determine net returns.

RESULTS AND DISCUSSION

Yield Data

No significant differences in yield were observed at NEREC and yields ranged from 1044 to 1220 lb/acre (Table 1). Lower yields (possibly due to late planting) were observed at SEBES and ranged from 704 to 1025 lb/A. At SEBES, higher yields of 1025, 974, and 885 lb/acre were observed with SG 215 BR, ST 4892 BR, and DP 20 B, respectively.

Individual Boll Data

End-of-season box mapping data allowed for comparison of individual boll number by node and position, and their corresponding weights for each of the cultivars (Table 2). When comparing first-position boll weights, FM 966 and SG 215 BR both averaged 5.2 g. The remaining cultivars were lower and averaged 4.3-4.7 g. These first-position bolls contributed at least 46% of the total bolls for all cultivars. No differences in second-position boll weights were observed and ranged from 3.9 to 4.7 g, which represented 21 to 29% of the total bolls for each cultivar. Mean boll weight (average boll weight per plant) followed the same trends as first-position boll weights, with FM 966 and SG 215 BR being the highest with 4.9 and 5.0 g, respectively.

Boll Distribution Data

End-of-season box-mapping data also allowed for comparison of boll distribution among cultivars (Table 3). When evaluating the lower portion of the plant (nodes 6 to 10), at least 30% of the bolls were located in this region for PSC 355, SG 215 BR, PM 1199 R, and DP 20 B. No differences among cultivars were observed for nodes 11 to 15 and ranged from 37 to 53%. Less than 14% of the bolls were observed above the sixteenth node.

Relative Maturity, Percent Turnout, and Fiber Quality Data

COTMAN results indicated only minor differences in relative maturity for the cultivars ranging from 82 to 85 days after planting (DAP) (Table 4). No differences in percent turnout were observed with values ranging from 39 to 42% for all cultivars. Fiber quality data indicated that length values ranged from 1.11 to 1.17. Higher length and strength values were reported with FM 966. Micronaire values ranged from 4.0 with DP 20 B to 5.1 with PSC 355.

Economic Analysis

The differences in costs between cultivars were due to herbicide programs and technology fees (Table 5). At each location, the cost advantage definitely favored the Roundup Ready cultivars. These results indicate that the highest yielding cultivars tend to produce the greatest net returns.

PRACTICAL APPLICATION

With the popularity of transgenic cultivars, additional research is needed to assist producers in properly choosing the most productive and economical cotton production systems. Since these individual technologies will be used in production cotton fields in combination with other transgenic and conventional production practices, it is important to begin learning more about how the combinations compare to each other with respect to pest-management options and economic returns.

LITERATURE CITED

Anonymous. 2000. Cotton Varieties Planted-2000 Crop. USDA AMS-Cotton Program, Memphis, TN. 10 p.

Benedict, J.H. 1996. *Bt* Cotton: Opportunities and challenges. *In:* P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 25-29.

Benson, N.R., F.M. Bourland, W.C. Robertson, J.M. Hornbeck, and F.E. Groves. 2000. Arkansas Cotton Variety Tests-2000. University of Arkansas Agricultural Experiment Station Research Series 481, Fayetteville, AR.

Bourland, F.M., D.S. Calhoun, and W.D. Caldwell. 1997. Cultivar evaluation of *Bt* cottons in the mid-South. *In:* D.M. Oosterhuis (ed.). Proc. 1997 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 183:36-44. Fayetteville, AR.

Collins, J.R. 1996. BXN cotton: Marketing plans and weed control programs utilizing buctril. *In:* P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 201.

Stewart, S. 1996. Roundup Ready cotton: Marketing plans and weed control programs using roundup ultra. *In:* P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 201.

Tugwell, N.P., G. Lorenz, K.W. Vodraska, T.G. Teague, F.M. Bourland, and D.M. Danforth. 1998. COTMAN sampling and data collection. *In*: COTMAN Expert System Publication. University of Arkansas, Agricultural Experiment Station. Chapter 2:7-11, Fayetteville, AR.

Table 1. Yield data from agronomic systems evaluation, Arkansas, 2001[z].

Cultivar	Lint yield[y] NEREC[x]	Lint yield[y] SEBES
	(lb/acre)	(lb/acre)
Stoneville 474	1044 a	846 bcd
Stoneville BXN 47	1154 a	822 cd
Stoneville 4892 BR	1063 a	974 ab
Stoneville 4793 R	1079 a	776 cd
Stoneville 4691 B	1095 a	819 bc
FiberMax 966	1146 a	879 bc
PhytoGen 355	1135 a	796 cd
Suregrow 215 BR	1220 a	1025 a
Paymaster 1199 R	1055 a	704 d
Deltapine 20 B	1097 a	885 abc

[z] Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[y] Lint yield determinations based on individual plot gin turnout for NEREC and standard 35% for SEREC.

[x] NEREC: Northeast Research and Extension Center, Keiser, AR; SEBES: Southeast Branch Experiment Station, Rohwer, AR.

Table 2. Individual boll data, NEREC, 2001.[z]

Cultivar	Mean boll weight 1st position[y]	Percent 1st position bolls	Mean boll weight 2nd position	Percent 2nd position bolls	Mean boll wight
	(g)	(%)	(g)	(%)	(g/plant)
Stoneville 474	4.6 b	53 a	4.1 a	25 a	4.3 b
Stoneville BXN 47	4.3 b	57 a	4.0 a	25 a	4.0 b
Stoneville 4892 BR	4.6 b	54 a	4.2 a	21 a	4.3 b
Stoneville 4793 R	4.6 b	50 a	4.1 a	29 a	4.2 b
Stoneville 4691 B	4.6 b	53 a	3.9 a	27 a	4.3 b
FiberMax 966	5.2 a	59 a	4.7 a	23 a	4.9 a
PhytoGen 355	4.4 b	57 a	4.0 a	26 a	4.1 b
Suregrow 215 BR	5.2 a	55 a	4.8 a	26 a	5.0 a
Paymaster 1199 R	4.7 b	46 a	4.6 a	27 a	4.4 b
Deltapine 20 B	4.7 b	56 a	3.9 a	21 a	4.2 b

[z] Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[y] Boll weight represents seedcotton weight.

Table 3. Boll distribution data, NEREC, 2001.[z]

Cultivar	Main-stem nodes		
	6-10	11-15	16-20
Stoneville 474	28 abcd	48 a	5 c
Stoneville BXN 47	25 cd	50 a	12 ab
Stoneville 4892 BR	27 bcd	43 a	9 abc
Stoneville 4793 R	22 d	53 a	9 abc
Stoneville 4691 B	26 bcd	49 a	7 bc
FiberMax 966	23 d	47 a	14 a
PhytoGen 355	33 abc	45 a	6 bc
Suregrow 215 BR	37 a	44 a	4 c
Paymaster 1199 R	35 ab	37 a	6 c
Deltapine 20 B	33 abc	43 a	7 bc

[z] Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

Table 4. Relative maturity, percent turnout, and fiber quality data, NEREC, 2001.[z]

Cultivar	Days to cutout[y]	Gin turnout	Length	Strength	Micronaire
	(%)	(%)	(inches)	(g/tex)	
Stoneville 474	84 b	39 a	1.15 abc	29.7 d	4.5 bc
Stoneville BXN 47	83 c	42 a	1.14 abc	29.6 d	4.3 cd
Stoneville 4892 BR	84 b	39 a	1.11 c	31.3 bcd	4.5 bc
Stoneville 4793 R	85 a	41 a	1.12 bc	30.3 cd	4.5 bc
Stoneville 4691 B	85 a	40 a	1.16 ab	30.3 cd	4.2 cd
FiberMax 966	82 d	39 a	1.17 a	35.0 a	4.4 bcd
PhytoGen 355	85 a	40 a	1.13 abc	33.0 b	5.1 a
Suregrow 215 BR	85 a	40 a	1.11 bc	27.8 e	4.8 ab
Paymaster 1199 R	83 c	40 a	1.11 bc	32.1 bc	4.5 bc
Deltapine 20 B	83 c	39 a	1.13 bc	26.7 e	4.0 d

[z] Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[y] Days to Cutout: days after planting to reach five nodes above first position white flower (NAWF) = 5.

Table 5. Input costs and net returns for agronomic systems, 2001.

Cultivar	NEREC[z]		SEBES	
	Input costs[z]	Net returns[x]	Input costs	Net returns
	($/acre)			
Stoneville 474	157.60	405.72	197.49	244.97
Stoneville BXN 47	151.76	471.86	191.54	238.37
Stoneville 4892 BR	161.77	403.53	178.40	330.48
Stoneville 4793 R	131.98	452.62	149.14	256.71
Stoneville 4691 B	185.76	408.39	225.09	203.25
FiberMax 966	157.05	468.09	196.99	262.73
PhytoGen 355	156.50	413.66	196.49	219.82
Suregrow 215 BR	157.85	480.70	174.59	361.49
Paymaster 1199 R	131.08	439.69	148.33	219.86
Deltapine 20 B	184.86	403.24	224.28	238.58

[z] NEREC - Northeast Research and Extension Center, Keiser, AR; SEBES - Southeast Branch Experiment Station, Rohwer, AR.

[y] Input costs reflect seed, technology fee (when appropriate), herbicide, insecticide, and application costs.

[x] Net returns calculations based on yield, loan value, and input costs.

COMPARISON OF CONVENTIONAL AND TRANSGENIC COTTON IN ARKANSAS

*Kelly J. Bryant, William C. Robertson,
Gus M. Lorenz, Rob Ihrig, and George Hackman*[1]

RESEARCH PROBLEM

The University of Arkansas, in cooperation with Arkansas cotton producers, county agents and industry representatives, has implemented side-by-side comparisons of Bollgard cotton varieties to non-*Bt* varieties each year since 1996. *Bt* and non-*Bt* varieties were grown in adjacent fields. Each variety was managed using Best Management Practices for that field and variety. Results indicate that *Bt* varieties have increased profit in most cases for the southern regions of the state but have not been profitable for the northern regions. Also, yields are the driving force in selecting the most economical cotton variety and/or technology.

BACKGROUND INFORMATION

The number of transgenic cotton varieties available for commercial production has increased greatly in recent years. Cotton producers now have multiple choices when choosing transgenic cotton varieties. The choice of variety now dictates the insect and weed control programs that will, or can, be used. Cotton varieties containing the Bollgard gene, the Roundup Ready gene, and the Buctril-resistant gene have been planted on a significant amount of Arkansas' cotton acreage since 1996. The success of these varieties has been mixed. The University of Arkansas, in cooperation with Arkansas cotton producers, county agents, and industry representatives, has implemented side-by-side comparisons of Bollgard cotton varieties to non-*Bt* varieties each year beginning in 1996. This manuscript presents the economic results of these comparisons. Partial budgeting was used to account for any differences in management

---

[1] Area extension specialist - Farm Management, University of Arkansas, Southeast Research and Extension Center, Monticello; extension agronomist - cotton and extension entomologist, University of Arkansas Cooperative Extension Service, Little Rock; Roundup cotton specialist, Monsanto Co., Collierville, TN; and agronomic systems manager, Monsanto Co., Tumbling Shoals.

and to assess the change in profit associated with growing the *Bt* variety rather than the non-*Bt* variety.

RESEARCH DESCRIPTION

In each of several Arkansas counties, a cotton variety containing the *Bt* gene was planted adjacent to a non-*Bt* cotton variety in order to compare cost and return differences. In 1996, the Delta and Pine Land (D&PL) variety NuCOTN 33B was compared primarily to other D&PL varieties. In subsequent years, DP NuCOTN 33B was compared to non-*Bt* varieties from other seed companies considered to be the best conventional varieties for the production region. As additional *Bt* and stacked gene varieties became available, the best (or most popular) varieties containing the *Bt* gene were compared to the best (or most popular) non-*Bt* varieties. Fields were chosen that were very similar in nature. Each field was managed using Best Management Practices for that field and variety. The primary differences in management between the two fields being compared in each observation involved insect and weed control due to the transgenic properties of the varieties involved.

Partial budgeting was used to account for any differences in management and to assess the change in profit associated with growing the *Bt* variety rather than the non-*Bt* variety. Input prices paid by the cotton producer were used when available. Otherwise, input prices listed in the cotton budgets were used (Bryant and Windham, 2001). When farmers provided information on prices received for cotton yield from the varieties being compared, those cotton prices were used. Otherwise, season average prices obtained from the Arkansas Agricultural Statistic Service in that year were used (Anonymous, 1996-2000). These prices were $0.71/lb, $0.66/lb, $0.68/lb, $0.60/lb, $0.568/lb, and $0.52/lb for 1996 through 2001, respectively. When cotton grades for the varieties being compared were available, premiums or discounts were added to these prices using the CCC loan values table for the year in question.

RESULTS

The partial budgeting results are displayed in Tables 1-5. The forty comparisons in all are grouped by region and listed by year. The "change in gross return" column lists the changes in gross returns associated with growing the *Bt* variety instead of the non-*Bt* variety. This change in returns is the result of the yield difference between the two varieties and, in some cases, price differences due to cotton grade. Changes in gross return are mostly positive in the southern regions of the state (Tables 1 and 2); both positive and negative in south central Arkansas (Table 3); and mostly negative in the northern regions of the state (Tables 4 and 5). Across all forty observations, the average change in gross return was a positive $9.70/acre.

The "change in variable cost" column lists the changes in variable cost associated with growing the *Bt* variety instead of the non-*Bt* variety. These changes are the result of differences in seed costs, technology fees, herbicide programs, and insecticide programs. The change in variable cost is mostly negative in southeast Arkansas (Table 2) indicating that the *Bt* varieties reduce variable cost in this region. The other regions (Tables 1, 3, 4, and 5) indicate mostly increases in variable costs associated with growing the *Bt* varieties. Across all forty observations, the average change in variable cost was a negative $3.37/acre.

The "change in profit" column lists the changes in profit associated with growing the *Bt* variety instead of the non-*Bt* variety. These changes in profit are the result of the changes in gross returns and the changes in variable costs. Changes in profit are mostly positive in the southern regions of the state (Tables 1 and 2); both positive and negative in south central Arkansas (Table 3); and mostly negative in the northern regions of the state (Tables 4 and 5). Across all forty observations, the average change in profit was a positive $13.06/acre.

PRACTICAL APPLICATION

Economic comparisons of *Bt* to non-*Bt* cotton varieties in Arkansas indicate that *Bt* varieties have increased profit in most cases for the southern regions of the state, but have not been profitable for the northern regions. *Bt* varieties in south-central Arkansas have effected neither an increase nor a decrease in profit. In a large majority of the cases, regardless of region, a positive change in gross return results in a positive change in profit. Thus we can conclude that yields are the driving force in selecting the most economical cotton variety and/or technology, and that costs are of secondary importance.

LITERATURE CITED

Anonymous. 1996-2000. Annual Reports from 1996 to 2000. Arkansas Agricultural Statistics Service. Little Rock, AR.

Bryant, K.J., and T.E. Windham. 2001. Estimating the Costs of Production: Cotton. 1996-2001. Published annually by the University of Arkansas Cooperative Extension Service, Little Rock, AR.

Table 1. Field observations on returns, costs, and profits comparing Bollgard (BG) cotton to non-*Bt* varieties. Southwest Arkansas (Lafayette Co.), 1996-1999.

Year	BG variety	Non-*Bt* variety	Change in gross return[z]	Change in variable cost[z]	Change in profit[z]
1996	DP NuCOTN 33B	DP 5415	$58.22	($10.16)	$68.38
1997	DP NuCOTN 33B	SG 125	$68.64	$13.63	$55.01
1998	DP NuCOTN 33B	DP 20	$91.80	$24.97	$66.83
1999	DP NuCOTN 33B	DP 51	$31.20	$14.94	$16.26
Average			$62.47	$10.85	$51.62

[z] A positive number indicates that the value was greater for the *Bt* variety while a negative number, in parentheses, indicates that the value was less for the *Bt* variety compared to the non-*Bt* variety.

Table 2. Field observations on returns, costs, and profits comparing Bollgard (BG) cotton to non-*Bt* varieties. Southeast Arkansas (Desha and Lincoln Counties), 1997-2001.

Year	BG variety	Non-*Bt* variety	Change in gross return[z]	Change in variable cost[z]	Change in profit[z]
1997	DP NuCOTN 33B	DP 5409	$116.16	($18.21)	$134.37
	DP NuCOTN 33B	SG 501	$18.48	($17.31)	$35.79
	DP NuCOTN 33B	DP 5415	($58.08)	($8.04)	($50.04)
1998	DP NuCOTN 33B	DP 5415	$189.72	($61.24)	$250.96
	STV 4740BG	STV 373	$118.32	($2.99)	$121.31
	STV 4740BG	STV 373	$79.56	($2.99)	$82.55
1999	Three variety avg.[y]	Three variety avg.[x]	$325.14	($8.40)	$333.54
2000	DP 451 B/RR	SG 747	$6.47	($97.14)	$103.61
	DP 451 B/RR	PSC 355	$42.04	($6.73)	$48.77
2001	DP 451 B/RR	STV BXN47	($17.69)	($96.37)	$78.69
Average			$82.01	($31.94)	$113.95

[z] A positive number indicates that the value was greater for the *Bt* variety while a negative number, in parentheses, indicates that the value was less for the *Bt* variety compared to the non-*Bt* variety.

[y] The yields and grades of three varieties, DP 451B/RR, SG 125B/R, and PM 1220BG/RR, were averaged.

[x] The yields and grades of three varieties, DP 5111, SG 747, and ST 474, were averaged.

Table 3. Field observations on returns, costs, and profits comparing Bollgard (BG) cotton to non-*Bt* varieties. South central Arkansas (Jefferson and Phillips counties), 1996-2000.

Year	BG variety	Non-*Bt* variety	Change in gross return[z]	Change in variable cost[z]	Change in profit[z]
1996	DP NuCOTN 33B	DP 20	$207.32	$3.03	$204.29
	DP NuCOTN 33B	DP 5409	$189.57	$10.33	$179.24
	DP NuCOTN 33B	SG 125	$76.86	$5.71	$70.97
	DP NuCOTN 33B	SG 125	($9.23)	$2.73	($11.96)
1997	DP NuCOTN 33B	SG 125	$10.56	$32.76	($22.20)
	DP NuCOTN 33B	STV 474	($153.78)	$12.87	($166.65)
	DP NuCOTN 33B	SG 125	($110.88)	$64.02	($174.90)
1998	DP 50BG	STV BXN47	($4.76)	$0.34	($5.10)
1999	DP 20B	STV BXN47	($206.40)	($8.90)	($197.49)
2000	ST 4892 BG/RR	PSC 355	($54.76)	($35.00)	($19.76)
	PM 1218 BG/RR	SG 747	$136.86	$0.52	$136.34
Average			$7.40	$8.04	($0.66)

[z] A positive number indicates that the value was greater for the *Bt* variety while a negative number, in parentheses, indicates that the value was less for the *Bt* variety compared to the non-*Bt* variety.

Table 4. Field observations on returns, costs, and profits comparing Bollgard (BG) cotton to non-*Bt* varieties. Central Arkansas (Crittenden, St. Francis, and Lonoke Counties), 1996-2001.

Year	BG variety	Non-*Bt* variety	Change in gross return[z]	Change in variable cost[z]	Change in profit[z]
1996	DP NuCOTN 33B	DP 5415	$58.22	($10.16)	$68.38
1996	DP NuCOTN 33B	DPL 5415	$24.14	$14.62	$9.52
1998	Variety Demo	STV 373	($129.20)	($22.75)	($106.45)
1999	PM 1560 BG	ST BXN 47	($59.89)	$58.82	($118.71)
	Three variety avg.[y]	Three variety avg.[x]	$48.80	$0.97	$47.83
	Three variety avg.[y]	Three variety avg.[x]	$15.91	$29.51	($13.60)
	Three variety avg.[y]	Three variety avg.[x]	($305.82)	($34.65)	($271.17)
2000	PM 1218 BG/RR	PSC 355	$46.13	($35.42)	$81.55
	ST 4892 BG/RR	ST BXN 47	($11.93)	$42.47	($54.40)
	PM 1218 BG/RR	PSC 355	$31.42	($82.82)	$114.06
2001	PM 1218 BG/RR	SG 105	($67.41)	$20.10	($87.51)
	DP 451 B/RR	PM 1199 RR	($82.17)	($4.50)	($77.67)
	PM 1218 BG/RR	PM 1199 RR	($86.86)	$11.11	($97.97)
Average			($48.09)	($0.21)	($47.88)

[z] A positive number indicates that the value was greater for the *Bt* variety while a negative number, in parentheses, indicates that the value was less for the *Bt* variety compared to the non-*Bt* variety.

[y] The yields and grades of three varieties, DP 451B/RR, SG 125B/R, and PM 1220BG/RR, were averaged.

[x] The yields and grades of three varieties, DP 5111, SG 747, and ST 474, were averaged.

Table 5. Field observations on returns, costs, and profits comparing Bollgard (BG) cotton to non-*Bt* varieties. Northeast Arkansas (Craighead and Mississippi Counties), 1999-2000.

Year	BG variety	Non-*Bt* variety	Change in gross return[z]	Change in variable cost[z]	Change in profit[z]
1999	Three variety avg.[y]	Three variety avg.[x]	($82.24)	$39.71	($121.95)
2000	PM 1218 BG/RR	ST BXN 47	($45.08)	($4.42)	($40.66)
	PM 1218 BG/RR	ST BXN 47	($59.07)	$20.11	($79.18)
Average			($62.13)	$18.47	($80.60)

[z] A positive number indicates that the value was greater for the *Bt* variety while a negative number, in parentheses, indicates that the value was less for the *Bt* variety compared to the non-*Bt* variety.

[y] The yields and grades of three varieties, DP 451B/RR, SG 125B/R, and PM 1220BG/RR, were averaged.

[x] The yields and grades of three varieties, DP 5111, SG 747, and ST 474, were averaged.

BOLLGARD II PERFORMANCE IN ARKANSAS, 2001

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

RESEARCH PROBLEM

Bollgard II, Monsanto line DPLX-01L90-D, was compared to Bollgard and conventional cotton in Jefferson and Lincoln Counties, AR, 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 Arkansas growers with excellent control of the tobacco budworm, *Heliothis virescens* F. However, control of bollworm, *Helicoverpa zea* (Boddie) and other lepidopterous pests has been less dependable with additional foliar insecticide applications being needed at times 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 increase 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.

---

[1] Extension entomologist, pest management section leader and IPM coordinator, entomology associate specialist, and entomology extension specialist, University of Arkansas Cooperative Extension Service, Little Rock; Jefferson County extension agent - agriculture, University of Arkansas Cooperative Extension Service, Pine Bluff; and staff chair, Lincoln County Extension Office, University of Arkansas Cooperative Extension Service, Star City.

RESEARCH DESCRIPTION

Studies were conducted on the Hooker Farm in Jefferson County, AR, and on the McGraw Farm in Lincoln County, AR. The studies were planted on 30 April and 1 May at Jefferson and Lincoln County, respectively, with the same treatments used at both locations. The test consisted of a randomized complete block design with four replications. The six treatments were the varieties: Sure Grow 125 (untreated check), Sure Grow 125 BR (Bollgard), and DPLX-01L90-D (Bollgard II) with each variety either treated or untreated with a foliar-applied insecticide. Each plot was 8 rows wide and 50 feet long in Jefferson County and 4 rows by 50 feet long in Lincoln County. Insecticides 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 both locations using Baythroid were 6 July and 11 July in addition to two applications of Tracer on 18 July and 3 August. Scouting data taken included damaged fruit counts and larval counts. Plots were machine picked 23 October (Jefferson County) or 18 October (Lincoln County). All data were analyzed using Analysis of Variance and LSD (P=0.05).

RESULTS AND DISCUSSION

Populations of tobacco budworm (TBW) and cotton bollworm (CBW) were lower than those observed in previous years. Normally, tobacco budworm populations are highest in late July through early August. While this trend held true in 2001 (Fig. 1), the overall bollworm/budworm ratio was higher throughout the growing season than normal.

Judging from data obtained throughout the growing season, Heliothine pressure was higher at the Jefferson County location compared to the location in Lincoln County (Fig. 2, 3, 5, and 6). No significant difference in square damage was observed between Bollgard and Bollgard II at either location (Fig. 2 and 5). Both the Bollgard and Bollgard II varieties resulted in fewer seasonal live larvae compared to untreated Sure Grow 125 regardless of insecticide treatment; however, no differences were observed when compared to treated Sure Grow 125, indicating a possible result of low budworm pressure as well as lower Heliothine pressure throughout the growing season.

In Jefferson County, all treatments yielded significantly higher than the untreated Sure Grow 125, a direct result of increased Heliothine control. Although Heliothine control was virtually identical between the locations, yield results were substantially different. Lincoln County yields were much lower than those observed in Jefferson County. No significant difference was observed between Bollgard and Bollgard II regardless of insecticide treatment. However, yields of untreated and treated Bollgard II were not significantly different than untreated Sure Grow 125. Based upon Heliothine control at this location and the results from Jefferson County, it is likely that other environmental influences affected yield at this location.

The data obtained from both locations indicate Bollgard and Bollgard II were very effective in controlling the Heliothine complex in 2001. The economic benefit of these technologies, however, were not as clear due to the low insect pressure observed throughout the growing season. Further evaluation of Bollgard II is necessary to determine its feasibility in Arkansas cotton production.

PRACTICAL APPLICATION

In both trials, Bollgard and Bollgard II significantly reduced square damage and the presence of live larvae throughout the growing season compared to the untreated conventional variety. This increased control resulted in greater yields in Jefferson County; however, Bollgard II yields were not significantly higher in Lincoln County. Further evaluation of Bollgard II is necessary to determine its feasibility in Arkansas cotton production.

ACKNOWLEDGMENTS

We thank Monsanto for supporting this work by providing the seed and grant support. Also, we thank Chuck Hooker and Johnny McGraw for allowing us to do this work on their farms.

LITERATURE CITED

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. pp. 1093-1094. *In:* Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

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.* pp. 1057-1058. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

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

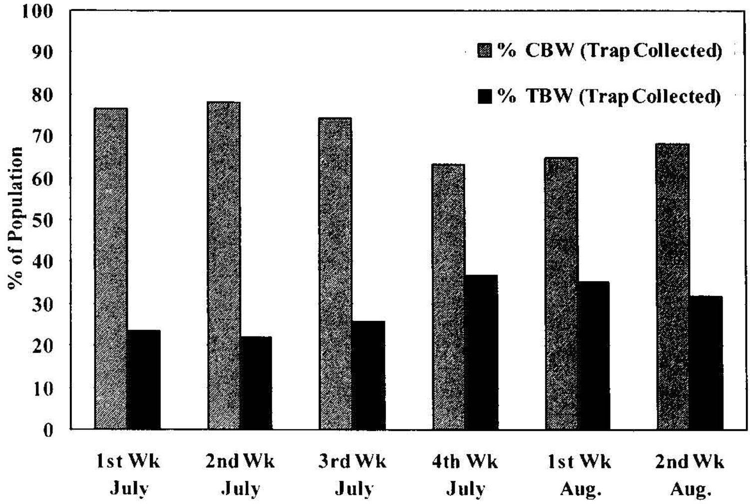


Fig. 1. Heliothine population distribution based on pheromone trap collections, Jefferson County, AR. 2001.

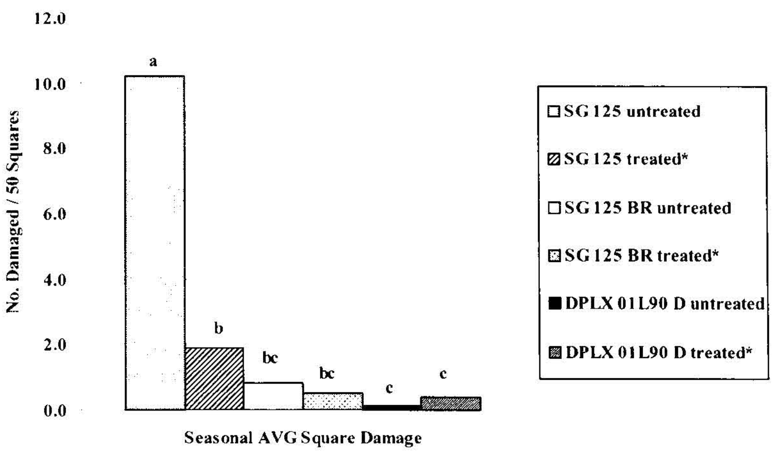


Fig. 2. Seasonal average Heliothine square damage: Heliothine control in Bollgard and Bollgard II cotton, Jefferson County, AR. 2001.

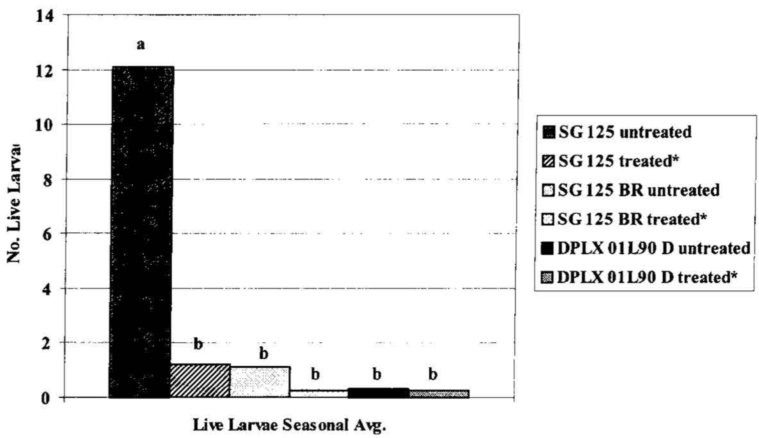


Fig. 3. Live Heliothine larvae seasonal average: Heliothine control in Bollgard and Bollgard II cotton, Jefferson County, AR. 2001.

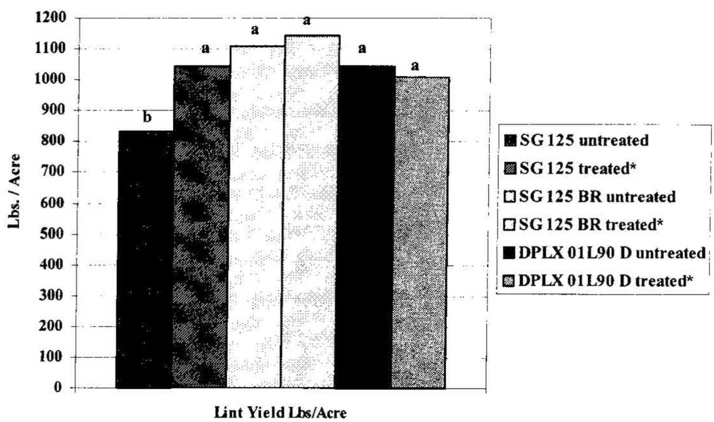


Fig. 4. Lint yield: Heliothine control in Bollgard and Bollgard II cotton, Jefferson County, AR. 2001.

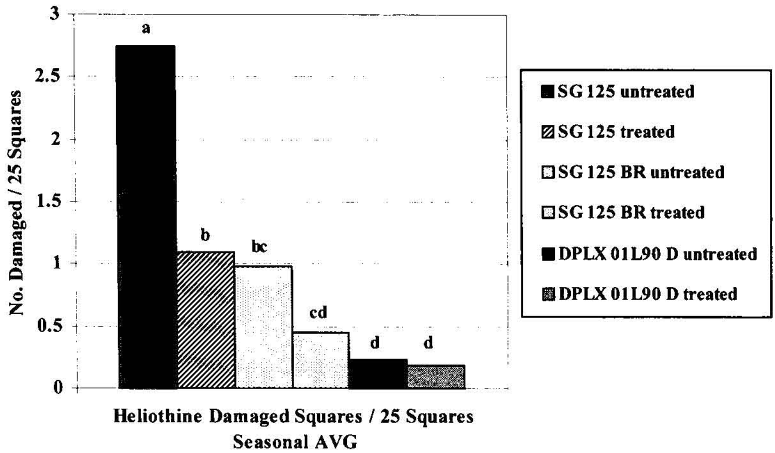


Fig. 5. Seasonal average Heliothine square damage: Heliothine control in Bollgard and Bollgard II cotton, Lincoln County, AR. 2001.

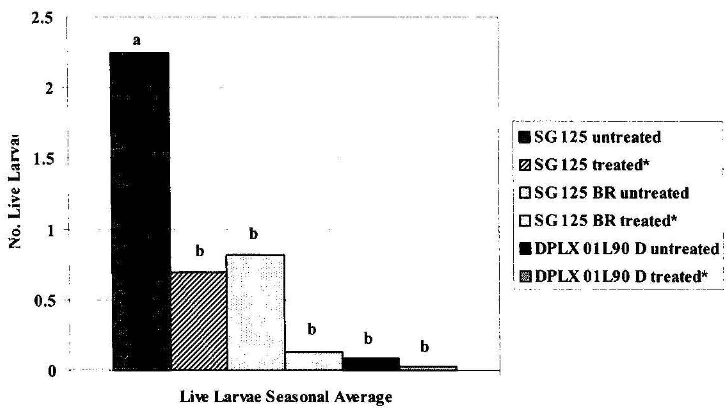


Fig. 6. Live Heliothine Larvae seasonal average: Heliothine control in Bollgard and Bollgard II cotton, Lincoln County, AR. 2001.

COMPARING THE LAST EFFECTIVE BOLL POPULATIONS IN ULTRA-NARROW-ROW AND CONVENTIONAL COTTON

Earl D. Vories and Robert E. Glover[1]

RESEARCH PROBLEM

Identification of the last effective boll population allows informed decisions for termination of insecticide and application of harvest aids. However, the current COTMAN cutout reference, i.e., NAWF=5 (Oosterhuis et al., 1999), may need to be changed for ultra-narrow-row (UNR) cotton. This study is part of a multi-state project which has an overall objective of determining the main-stem node number of the last effective boll population in UNR cotton grown in a range of typical field environments, compared to wide-row cotton in those same environments. This report describes the study conducted in northeast Arkansas in 2001.

BACKGROUND INFORMATION

A great deal of research has gone into COTMAN, the COTton MANagement system developed at the University of Arkansas (Danforth and O'Leary, 1998). Comparison with a target development curve (TDC) indicates when the crop is under stress. Identification of the last effective boll population allows informed decisions for termination of insecticide and application of harvest aids. Additional decisions (e.g., irrigation, plant growth regulators, etc.) may soon be linked to observations from COTMAN.

COTMAN relies on empirical data obtained from wide-row cotton (i.e., 30- to 40-inch row spacing) that may not accurately reflect the boll population of UNR cotton (i.e., row spacing <~15 inches). Research in Arkansas indicated that the last effective boll population is set in conventional wide-row cotton when there are five nodes above the highest first-position white flower (NAWF=5) (Bourland et al., 1992). Bolls set above this position (i.e., NAWF<5) are usually too small or too late in maturing to contribute significantly to yield. However, Gwathmey et al. (1999) reported that the

[1] Professor, Department of Biological and Agricultural Engineering, and research specialist, University of Arkansas Northeast Research and Extension Center, Keiser.

current COTMAN cutout reference (NAWF=5) might need to be changed for UNR cotton. UNR cotton is typically much shorter, with fewer main-stem nodes and fewer bolls per plant than wide-row cotton. Exploratory studies with COTMAN in UNR cotton have produced crop development curves that differ markedly from wide-row cotton and from the COTMAN TDC (Gwathmey et al., 1999; Vories, 2001). A typical UNR curve has a low peak and an abrupt cutout relative to wide-row cotton in the same environment. This suggests that NAWF=5 may not represent the last effective boll population in UNR, which may be set relatively higher on the plant than with wide rows.

Effective late-season management with COTMAN requires accurate identification of the last effective boll population. In addition to the observations with UNR cotton, previous observations of growth curves for conventional cotton (unpublished data) suggest that the natural stresses resulting from growing in clay lead to a development curve different from the COTMAN TDC. Such observations have led to suggestions that a different NAWF value for cutout might be appropriate on those soils. The relatively small amount of cotton produced on such soils has precluded development of a separate TDC. However, if UNR cotton is going to expand cotton acreage, it must do so by allowing production of cotton on soils previously considered "marginal" cotton ground.

RESEARCH DESCRIPTION

A field study was conducted at the Northeast Research and Extension Center (NEREC) at Keiser on non-irrigated cotton (*Gossypium hirsutum* L. cv. PM 1218 BG/RR) in 2001 on Sharkey silty clay (Chromic Epiaquerts). The experimental design consisted of a randomized complete block with two systems: conventional cotton produced on 38-inch rows (CONV), and ultra-narrow-row cotton produced on 7.5-inch rows (UNR), with six replications. Plots were approximately 50 ft wide by 600 ft long. The CONV plots were planted on beds with a John Deere 1700 planter at a seeding rate of 5 seed/ft, resulting in 41,000 plants/acre; UNR plots were flat planted with a John Deere 750 grain drill and a seeding rate of 2.7 seed/ft, resulting in 115,000 plants/acre. Planting date was 29 May, with imidicloprid (Gaucho)-treated seed. Nitrogen was aerially applied at 128 lb N/acre as urea on both treatments on 2 July.

At first flower, 15 typical plants per plot were flagged for subsequent flower tagging, with all first-position flowers tagged every other day with date and NAWF. White flowers were tagged with the current day's date; pink flowers were tagged with the previous day's date. Tagging continued until 24 August. Plots were defoliated 20 September with a tank mix of 10 oz product/acre tribufos (Def) and 2.0 lb ai/acre ethephon (Prep). The tagged bolls were hand picked and the seedcotton was air-dried before weighing. Plots were machine harvested on 9 October. Eight rows from CONV were spindle picked, while an equivalent width (~25 ft) from UNR was harvested with a cotton stripper with a platform header.

RESULTS

White flowers were first observed in CONV on 21 July, 53 days after planting (DAP), and in UNR on 23 July, 55 DAP, earlier than the 60 DAP for first flower on the COTMAN TDC (Table 1). The faster flowering was likely the result of waiting until 29 May for planting, after temperatures were warmer than typical for cotton planted earlier in the growing season. A total of 862 flower tags were recovered, with 545 from CONV plots and 317 from UNR plots. Although NAWF on the TDC begins at 9.25 and declines at a rate of 0.2 per day, cotton in this study did not begin at as large a NAWF value and declined faster. Regression analysis indicated a NAWF at first flower of 8.5 for the CONV plots and 6.5 for UNR. The days from planting to NAWF=5 were 67 and 62 DAP for CONV and UNR, respectively, much less than the 80 DAP associated with the COTMAN TDC. However, the late planting date and drought stress probably affected the days to NAWF=5 and possibly the NAWF at first flower.

Lint yields were significantly greater for UNR, with 620 and 540 lb/acre for UNR and CONV, respectively. Three-year average gin turnout values reported by Vories et al. (2001) of 33% and 29% for CONV and UNR, respectively, were used to estimate lint yield because those values were associated with a commercial gin with lint cleaners. However, the NAWF associated with the yield differed between treatments (Fig. 1). Significantly more of the yield was associated with UNR from NAWF = 3 and 4; while more was associated with CONV from NAWF = 5 and 6. Other bolls, primarily second sympodial-position bolls, made up significantly more of the yield for CONV.

The relationship between first-position white flower (hereafter called flower) number per plant and the associated NAWF was quite different between treatments (data not included). No significant differences were observed for NAWF ≤ 3; however, significantly more flowers were observed for CONV for 4 ≤ NAWF ≤ 8. No flowers were observed in UNR for NAWF ≥ 9. Flowers per plant can be misleading due to the great difference in stand densities between treatments; therefore, flowers per acre (Fig. 2) may be more indicative. For 1 ≤ NAWF ≤ 3, there were more flowers per acre for UNR. For 6 ≤ NAWF ≤ 8, CONV had more flowers per acre. Peak flower numbers were associated with NAWF = 3 and 6 for UNR and CONV, respectively.

Of the 862 flower tags recovered, 444 were associated with whole bolls, with 314 and 130 from CONV and UNR plots, respectively. There was significantly higher retention of flowers with UNR for NAWF = 3 and 4 and with CONV for NAWF = 8 (Fig. 3). Boll size was not significantly different for NAWF ≤ 6 (data not included). Bolls were significantly larger for CONV for NAWF = 7 and 8.

PRACTICAL APPLICATION

UNR plots yielded more than CONV, with 51% of UNR yield associated with NAWF = 3 and 4; 31% of CONV yield was associated with other than first position bolls. These data will be combined with data from similar studies at other locations to

determine whether a different target development curve will be required for COTMAN with UNR cotton. However, with more of the UNR cotton's yield coming from higher in the plant (NAWF<5), these preliminary findings suggest a different curve will be appropriate.

ACKNOWLEDGMENTS

This study is part of a multi-state project supported by Cotton Incorporated and led by Owen Gwathmey, University of Tennessee.

LITERATURE CITED

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

Danforth, D.M. and P.F. O'Leary (ed.). 1998. COTMAN expert system version 5.0. Ark. Agric. Exp. Sta., Fayetteville, AR. 198 pp.

Gwathmey, C.O., C.E. Michaud, R.D. Cossar, and S.H. Crowe. 1999. Development and cutout curves for ultra-narrow and wide-row cotton in Tennessee. p. 630-632. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Vories, E.D. 2001. Defining the COTMAN target development curve for ultra-narrow row cotton on clay soil. Report of Research to Cotton Inc., Project No. 00-836. 9 pp.

Vories, E.D., T.D. Valco, K.J. Bryant, and R.E. Glover. 2001. Three-year comparison of conventional and ultra-narrow-row cotton production systems. Appl. Eng. Agric. 17:583-589.

Table 1. Nodes above white flower data from tagged flowers from a conventional versus ultra-narrow-row cotton study at the University of Arkansas Northeast Research and Extension Center at Keiser in 2001.

	NAWF equation[y]		First flower[x]		NAWF=5[x]
Treatment[z]	slope	intercept	DAP	NAWF	DAP
CONV	-0.2600	22.3	53	8.50	67
UNR	-0.2240	18.8	55	6.50	62
TDC[w]	-0.2125	22.0	60	9.25	80

[z] CONV produced in 38-inch rows, UNR produced in 7.5-inch rows.

[y] NAWF = slope*DAP + intercept; DAP = days after planting.

[x] First Flower: DAP observed for plots; NAWF at first flower and DAP at NAWF=5 calculated from NAWF equation.

[w] TDC = COTMAN Target Development Curve.

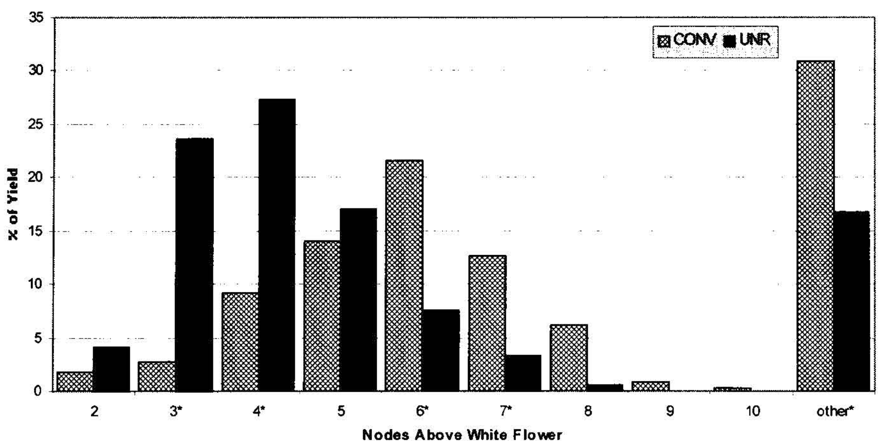


Fig. 1. Distribution of yield by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2001. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. "Other" bolls were collected from somewhere other than first sympodial position. Nodes with an "*" represent a significant difference between treatments at α=0.05.

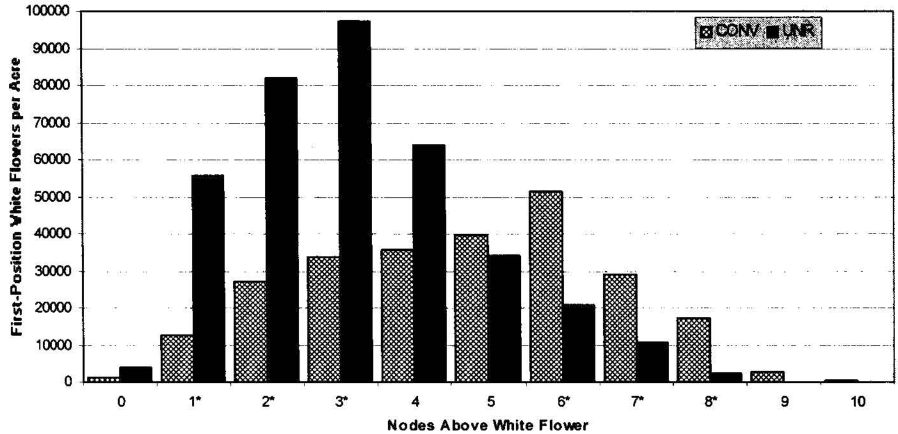


Fig. 2. First-position white flowers per acre by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2001. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. "Other" bolls were collected from somewhere other than first sympodial position. Nodes with an "*" represent a significant difference between treatments at α=0.05.

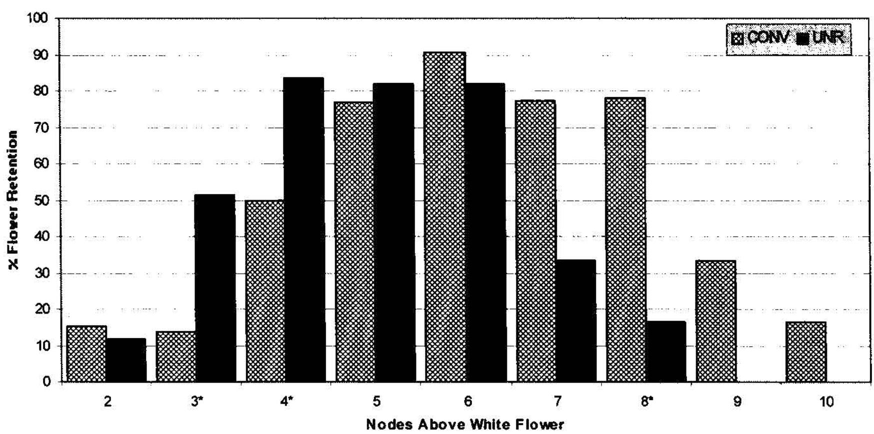


Fig. 3. First-position white flower retention by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2001. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. "Other" bolls were collected from somewhere other than first sympodial position. Nodes with an "*" represent a significant difference between treatments at α=0.05.

DETERMINING THE OPTIMAL TIMING FOR THE FINAL IRRIGATION ON ARKANSAS COTTON

Earl D. Vories, Jeremy Greene, Tina G. Teague, and William C. Robertson[1]

RESEARCH PROBLEM

Irrigation termination recommendations for cotton tend to key on first open boll, a better indicator of the maturity of the first fruit than the whole crop. The studies reported here are part of a multi-state project whose overall objective is to develop crop-based recommendations for timing the final irrigation on cotton as grown in a range of typical field environments. This report describes the studies conducted in Arkansas in 2001.

BACKGROUND INFORMATION

Cotton growers across the Cotton Belt are adopting COTMAN, a COTton MANagement system developed at the University of Arkansas used to monitor crop development and aid in making end-of-season decisions (Danforth and O'Leary, 1998). The later-season portion of the system is based on monitoring the number of nodes above the uppermost first-position white flower (NAWF) on a plant. Bourland et al. (1992) found that a first-position white flower five nodes below the plant terminal represented the last effective flower population. Based on their findings, NAWF=5 is generally accepted as physiological cutout.

The COTMAN system uses a target development curve (TDC) as a reference to compare with actual crop development. The TDC has flowering beginning at 60 days after planting (DAP) and NAWF=5 at 80 DAP. Comparisons of actual crop development to the TDC provide an indication of the maturity of the crop. Early-season stress often results in first flower at a relatively low NAWF value and physiological cutout occurring in less than 80 DAP (Bourland et al., 199?). Currently, research-based deci-

[1] Professor, Department of Biological and Agricultural Engineering, University of Arkansas Northeast Research and Extension Center, Keiser; extension entomologist, University of Arkansas Southeast Research and Extension Center, Monticello; professor, Arkansas State University, Jonesboro; and extension agronomist - cotton, University of Arkansas Cooperative Extension Service, Little Rock.

sion guides have been developed to aid in identifying the last effective boll population and determining dates for safe termination of insect control and the application of defoliants based on physiological cutout. Another area of cotton production that may benefit from COTMAN is the decision of when to stop irrigating the crop. A recommendation that relates the timing of the final irrigation to physiological cutout should fit the needs of the crop and follows the approach taken with other management recommendations.

RESEARCH DESCRIPTION

Five irrigation termination studies were conducted in Arkansas during the 2001 growing season. Cotton was planted on 38-inch rows and furrow irrigated. With the exception of irrigation termination, cultural practices followed Cooperative Extension Service (CES) recommendations. Seedcotton weights were determined with an instrumented boll buggy and an assumed gin turnout of 35% was used to calculate lint yield. NAWF data were collected weekly from early flower until NAWF<5. Information about the crops in each study is included in Table 1. For each site, the first termination treatment was targeted for approximately NAWF=5 (physiological cutout). An additional treatment was terminated with each subsequent irrigation. Fiber samples were submitted to Cotton Incorporated for high-volume instrument (HVI) analyses.

Northeast Arkansas

Three studies were conducted in Mississippi County in northeast Arkansas. One study was on the University of Arkansas Northeast Research and Extension Center (NEREC) at Keiser, on a field containing areas of Sharkey silty clay and Sharkey-Steele complex soils. Irrigation plots consisted of 4 rows approximately 800 ft long, with 4 buffer rows between plots, and seedcotton weights were obtained from all 4 rows for two harvests. A second study was on Field 89 of Wildy Farms near Manila, with areas of Routon-Dundee-Crevasse complex and Amagon sandy loam soils. Irrigation plots consisted of 18 rows approximately 1200 ft long and seedcotton weights were determined from the center 12 rows for two harvests. A third study was on Field 78 of Wildy Farms, with Routon-Dundee-Crevasse complex soils. Irrigation plots consisted of 18 rows approximately 1300 ft long and seedcotton weights were determined from the center 4 rows for one harvest.

Southeast Arkansas

Two studies were conducted in Desha County in southeast Arkansas on the Steve Stevens Farm near Rohwer. One experiment was on E Pond field on a Hebert silt loam. Irrigation plots consisted of 12 or 16 rows approximately 1000 ft long and seedcotton weights were determined from the center 4 rows for one harvest. The

second experiment was on Barrett field on a Rilla silt loam. Irrigation plots consisted of 16 rows approximately 500 ft long and seedcotton weights were determined from the center 8 rows for one harvest.

RESULTS

Northeast Arkansas

Even though two cultivars and three planting dates were used, all three fields reached NAWF=5 on 95 DAP, 15 days later than the 80 DAP for the COTMAN TDC (Table 1). However, none of the crops appeared to have suffered any early-season stress, with each having a relatively high NAWF at first flower (~9, data not included). Final irrigations ranged from 27 July (3 days or 70 DD60 before NAWF=5 at NEREC) to 4 September (32 days or 609 DD60 after NAWF=5 at Wildy 89) (Table 2). At Wildy 89 and Wildy 78, a 0.5-inch rain occurred on 8 August, one day after irrigation. Therefore, 8 August was considered the "effective" irrigation date. While each of the crops tended to have the lowest yield associated with the earliest final irrigation, the irrigation termination effect was significant for yield only at Wildy 89, and there were no significant differences among the four latest termination treatments (≥11 days or 220 DD60 after NAWF=5) in that study (Table 3). At NEREC and Wildy 89 it was possible to make two harvests, allowing percent first harvest to be used to indicate earliness. For both crops, the earliest crops (i.e., highest percent first harvest) were associated with the earliest final irrigation. Fiber quality was not affected. These findings are consistent with the results reported by Vories et al. (2001) for northeast Arkansas in 2000.

Southeast Arkansas

Even though the planting dates were similar, the fields reached NAWF=5 on 86 and 101 DAP for Stevens E Pond and Stevens Barrett, respectively (Table 1). The late date for Stevens Barrett resulted from early-season stress that delayed fruiting. The relatively low yields (Table 3) were probably affected by the early stress. A 5-inch rain occurred at Stevens Farm on 29 August, about the time the treatments were to begin being implemented on Stevens Barrett field. For the purposes of the experiment, the rainfall was considered the effective final irrigation for one treatment (21 days or 426 DD60 after NAWF=5, Table 2), even though the time required for drying out from that much rain would be much greater than is typical after irrigation. Another portion of the field was irrigated on 13 September (36 days or 673 DD60 after NAWF=5). Neither the yield difference nor fiber quality differences were significant at Stevens Barrett (Table 3).

The large rain came relatively later in the study period on Stevens E Pond, on the day following the final irrigation on the 4th treatment. Therefore, 29 August was considered the effective irrigation date for that treatment (Table 2). Final irrigations ranged from 9 August (20 days or 470 DD60 after NAWF=5) to 29 August (40 days or 890 DD60

after NAWF=5). Yield was significantly affected, with higher yield associated with later irrigation (Table 3). Although the difference between treatments 3 and 4 was not significant, the 29 August rain was likely close enough to the final irrigation on treatment 3 (22 August) to minimize any possible effect. Micronaire was significantly affected, with higher micronaire associated with the later irrigations (Table 3).

PRACTICAL APPLICATION

Only two of the five studies showed significant differences in cotton yield with later irrigation; however, rainfall affected the studies in southeast Arkansas. Where yield differences were significant, the differences for southeast Arkansas (Stevens E Pond) were observed later in the growing season (after 20 days or 470 DD60 after NAWF=5) than for northeast Arkansas (Wildy 89, where no differences were observed later than 11 days or 220 DD60 after NAWF=5). Only two of the studies were harvested twice and in both (NEREC and Wildy 89) there was a significantly lower percent first harvest associated with later irrigation. Very little difference was observed in fiber quality for the different irrigation termination treatments. Micronaire was significantly affected in Stevens E Pond in southeast Arkansas, where micronaire tended to increase with later irrigation. Similar coordinated studies were conducted in Louisiana and Missouri in 2001. In addition to these locations, studies will be conducted in Mississippi and Texas in 2002. Crop-based recommendations should be developed soon by comparing the findings from all of these studies, leading to more efficient use of irrigation water and the energy associated with pumping.

ACKNOWLEDGMENTS

Cotton Incorporated provided funding and technical assistance for this research. Additional assistance was provided by Wildy Farms, Stevens Farms, Ray Benson, Chuck Capps, Bob Glover, and Dale Wells.

LITERATURE CITED

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

Danforth, D.M. and P.F. O'Leary (ed.). 1998. COTMAN expert system version 5.0. University of Arkansas Agricultural Experiment Station, Fayetteville, AR. 198 pp.

Vories, E.D., R.E. Glover, N.R. Benson, Jr., and V.D. Wells. 2001. Identifying the optimum time for the final surface irrigation on mid-south cotton. ASAE Meeting Paper No. 01-2176. St. Joseph, Mich.: ASAE.

Table 1. Cultivar and significant dates for each site from the 2001 cotton irrigation termination studies.

Location	Cultivar	Planting date	NAWF=5 Date	NAWF=5 DAP	Harvest
NEREC	Sure-Grow 747	26 Apr	30 Jul	95	21 Sep; 9 Oct
Wildy 89	ST 4892BR	30 Apr	3 Aug	95	26 Sep; 18 Oct
Wildy 78	ST 4892BR	8 May	11 Aug	95	18, 22 Oct
Stevens E pond	DP 451 B/RR	25 Apr	20 Jul	86	28 Sep
Stevens Barrett	ST 4892BR	29 Apr	8 Aug	101	26 Oct

Table 2. Timing of the final irrigation in the 2001 cotton irrigation termination studies.

Treatment	Date	Final irrigation: Days after planting	Days after NAWF=5[z]	DD60 after NAWF=5[z]
NEREC				
1	27 Jul	92	-3	-70
2	9 Aug	105	10	234
3	20 Aug	116	21	444
4	30 Aug	126	31	669
Wildy 89				
1	8 Aug[y]	100	5	102
2	14 Aug	106	11	220
3	21 Aug	113	18	334
4	28 Aug	120	25	489
5	4 Sep	127	32	609
Wildy 78				
1	8 Aug[y]	92	-3	-67
2	14 Aug	98	3	52
3	21 Aug	105	10	166
4	28 Aug	112	17	321
5	4 Sep	119	24	441
Stevens E pond				
1	9 Aug	107	20	470
2	15 Aug	113	26	592
3	22 Aug	120	33	735
4	29 Aug[y]	127	40	890
Stevens Barrett				
1	29 Aug	122	21	426
2	13 Sep	137	36	673

[z] Negative values signify that the final irrigation was made before a field-average NAWF=5.
[y] Date changed by one day to account for rain on the day following irrigation.

Table 3. Lint yield, earliness and fiber quality findings from the 2001 cotton irrigation termination studies.

Treatment	Lint yield[z]	% First harvest	Micronaire	Strength	Length
NEREC					
1	1199	88	4.45	26.3	1.15
2	1275	83	4.40	27.1	1.18
3	1268	79	4.38	26.7	1.15
4	1252	78	4.55	26.0	1.16
$LSD_{(0.05)}$	NS	4	4.42	26.3	1.18
Wildy 89[y]					
1	1014	85	4.42	29.1	1.13
2	1110	82	4.58	29.5	1.13
3	1137	79	4.70	29.1	1.16
4	1082	80	4.58	29.4	1.13
5	1116	81	4.65	30.5	1.17
$LSD_{(0.05)}$	67	4	NS	NS	NS
Wildy 78					
1	806	--	4.48	29.5	1.16
2	898	--	4.45	28.6	1.15
3	874	--	4.60	29.2	1.17
4	944	--	4.65	29.4	1.17
5	890	--	4.60	28.7	1.17
$LSD_{(0.05)}$	NS	--	NS	NS	NS
Stevens E pond					
1	958	--	4.48	27.1	1.09
2	986	--	4.38	26.9	1.08
3	1045	--	4.72	26.8	1.07
4	1029	--	4.75	27.4	1.10
$LSD_{(0.05)}$	55	--	0.18	NS	NS
Stevens Barrett					
1	589	--	5.02	29.6	1.13
2	615	--	5.00	29.5	1.14
$LSD_{(0.05)}$	NS	--	NS	NS	NS

[z] Assuming 35% gin turnout.

[y] Fiber-quality samples collected from first of two harvests.

IMPROVING COTTON IRRIGATION SCHEDULING IN ARKANSAS

Earl D. Vories, Phil L. Tacker, and Robert E. Glover[1]

RESEARCH PROBLEM

Timely irrigation of cotton has been shown to increase yields, but producers and researchers observe poor plant development even with irrigation under some conditions almost every year. Adequate moisture must be present when the cotton crop needs it, but saturated soil conditions deprive the roots of necessary oxygen. Published University of Arkansas recommendations do not include sufficient detail concerning irrigation management. Use of the Arkansas Irrigation Scheduler is recommended; however, the crop water-use function in the Scheduler was not experimentally developed.

BACKGROUND INFORMATION

Cotton was harvested from 950,000 acres in Arkansas in 2000, with over 69% of those acres irrigated (Arkansas Agricultural Statistics Service, 2001). Published University of Arkansas recommendations (Bonner, 1995) do not include much detail concerning irrigation management. While use of the Arkansas Irrigation Scheduler (Cahoon et al., 1990) is recommended, the crop water-use function (i.e., crop coefficient curve used to predict daily crop water use as a function of crop age) in the Scheduler was not experimentally developed. The original curve was adapted from Supak and Metzer (1977), based on older varieties and Texas High Plains conditions. Concerns that the curve caused an underestimation of early-season water use led to a modification in 1989. However, it was felt that the "new" curve was still not closely linked to the development of the cotton crop in Arkansas, so another curve was developed in 1991 and is still in use today. The current curve represented the best estimates of an agricul-

[1] Professor, Department of Biological and Agricultural Engineering, University of Arkansas Northeast Research and Extension Center, Keiser; agricultural engineer, University of Arkansas Cooperative Extension Service, Little Rock; and research specialist, University of Arkansas Northeast Research and Extension Center, Keiser.

tural engineer (Vories), a cotton physiologist (Oosterhuis), and a cotton breeder (Bourland), but was not experimentally verified. The objective of this research is to validate or develop a new crop coefficient curve for the Arkansas Irrigation Scheduler.

RESEARCH DESCRIPTION

A study was conducted at the University of Arkansas Northeast Research and Extension Center (NEREC) at Keiser on Sharkey-Steele complex soil to validate the crop water-use function for cotton in the Arkansas Irrigation Scheduler. Subsurface drip irrigation, with tubing placed approximately 12 inches below the original soil surface on a 38-inch spacing, was used to precisely control the water applied to plots and Watermark sensors were used to track soil moisture status. The study was designed as a randomized complete block split plot with four replications. Three levels of irrigation [nonirrigated, NI; 60% of estimated daily evapotranspiration (ET), Lo; 100% of estimated daily ET, Hi] were the whole-plot treatments and three varieties: Sure-Grow 747 (747), PSC 355 (355), and NuCOTN 33 B (33B) were the split-plot treatments. The study was planted on 18 May, 2001. COTMAN (Danforth and O'Leary, 1998) data were collected throughout the growing season and sequential hand harvests were conducted during the boll-opening period. Daily ET was estimated using the system of Cahoon et al. (1990) adapted for subsurface drip irrigation. The drip irrigation system began daily applications on July 3. The Watermark sensors were placed 8 inches below the surface of the soil bed, approximately 6 inches above the drip tape. Data were collected hourly from the sensors beginning 21 July. Lint yields were estimated assuming a 35% gin turnout.

RESULTS

Rainfall during the early part of the growing season was plentiful, with approximately 6 inches from planting through June 7 (Fig. 1). From that point until the end of August there were less than four additional inches. The crop in the drip-irrigated plots developed at a normal pace. Regression analysis indicated that the nodes above white flower (NAWF) on 17 July, 60 days after planting (DAP) or approximately first flower, averaged 8.6 and was not significantly affected by irrigation treatment or variety. That value (8.6) is slightly below the apogee of the COTMAN target development curve (TDC), i.e., 9.25. Days to NAWF=5 were significantly affected by the water treatments, but not by variety (Table 1). As expected, NI was the first treatment to reach NAWF=5 and Hi was the last. Similarly, the days to mean maturity based on sequential hand harvests followed the same trend, although the difference between the two irrigated treatments (Lo and Hi) was not significantly different.

The differences in maturity were not reflected in yield differences (Table 2). The irrigation treatment effect was not significant, while the variety effect was significant.

Variety effects were significant for micronaire and strength, but only fiber length had a significant irrigation treatment effect with NI shorter than the irrigated treatments. Larger differences among the irrigation treatments were expected and were observed in other NEREC cotton studies. The differences in water status of the plots were large, as indicated by the estimated soil water deficits (data not included) and supported by the soil moisture tension readings from the Watermark sensors (Fig. 2), and these differences were reflected in the maturity results (Table 1). The soil disturbances fairly near planting (installing the drip lines with a subsoil plow and then rebuilding the soil beds) may have influenced responses and reduced the observed differences among treatments. If so, the soil should be much less affected in 2002 after the system has been in place for a year.

PRACTICAL APPLICATION

A nonirrigated treatment was the first treatment to reach NAWF=5 and a treatment with daily applications of 100% of the estimated daily water use was the last. Days to mean maturity followed the same trend. The irrigation treatment effect was not significant, but the variety effect was significant. Only fiber length had a significant irrigation treatment effect, with lint from the nonirrigated treatment shorter than from the irrigated treatments. Soil disturbances associated with installing the irrigation system fairly near planting may have influenced responses and reduced the observed differences among irrigation treatments.

ACKNOWLEDGMENTS

This study was supported by Cotton Incorporated.

LITERATURE CITED

Arkansas Agricultural Statistics Service. 2001. Arkansas county estimates 1999-2000. online at http://www.nass.usda.gov/ar/00ctyest.

Bonner, C.M. 1995. Cotton production recommendations. University of Arkansas Cooperative Extension Service AG422-4-95.

Cahoon, J., J. Ferguson, D. Edwards, and P. Tacker. 1990. A microcomputer-based irrigation scheduler for the humid mid-south region. Applied Engineering in Agriculture 6:289-295.

Danforth, D.M. and P.F. O'Leary (ed.). 1998. COTMAN expert system version 5.0. University of Arkansas Agricultural Experiment Station, Fayetteville, AR. 198 pp.

Supak, J.R. and R.B. Metzer. 1977. Keys to profitable cotton production in the High Plains. Texas Ag. Ext. Serv. MP-1311, AGR 2 15M-1-77.

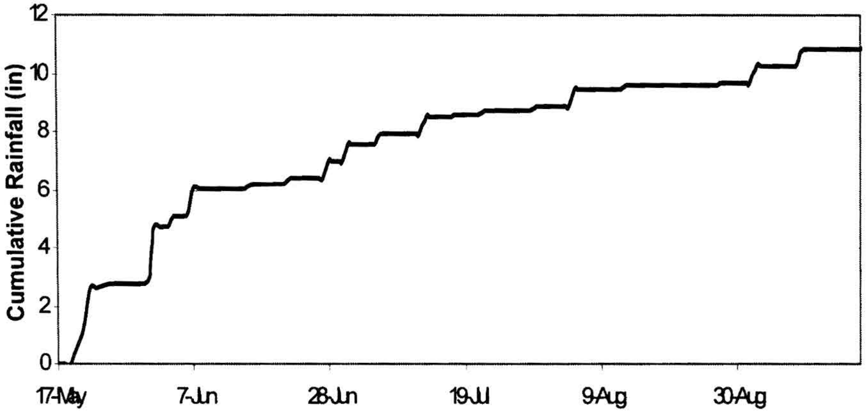


Fig. 1. Cumulative rainfall during the 2001 growing season at NEREC.

Table 1. Crop maturity parameters for drip irrigation study. Keiser, AR, 2001.

Irrigation treatment	Parameter value			
	Variety			
	747	355	33B	Avg.
	NAWF = 5 (DAP)			
N	73 a	77 a	76 a	75 c
Lo	79 a	80 a	82 a	80 b
Hi	84 a	82 a	85 a	84 a
Avg.	79 a	80 a	81 a	
	Mean maturity date (DAP)			
N	128 a	132 a	129 a	130 b
Lo	139 a	135 a	143 a	139 a
Hi	140 a	139 a	143 a	141 a
Avg.	136 a	135 a	138 a	

Table 2. Crop yield and quality for drip irrigation study. Keiser, AR, 2001.

Irrigation treatment	Parameter value			
	Variety			
	747	355	33B	Avg.
	Lint yield (lb/acre)			
NI	1150 a	957 a	956 a	1021 a
Lo	1135 a	1068 a	1019 a	1074 a
Hi	1090 a	1008 a	867 a	988 a
Avg.	1125 a	1011 b	947 b	
	Micronaire			
NI	4.68 a	4.70 a	4.32 a	4.57 a
Lo	4.32 a	4.65 a	4.28 a	4.42 a
Hi	4.55 a	4.52 a	4.38 a	4.48 a
Avg.	4.52 ab	4.62 a	4.32 b	
	Length (in.)			
NI	1.14 a	1.13 a	1.15 a	1.14 b
Lo	1.19 a	1.20 a	1.19 a	1.19 a
Hi	1.17 a	1.19 a	1.18 a	1.18 a
Avg.	1.17 a	1.17 a	1.18 a	
	Strength (g/tex)			
NI	27.9 a	30.8 a	30.3 a	29.6 a
Lo	26.5 a	29.4 a	29.7 a	28.5 a
Hi	26.6 a	29.2 a	28.9 a	28.2 a
Avg.	27.0 b	29.8 a	29.6 a	

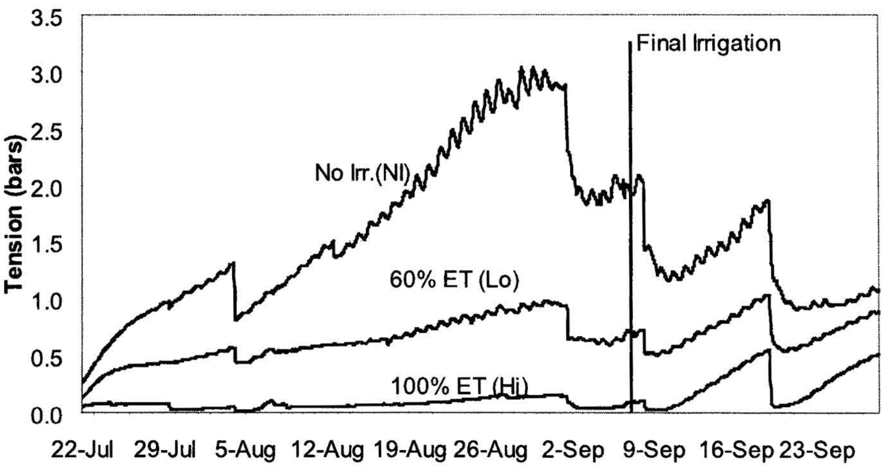


Fig. 2. Soil moisture tension in cotton drip irrigation study.

PHYSIOLOGICAL CHARACTERIZATION OF COTTON GENOTYPES IN RESPONSE TO WATER-DEFICIT STRESS

Cassandra R. Meek, Derrick M. Oosterhuis, and James M. Stewart[1]

RESEARCH PROBLEM

While water-deficit stress is a major limiting factor in cotton *(Gossypium hirsutum* L.) production, the level of drought tolerance among currently-grown commercial cultivars is largely unknown. Plants have evolved novel strategies for tolerating water-deficit stress, however, in agronomically important plants it is not enough to merely survive. In cotton, traditional selection approaches have generally proved unsuccessful in improving agronomic yields due to interactions between genotype and environment, therefore, research efforts need to be directed toward identifying traits associated with maintenance of growth under water-deficient conditions.

BACKGROUND INFORMATION

When water-deficit stress is encountered, a cascade of events is triggered in a plant. One of the first signs of water-deficit stress is decreased turgor pressure (Kramer and Boyer, 1995), which is eventually manifested as wilting. Because cellular expansion is dependent on sufficient turgor pressure, growth can be negatively affected if the stress is prolonged. Insufficient turgor pressure also results in stomatal closure, which decreases carbon fixation via photosynthesis inhibiting growth by diminishing both sink and source components (Bradford and Hsaio, 1982). A decrease in transpiration usually occurs during water-deficit stress in an effort to conserve water and is directly related to stomatal closure. Commonly, water-deficit stressed cotton leaves will exhibit an increase in the waxy cuticular layer of the leaf (Weete et al., 1978; Oosterhuis et al., 1991) for water conservation. It is obvious that water-deficit stress affects a plant at many levels, and a yield reduction is often the ultimate consequence.

[1] Distinguished professor, graduate assistant, and professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

After consulting top cotton breeders in the US and abroad, seven cultivars representative of the major cotton areas in the US were chosen. These included Maxxa (west), Sphinx (southwest), Fibermax (midsouth), Deltapine Nu33B, Stoneville 747, Sure-Grow 474 (Mississippi River Delta), and Paymaster 1218 (east). An Australian cultivar, Siokra L-23, was included for its known level of drought tolerance (Nepomuceno,1998). Studies were performed in Fayetteville, Arkansas, in a growth chamber and in the field. In the growth chamber studies, plants were grown in 2-L plastic pots containing "Sunshine", a soilless horticultural mix. Plants were arranged in a completely randomized design with three replications, and the study was repeated five times. Plants were given half-strength Hoagland's nutrient solution to maintain adequate nutrients and water. At four weeks after planting, half the plants were subjected to water-deficit stress past the point of stomatal closure to full wilt. After full rehydration, osmotic adjustment was measured using end-window thermocouple psychrometry. Gas exchange measurements were taken 1, 3, and 7 days after stress recovery with a LI-COR 6200 portable photosynthesis system. Leaf epicuticular wax content was measured at 7 days after rehydration by soaking leaves in chloroform for 30 seconds, followed by evaporation, leaving only the wax. Differential carbon isotope analyses were performed to further elucidate differences in drought tolerance in these cultivars. In the field study, plants were arranged in a split-plot design with six replications. Half the plants were irrigated with in-furrow irrigation, while the other half were unirrigated. At first-flower (FF), FF + 2 and FF + 4 weeks, leaf water and osmotic potentials, relative water content, and gas exchange measurements were collected. All data were analyzed using SAS PROC GLM.

RESULTS

Means of five experiments indicated a narrow range of osmotic adjustment. Several significant differences existed in osmotic adjustment between cultivars (Table 1), with Sphinx (44 %) showing the highest and Maxxa (12 %) the lowest level of osmotic adjustment. Stressed plants of several cultivars showed significant increases in photosynthetic rate at three days after stress cessation compared to control plants, especially Siokra L-23 and Sphinx (Fig. 1). Leaf epicuticular wax content was significantly higher in all stressed plants, and transpiration rates were inversely related to amount of wax (data not shown). Stressed Sphinx plants showed the greatest degree of wax accumulation compared to other cultivars. A highly significant cultivar by water interaction was observed in carbon isotope discrimination (Table 2). Stressed plants in all cultivars discriminated less compared to the well-watered control plants. Generally, cultivars with high levels of osmotic adjustment exhibited less differences in carbon discrimination between stressed and well-watered control plants, indicating that stomates of these cultivars remained open longer when compared to other cultivars.

Under field conditions, osmotic measurements mimicked results from the controlled studies (data not shown). Because adequate amounts of rainfall were received, the degree of water-deficit stress was minimal. No significant differences in yield between cultivars or water regimes were observed in the field study (Table 3) due to the lack of drought stress. Overall, results indicated a limited amount of drought tolerance in current commercial cultivars. However, there was evidence of enhanced photosynthetic recovery from water-deficit stress in several cultivars.

PRACTICAL APPLICATION

Due to the complex nature and far-reaching effects of water-deficit stress, it is essential to characterize the responses at many different levels. Knowledge gained from this research can assist producers in making informed decisions regarding appropriate cultivars in areas prone to drought. Breeding and screening efforts can also be improved based on information arising from this project.

LITERATURE CITED

Bradford, K.J., and T.C. Hsaio. 1982. Physiological responses to moderate water stress. *In:* O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Zeigler. (eds.). Encyclopedia of Plant Physiology Vol. 12B Physiological Plant Ecology II. Springer-Verlag. Heidelberg, Germany. pp. 264-331.

Kramer, P.J. and J.S. Boyer. 1995. Water Relations of Plants and Soils. Academic Press. Orlando, FL. pp. 495.

Nepomuceno, A.L., D.M. Oosterhuis, and J. McD. Stewart. 1998. Physiological responses of cotton to water deficit induced by polyethylene glycol. Environmental and Exper. Bot. 40:29-41.

Oosterhuis, D.M., R.E. Hampton, and S.D. Wullschleger. 1991. Water deficit effects on the cotton leaf cuticle and the efficiency of defoliants. J. Prod. Agric. 4:260-265.

Weete, J.D., G.L. Leek, C.M. Peterson, H.E. Currie, and W.D. Branch. 1978. Lipid and surface wax synthesis in water-stressed cotton leaves. Plant Physiol. 62:675-677.

Table 1. Osmotic adjustment observed under controlled environmental conditions. These values represent means of five experiments.

Cultivar	Adjustment[z]
	(%)
Sphinx	44 a[y]
Suregrow 747	31 b
Siokra L-23	24 bc
Stoneville 474	23 bc
Paymaster 1218	21 c
DeltaPine Nu33b	19 c
Fibermax 989	18 c
Maxxa	12 d

[z] Percentage adjustment in osmotic potential compared to the well-watered control.
[y] Means followed by the same letter are not significantly different (P=0.05).

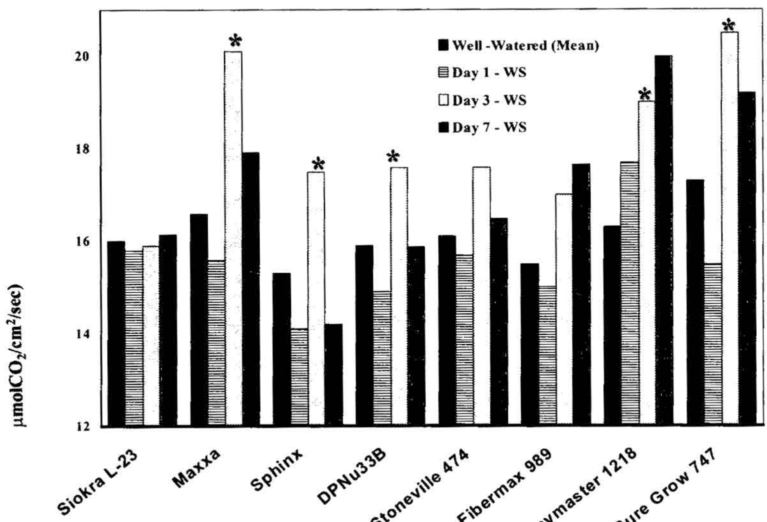


Fig. 1. Photosynthesis of the cotton cultivars after 1, 3, and 7 days of rehydration. Significant differences between cultivars within a given water treatment are denoted by an asterisk.

Table 2. Carbon isotope discrimination observed under controlled environmental conditions. The cultivar by water interaction was highly significant (P=0.0013).

Cultivar	Well-watered	Water-stressed
Sphinx	-31.3	-31.1[z]
Suregrow 747	-31.6	-31.3
Siokra L-23	-31.8	-31.3
Stoneville 474	-31.7	-30.6
Paymaster 1218	-31.2	-30.8
DeltaPine Nu33b	-31.1	-30.1
Fibermax 989	-31.8	-31.0
Maxxa	-32.0	-31.2

[z] A lower value depicts comparatively more discrimination in water-stressed plants, i.e., more drought tolerance.

Table 3. Seedcotton yield results from the field study. No significant differences were observed.

Cultivar	Irrigated	Unirrigated
Sphinx	1635	1751
Suregrow 747	1868	1573
Siokra L-23	1793	1709
Stoneville 474	2231	1798
Paymaster 1218	1910	1537
DeltaPine Nu33b	1793	1705
Fibermax 989	2217	1639
Maxxa	1551	1318
LSD (P=0.05)	NS[z]	NS

[z] NS = non-significant (P=0.05).

GENOTYPIC AND ENVIRONMENTAL EFFECTS ON PARTITIONING IN THE COTTON PLANT AND BOLL FOR EXPLAINING YIELD VARIABILITY

Robert S. Brown, Derrick M. Oosterhuis, and Dennis L. Coker[1]

RESEARCH PROBLEM

Cotton yields in the U.S. increased steadily throughout the 1980s, but leveled off and even decreased in the 1990s. Of more concern, however, is the increased year-to-year variability. A clear understanding of why yields have leveled off the past decade and why increased variability from year-to-year has occurred is urgently needed. It is speculated that the reason for this decrease in yield is a combination of adverse environmental conditions, particularly during boll development, coupled with changes in cotton genotypes due to changes in breeding objectives over the past few decades. This is a preliminary report of a study to explain yield variability by evaluating cotton yield components as influenced by genotype and environment to .

BACKGROUND INFORMATION

Cotton yields in Arkansas as well as much of the U.S. increased steadily throughout the 1980s, but leveled off and even decreased in the 1990s (Chaudry, 1997; Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the increased year-to-year variability in which record yields occur one year followed by disastrous yields the next year. Generally, each year the cotton crop appears to have good yield potential at mid-season, but high yields are not always achieved at final harvest. One reason for poor yields is related to subtle genotypic changes in modern cultivars due to the way in which carbohydrate and energy are partitioned between seed and fiber within the boll. However, the main reasons for poor yields in recent years may be due to extremely hot temperatures, coupled with drought, during the crucial first three to five weeks of flowering and boll development (Oosterhuis, 1995, 1997, 1999).

[1] Graduate assistant, distinguished professor, and research specialist, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

The current hypothesis is that modern cultivars produce smaller bolls with smaller, more numerous seeds. Under adequate growing conditions this allows for more seed per acre and the potential for more fiber aiding in higher lint yields. However, under adverse environmental conditions (mainly drought) the modern cultivars are unable to tolerate the added carbohydrate stress associated with trying to appropriately fill seed and produce fiber. To test this hypothesis, the following research objectives were designed for an ongoing field trial. The main objective was to investigate dry-matter partitioning at the whole plant, boll, and seed level in relation to genotype and environment. A second objective will include future investigation of night temperatures as related to boll development. Collectively, this information should help in the development of an "early warning" signal for detecting low boll-weight development in the field before yields are adversely affected.

RESEARCH DESCRIPTION

In 2001, a field study was designed in northeast Arkansas to test the impact of contrasting environmental conditions coupled with genotypic differences on dry matter partitioning in cotton. The study was planted 10 May 2001 in a randomized split-plot design consisting of 16 treatments replicated six times. The whole-plot factor was irrigation and consisted of either well-watered (WW) or water-stressed (WD) conditions, and the split-plot factor represented cultivar consisting of four obsolete (ST 213, DP 16, Rex, SJ2) and four modern (ST 474, SG 747, DP33B, Acala Maxxa) cultivars. Each of the eight cultivars was subjected to both well-watered and water-stressed conditions to account for the 16 treatments tested in the study. The cultivars were chosen with the collaborative effort of breeders across the U.S cotton belt to insure that current germplasm pools from each region were represented. To evaluate dry-matter partitioning at the boll and seed levels, approximately 80 first-position bolls were tagged at upper and lower canopy positions. From these tagged bolls, 10 bolls were collected at two, four, and six week intervals and are currently being processed in order to determine dry matter of boll component parts, lint and seed indices, and seeds per boll. At final harvest, mature bolls were collected from a 2-m^2 harvest area to determine the same boll parameters measured on the tagged bolls, and final lint yields were recorded from mechanically harvesting the center two rows of each four-row plot.

RESULTS

Lint Yields

There were no differences in lint yields between well-watered and water-deficit treatments when averaged over cultivars (Fig. 1, Table 2). The 2001 cotton season experienced below normal temperatures with normal rainfall, which resulted in similar

yields between wet and dry plots. However, there was a significant difference in yield between modern and obsolete cultivars when averaged over water, with the modern cultivars showing a significantly higher yield than the obsolete cultivars (Fig. 1, Table 1). The only exception to this was Acala Maxxa, a modern cultivar, which yielded less than the obsolete cultivars tested because of an inability to mature all of its bolls within the short Mississippi Delta season. A more important result was that there was a significant interaction between water and cultivar levels, indicating that different cultivars responded differently to water in terms of yield potential (Fig. 1).

Boll Number and Weight (Whole Plant Analysis)

Immediately prior to mechanical harvest, all mature bolls were collected from a two-meter row length within each plot to estimate average boll weight, bolls per acre, seeds per acre, seeds per boll, seed weight, and fiber per seed. Final boll harvest supported the hypothesis that modern cultivars had more bolls and seeds per acre than obsolete cultivars when averaged over water treatments (Table 1). As expected, the obsolete cultivars also had larger bolls with larger seeds. We had anticipated that the obsolete cultivars would have fewer seeds per boll and more fiber per seed than the modern cultivars due to modern cultivars investing less energy in seed development. However, the replicated field study indicated that the modern cultivars produced more fiber per seed and had less seeds per boll (Table 1). Over the last few decades plant breeders have increased gin turnout (the amount of fiber relative to the amount of seed,) therefore this result appears to make sense. However, field results showed fewer seeds per boll in modern compared to obsolete cultivars, which still remains an unanswered question. Table 2 summarizes the effect that the environment, i.e. water deficit, had on modern and obsolete cultivars. There were no differences between wet and dry plots in the 2001 season as a result of appreciable rainfall during peak squaring and boll development. This boll component data also helps to explain why there were no differences in yields between wet and dry plots.

Average Boll Weight and Seed Percentages (Boll and Seed Levels)

To better explain the yield results and boll development parameters measured at the whole-plant level, individually tagged bolls at upper and lower canopy positions are currently being analyzed for dry-matter allocations. This should help to explain partitioning at the boll and seed level as bolls of different genetic potential develop in the field under contrasting environments. The data presented in Fig. 2 constitute the harvested lower position bolls at the six-week stage of growth. It was anticipated that boll weight would be lower for the modern cultivars when compared to the obsolete cultivars. However, data collected from the lower position bolls at six weeks failed to show this trend. When averaged over water treatments, the performance of modern

versus obsolete cultivars was quite variable in the detection of lower boll weights for the modern cultivars. It should be mentioned, however, that these data only reflect one position in the plant canopy and also only represent one sample time. The variation noticed in boll weight may be related to different tagging dates due to different maturities of the cultivars tested. Therefore, bolls may have experienced different weather conditions during the six-week boll development period. However, once we can calculate the amount of increase in boll weight per day per unit of water, we can better determine differences between modern and obsolete cultivars for developing boll weight.

PRACTICAL APPLICATION

This current and ongoing research project will continue to evaluate partitioning at the boll and seed level to gain insight into underlying principles of boll development as related to changes in genetics and the environment. Once all of the samples have been processed, analyzed, and weather data correlated back to the individual sampling, we anticipate being able to predict when bolls will begin to develop low boll weight in the field under different environments as related to genotypic differences. If this research is successful it will permit producers to be able to make management decisions to attempt to enhance boll development or reduce production inputs to save costs.

LITERATURE CITED

Chaudhry, M.R. 1997. Cotton yields stagnating. The ICAC Recorder XV (1).

Lewis, H.L. and P. Sasser. 1999. U.S. Upland cotton: Beltwide and Mid-South yield trends, 1960-1998. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN.

Meredith, W.R. Jr. 1998. Continued progress in breeding for yield in the USA? Proc. Cotton Biochemistry Conf., Cotton Incorporated, Raleigh, NC.

Oosterhuis, D.M. 1995. A postmortem of the disappointing yields in 1993 Arkansas Cotton Crop. *In:* D.M. Oosterhuis (ed.). Proc. 1994 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station. Special Report 166:22-26.

Oosterhuis, D.M. 1997. Effects of temperature extremes on cotton yields in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 1997 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station. Special Report 183:94-98.

Oosterhuis, D.M. 1999. Yield responses to environmental extremes in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 1999 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station. Special Report 193:30-38.

Table 1. Dry-matter components of yield. Cultivar effect–averaged over water. Two-meter harvest from Clarkedale, AR. Summer 2001.

Treatment	Lint yield	Average boll weight	Seed/boll	Fiber/seed	Seed weight	Bolls/acre	Seeds/acre
	(lb/acre)	(g/boll)	(no.)	(mg/seed)	(g/100 seed)	(no./acre)	
ST 474 (new)	917	3.19	21.9	56.9	8.59	340,000	7,450,000
DP 33B (new)	1033	3.62	27.7	48.3	8.12	378,000	10,500,000
SG 747 (new)	1110	3.67	25.2	58.5	8.62	369,000	9,300,000
Maxxa (new)	691	4.05	22.9	68.2	10.51	250,000	5,640,000
New (Average)[z]	938[y]	3.63	24.2	58.0[y]	8.96	334,000	8,220,000
ST 213 (old)	870	3.48	25.4	50.3	8.39	336,000	8,520,000
DP 16 (old)	922	3.73	27.3	48.4	8.58	323,000	8,840,000
Rex (old)	815	3.82	26.2	50.7	9.25	286,000	7,490,000
SJ2 (old)	833	4.28	26.5	56.7	10.28	256,000	6,710,000
Old (Average)[z]	771	3.83[y]	26.3	51.5	9.13	300,000	7,890,000

[z] Indicates that the measurement for a given treatment was significant at the $P \leq 0.05$ level.
[y] Statistics only compare significant differences between cultivars at the new vs. old level. Statistical comparisons were not made in regard to individual cultivars.

Table 2. Dry-matter components of yield. Water effect–averaged over cultivar. Two-meter harvest from Clarkedale, AR. Summer 2001.

Treatment	Lint yield	Average boll weight	Seed/boll	Fiber/seed	Seed weight	Bolls/acre	Seeds/acre
	(lb/acre)	(g/boll)	(no.)	(mg/seed)	(g/100 seed)	(no./acre)	
Well-watered (WW)	906	3.68	25.2	54.7	9.01	330,000	8,370,000 [z]
Water-deficit (WD)	891	3.78	25.6	54.8	9.07	303,000	7,740,000

[z] Indicates that the measurement for a given treatment was significant at the $P \leq 0.05$ level.

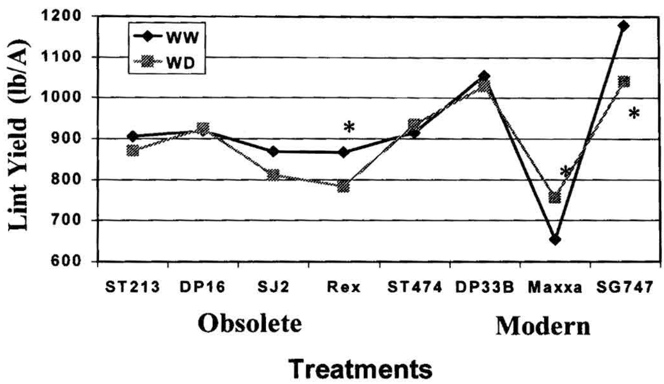


Fig. 1. Lint yields of four modern and four obsolete cultivars as affected by well-watered and water-deficit conditions. There was a significant cultivar x water interaction at the P<0.05 level.

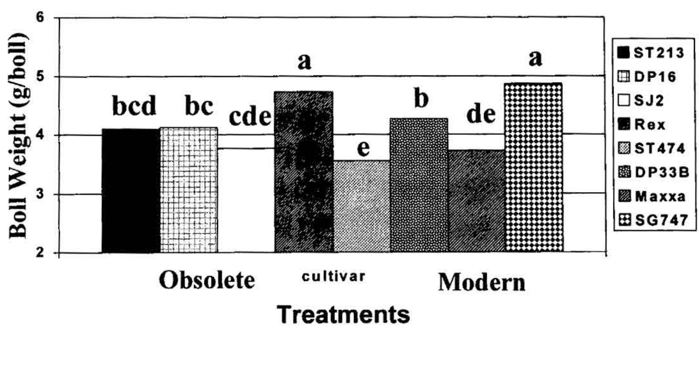


Fig. 2. Average boll weight of lower six-week-old bolls for four modern and four obsolete cultivars averaged over well-watered and water-deficit conditions. Bars followed by the same letter are not significantly different at P<0.05.

FIELD EVALUATION OF PLANT GROWTH REGULATORS

Derrick M. Oosterhuis, Dennis L. Coker, and Robert S. Brown[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) is a perennial with an indeterminate growth habit and is very responsive to changes in the environment. This has led to the need to manipulate plant growth, while maximizing yield, using plant growth regulators (PGRs). In the past two decades many new plant growth regulator (PGR) compounds have been developed and tested on field-grown crops. The objective of this study was to evaluate the effect of foliar application of the plant growth regulator ATONIK on the growth and yield of field-grown cotton.

BACKGROUND INFORMATION

Field evaluation of available PGRs has been routinely conducted at the University of Arkansas for the past twenty years (e.g., Urwiler et al., 1989; Oosterhuis et al., 1996; Zhao and Oosterhuis, 2001). Research has been directed towards determining the effect of PGRs on growth and yield (Oosterhuis and Zhao, 1997, 1998), investigating the physiological effects and underlying mechanisms of PGRs (Guo et al., 1994), and studying the effects of PGRs under stress conditions, i.e. drought, flooding or shade (Zhao and Oosterhuis, 1998). These studies improve our understanding of how individual PGRs work and assist with recommendations regarding the use of PGRs in current cotton production systems in Arkansas.

RESEARCH DESCRIPTION

Two field experiments were planted into a Calloway silt loam soil at the Delta Branch Station in Clarkedale, Arkansas, on 9 May 2001. Fertilizer, weed, and insect control measures were according to Cooperative Extension Service recommendations.

---

[1] Distinguished professor, research specialist, and graduate assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

Plots consisted of four rows 15 m long with 0.9 m between rows and 3 plants per foot in-row spacing. Plots were furrow-irrigated as needed throughout the growing season.

Atonik Rate Study

Treatments consisted of an untreated control and Atonik at four rates; 2.5, 5.0, 10, and 20 oz/acre, applied at matchhead square (29 June) and one week after first flower (19 July). Foliar spray applications were made with a CO_2 backpack sprayer calibrated to deliver 10 gallons solution/acre. The adjuvant Penetrator Plus (Helena Chemicals, Memphis, TN) was used at 0.5% v/v. The experimental design was a Latin Square with five replications. The cotton cultivar Suregrow 747 was planted on 5 May 2001. Physiological measurements were also made to understand the mode of action but the results will not be reported here. Petiole nutrients were recorded at 5 and 10 days after each Atonik application time. At maturity, boll weight and boll number were recorded by hand picking a one-meter length of row in the center two rows of each plot. Fiber quality was also determined from the hand-picked seedcotton samples, and final yield was determined by mechanically harvesting the center two rows of each plot.

Mepiquat Chloride and Atonik Combination

Treatments consisted of (1) an untreated control, (2) mepiquat chloride applied at matchhead square (MHS) at 8 oz/acre and at first flower at 16 oz/acre, (3) mepiquat chloride at MHS (8 oz/acre) plus Atonik at 5 oz/acre, and (4) mepiquat chloride at MHS (8 oz/acre) plus Atonik at 10 oz/acre. The experimental design was a randomized complete block with five replications. The cultivar used was DPL 33B. At harvest (3 October), yield and components of yield were recorded.

RESULTS

Lint Yield

In the Atonik Rate Study there were no significant differences (P=0.05) between treatments for yield or components of yield (Table 1) although there was a *trend* for Atonik to increase yields (i.e., 4.3% compared to the control). There was also no real difference in fiber quality between treatments (Table 2). Furthermore, petiole nutrient status was not different between treatments (Table 3) at first flower plus 10 days. There was no significant difference in lint yield between treatments in the Mepiquat Chloride plus Atonik trial (Table 4), although again, there was a slight trend (P=0.07) for Atonik to increase yields (i.e., by 6.3%).

PRACTICAL APPLICATION

The primary objective of this study was to evaluate Atonik under field conditions for effect on growth and yield. In the two trials, Atonik did not significantly increase yields. However, the 2001 growing season was favorable for cotton and in general, spray applications of PGRs (and foliar fertilizers, see Coker et al., 2002) did not have a statistically significant affect on yield in our studies. Generally, over the past ten years, our studies have shown a large year-to-year variability in growth and yield response, with most PGRs performing inconsistently and showing little or no significant increase in yield.

ACKNOWLEDGMENTS

The authors thank Larry Fowler, Director of the Delta Branch Experiment Station, for his help with this study.

LITERATURE CITED

Guo, C., D.M. Oosterhuis, and D. Zhao. 1994. Enhancing mineral nutrient uptake of cotton plants with plant growth regulators. *In:* W.E. Sabbe (ed.). 1993 Arkansas Soil Fertility Studies. University of Arkansas Agricultural Experiment Station Research Series 436:83-87.

Oosterhuis, D.M., and D. Zhao. 1998. Growth, yield and physiological responses of field-grown cotton to plant growth regulators. *In:* D.M. Oosterhuis (ed.). Proc. 1998 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 188:137-139.

Oosterhuis, D.M., J.N. Egilla, and A. Steger. 1996. Field evaluation of plant growth regulators in 1995. *In:* D.M. Oosterhuis (ed.). Proc. 1996 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 178:124-126.

Urwiler, M.J., C.A. Stutte, and T.H. Clark. 1988. Field evaluation of bioregulants on agronomic crops in Arkansas. University of Arkansas Agricultural Experiment Station Research Series 371.

Zhao, D., and D.M. Oosterhuis. 1997. Physiological response of growth chamber-grown plants to the plant growth regulator PGR-IV under water deficit stress. J. Environ. Exp. Bot. 38:7-14.

Zhao, D., and D.M. Oosterhuis. 1998. Physiological and yield responses of shaded cotton plants to application of the plant growth regulator PGR-IV. J. Plant Growth Regul. 17:47-52.

Zhao, D., and D.M. Oosterhuis. 2001. Comparison of cotton yield responses to Mepiquat chloride Plus and Mepiquat chloride. J. Plant Growth Regulation 19:415-422.

Table 1. Yield component response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar Atonik foliar-applied at matchhead square (MS) and one week after first flower (FF1), Clarkedale, 2001.

Treatment	Components of yield			
	Open bolls	Boll weight	Turnout	Lint
	(# m^{-2})	(g $boll^{-1}$)	(%)	(lb $acre^{-1}$)
Control	100.4 a[z]	3.74 a	36.8 a	1139 a
Atonik - 2.5 oz/A @ MS and FF1	100.0 a	3.92 a	37.8 a	1227 a
Atonik – 5 oz/A @ MS and FF1	94.4 a	3.71 a	37.1 a	1188 a
Atonik – 10 oz/A @ MS and FF1	96.8 a	3.90 a	37.9 a	1221 a
Atonik - 20 oz/A @ MS and FF1	97.0 a	3.98 a	37.8 a	1180 a

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

Table 2. Fiber quality (HVI) response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar Atonik foliar-applied at matchhead square (MS) and one week after first flower (FF1), Clarkedale, 2001.

Treatment	Fiber quality				
	Micronaire	Strength	Length	Uniformity	Elongation
		(g tex^{-1})	(in)	--------------(%)-----------	
Control	3.7 a[z]	30.2 a	1.14 a	83.8 a	7.2 a
Atonik - 2.5 oz/A @ MS and FF1	3.7 ab	31.1 a	1.15 a	83.4 a	7.1 a
Atonik – 5 oz/A @ MS and FF1	3.5 ab	31.1 a	1.15 a	83.6 a	7.1 a
Atonik – 10 oz/A @ MS and FF1	3.7 ab	30.1 a	1.13 a	83.0 a	7.0 a
Atonik - 20 oz/A @ MS and FF1	3.4 b	30.2 a	1.15 a	83.1 a	7.1 a

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

Table 3. Petiole nutrient concentrations of field-grown cotton cultivar SG 747 sampled at first flower plus 10 days (FF+10), Clarkedale, Arkansas, 2001.

Treatment	Petiole nutrient concentration (FF+10 days)			
	NO_3-N	P	K	S
	(μg g^{-1})[z]	(μg g^{-1})	(mg g^{-1})[y]	(μg g^{-1})
Control	4854 a[x]	3702 a	52.4 a	1454 a
Atonik - 2.5 oz/A @ MS and FF1	3886 a	3588 a	51.0 a	1218 b
Atonik - 5 oz/A @ MS and FF1	4682 a	3543 a	52.6 a	1387 ab
Atonik - 10 oz/A @ MS and FF1	3888 a	3533 a	53.6 a	1415 a
Atonik - 20 oz/A @ MS and FF1	4192 a	3520 a	51.4 a	1404 a

[z] Original lab value given as "ppm".
[y] Original lab value given as "%".
[x] Numbers followed by the same letter within a column are not significantly (P=0.05) different.

Table 4. Cotton lint yields for Mepiquat chloride and Mepiquat chloride + Atonik treatments at Clarkedale, Arkansas, 2001.

Treatment	Lint yield
	(lb/acre)
Control	1075 a[z]
Mepiquat chloride 8oz/A (MHS) + Mepiquat chloride 16oz/A (Flower)[y]	1102 a
Mepiquat chloride 8ox/A + Atonik 5 oz/A[x]	1143 a[w]
Mepiquat chloride 8oz/A + Atonik 10 oz/A[x]	1142 a[w]

[z] Means followed by the same letter within a column are not significantly different (P=0.05).
[y] Mepiquat chloride was sprayed at 8 oz/acre at matchhead square and 16 oz/acre at early flower.
[x] Treatment combinations were applied at both MHS and early flower intervals.
[w] Mepiquat chloride plus Atonik treatment combinations were significant at the P=0.07 probability level.

EFFECT OF APPLICATION TIMING OF MESSENGER™ ON THE PHYSIOLOGY AND YIELD OF FIELD-GROWN COTTON

Cassandra R. Meek and Derrick M. Oosterhuis[1]

RESEARCH PROBLEM

Recently, concern for the protection of the environment has escalated. This has inspired agricultural researchers to develop non-toxic crop protectants, often borrowing from nature itself. One such product is Messenger™ (Eden Bioscience, Seattle, WA), which contains the protein, harpin, isolated from bacterial plant pathogens. The protein is responsible for inducing a plant's natural defense mechanism. Preliminary studies have shown that Messenger may improve yields in a variety of crops including cotton (Wright et al., 2000)

BACKGROUND INFORMATION

The active ingredient in Messenger is harpin, an extracellular protein isolated from bacterial plant pathogens. Harpin activates a plant's natural defense mechanisms by inducing systemic acquired resistance. Foliar applications of Messenger can potentially improve cotton yields by providing resistance to a broad range of diseases and pests. Messenger has shown success in a variety of crops, including tomato (*Lypersicon esculentum* L.) and wheat (*Triticum aestivum* L.) in regard to pest management and yield enhancement.

RESEARCH DESCRIPTION

This study was conducted at the University of Arkansas Agricultural Research and Extension Center in Fayetteville in 2001 to determine the effects of Messenger on the yield and physiology of field-grown cotton. Cotton (*Gossypium hirsutum* L.) cultivar, Sure-Grow 215 BR, was planted into a Captina silt loam on 25 May 2001, in a

---

[1] Graudate assistant, and distinguished professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

randomized complete block design with five replications. Pest control and fertilizer management were according to Arkansas Cooperative Extension Service cotton production recommendations. Plots consisted of 4 rows, 36 feet in length, spaced 40 inches apart. The product was mixed with deionized water and applied at a volume of 10 gallons/acre with a CO_2 backpack sprayer. No adjuvant was used. All treatments were applied at a rate of 2.25 oz./acre. Treatments consisted of 1) untreated control; 2) Messenger applied at 2nd true leaf (2L); 3) Messenger applied at pinhead square (PHS); 4) Messenger applied at first flower (FF); 5) Messenger applied at 2nd TL, PHS, and FF; 6) Messenger applied at PHS and FF.

At one and three weeks after FF, leaf material was collected in the morning for nutrient analysis. On the same day within one hour of solar noon, gas exchange rates were evaluated in select treatments with a LI-COR 6200 (LICOR Environmental Services, Lincoln, NE). Plant mapping was performed using the COTMAP system (Bourland and Watson, 1990). Yield was determined by hand-harvesting 1m of row from each of the two middle rows in all five replications. Seedcotton was weighed for yield and aliquots from each plot were sent to STARLABS (Knoxville, TN) for gin turnout and fiber quality assessment.

RESULTS

Leaf Nutrient Concentrations

Mild potassium deficiencies were observed at FF (Table 1). While foliar applications were made to correct the deficiencies, potassium concentrations were even more deficient at FF + 3 weeks (Table 2). These deficiencies did not appear to be influenced by treatment or replication. It is suggested that in 2002 we investigate the effect of potassium deficiency on Messenger response in the potassium-water stress study at Clarkedale. Zinc levels and phosphorus were lowest in untreated control plants at both sampling times. At FF+3 weeks, several nutrients were lower in untreated control plants, including nitrogen, sodium, copper, and manganese.

Gas Exchange

Significant differences were observed in gas exchange data at FF +3 weeks, but not at FF +1 week (Table 3). At FF + 3 weeks, all Messenger-treated plants had significantly higher photosynthetic rates compared to untreated control plants. Although significant differences existed in transpiration rate at FF+3 weeks, these differences were not between Messenger-treated and untreated plants. No differences were observed in intercellular CO_2 rates. At FF+3 weeks, plants receiving Messenger application at FF had significantly higher stomatal conductance compared to untreated control plants.

Yield

While no significant differences were present in yield components (Table 4), untreated control plants had the lowest adjusted seedcotton yield. Messenger-treated plants generally had higher boll number and decreased boll weights compared to untreated plants. No differences were found in gin turnout percentages.

PRACTICAL APPLICATION

Even though yields were not significantly increased by foliar application of Messenger, numerical trends suggest that Messenger could potentially enhance cotton production. No major pest problems were encountered during the season, thus limiting the evaluation of the protective benefits attributed to the harpin protein.

LITERATURE CITED

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

Wright, D.L., P.J. Wiatrak, S. Grzes, and J. Pudelko. 2000. Messenger: A systemic acquired resistance influence on cotton. pp. 617-619. *In:* P. Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conference. National Cotton Council, Memphis, Tennessee.

Table 1. Leaf nutrient concentration at one week after FF.

Treatment	N	P	K	Ca	Mg	Na	Cu	Zn	Fe	Mn
	(%)						(ppm)			
Untreated control	5.03	0.40	1.30	3.95	0.50	0.06	8	71	127	30
2TL	4.81	0.41	1.34	3.92	0.54	0.08	7	83	125	27
PHS	5.15	0.46	1.28	4.10	0.57	0.08	5	78	110	29
FF	5.02	0.41	1.15	3.89	0.50	0.08	5	77	120	30
2nd TL, PHS, & FF	5.21	0.41	1.36	3.95	0.53	0.07	5	75	121	29
PHS & FF	5.05	0.41	1.33	4.05	0.56	0.07	7	77	136	29

Table 2. Leaf nutrient concentration at three weeks after FF.

Treatment	N	P	K	Ca	Mg	Na	Cu	Zn	Fe	Mn
	(%)						(ppm)			
Untreated control	3.62	0.39	1.16	3.79	0.44	0.07	9	69	86	18
2nd TL	4.01	0.47	1.24	3.68	0.45	0.08	10	86	81	22
PHS	4.15	0.46	1.29	3.96	0.43	0.08	12	98	98	19
FF	4.04	0.44	1.09	3.79	0.47	0.09	10	74	116	18
2nd TL, PHS, & FF	4.10	0.43	1.00	3.95	0.47	0.09	10	72	84	22
PHS & FF	4.10	0.41	1.14	3.77	0.42	0.09	13	71	90	18

Table 3. Physiological data from select treatments at one and three weeks after FF and the last Messenger application.

Treatment	Net photosynthesis[z] FF+1 wk	Net photosynthesis[z] FF+3 wks	Transpiration FF+1 wk	Transpiration FF+3 wks	Intercellular CO_2 FF+1 wk	Intercellular CO_2 FF+3 wks	Stomatal conductance FF+1 wk	Stomatal conductance FF+3 wks
	------- (mol/m^2/sec) ------		------- (mol/m^2/sec) -------		----------- (ppm) -----------		-------- (cm_2/sec) ---------	
Untreated control	29.7	29.8 b	0.0260	0.0196 ab	306.5	320.2	6.9	3.4 b
FF	33.7	34.1 a	0.0258	0.0188 b	318.9	327.1	6.6	4.0 a
2L, PHS, FF	31.7	33.4 a	0.0260	0.0204 a	313.0	308.5	6.6	3.6 ab
PHS, FF	29.7	33.4 a	0.0259	0.0189 b	311.4	322.4	6.9	3.4 b
LSD (P=0.05)	NS[y] (5.3)	3.5	NS (0.001)	0.0013	NS (29.4)	NS (23.5)	NS (1.4)	0.5

[z] Values in a column with the same letters are not significantly different at the P=0.05 level.
[y] NS = not significant

Table 4. Yield and yield components at time of harvest.

Treatment	Seedcotton	Adjusted seedcotton[z]	Boll weight	Total bolls[y]	Lint
	(lb/acre)	(lb/acre)	(g/boll)	(#/acre)	(%)
Untreated control	1658	1896	5.3	165444	38.0
2L	1654	1937	4.6	191622	39.2
PHS	1674	1930	4.6	190575	37.6
FF	1771	2129	4.7	206282	37.4
2L, PHS, & FF	1711	1990	4.8	190575	38.8
PHS & FF	1686	1958	4.8	186387	38.0
LSD (P=0.05)	NS[x] (341)	NS (434)	NS (0.78)	NS (41885)	NS (2.03)

[z] Extrapolated value if all mature green bolls were open
[y] Represents open bolls *plus* mature-sized green and hardlocked bolls
[x] NS = not significant

EVALUATION OF MESSENGER® FOR ROOT-KNOT NEMATODE SUPPRESSION IN COTTON

Terry L. Kirkpatrick, Joseph J. Paling, Ronnie J. Bateman, Cassandra Meek, and Ned French[1]

RESEARCH PROBLEM

Root-knot nematodes are a significant problem for cotton producers throughout the state. Severe infestations can suppress lint yield by at least 150 lb/acre. Currently there are no root-knot- resistant cotton cultivars that are adapted for production in the mid-South, so nematode control is primarily through the application of either aldicarb (Temik) or Telone II (1,3-dichloropropene). Both of these materials are expensive and may be toxic to humans and animals. A biorational product, Messenger®, has been suggested as a means of mitigating nematode damage to cotton through a novel mode of action. These experiments were established to evaluate the potential of Messenger for root-knot suppression or control in cotton.

BACKGROUND INFORMATION

Messenger is chemically identical to a protein that is produced by the plant pathogen *Erwinia amylovora*, which causes fireblight in pears and apples. This protein, named a harpin protein, was discovered by scientists at Cornell University about ten years ago. The protein is associated with a natural defense mechanism in plants known as a hypersensitive response, where host-plant cells die rapidly in localized areas in response to challenge by an incompatible pathogen. When harpin is exogenously applied to plants, the protein activates several different natural plant genes that are involved in plant growth and pest resistance, and this is the basis for interest in its potential for enhancing plant growth and pest resistance across a number of crop species.

[1] Plant pathologist, research associate, and pest management associate, University of Arkansas Southwest Research and Extension Center, Hope; graduate assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville; and field development scientist, Eden Biosciences, Little Rock.

RESEARCH DESCRIPTION

Messenger was evaluated in 2001 for its impact on cotton growth and the root-knot nematode in two field trials in Lafayette Coounty, and in one growth-chamber trial conducted at the Southwest Research and Extension Center. Experimental design for both field trials was a randomized complete block with six replications of each treatment. Individual plot size was four rows (38-inch spacing) by 30 ft. in length. Treatments used in trial 1 are listed in Table 1 and those used in trial 2 are listed in Table 2. Both tests were planted on 15 May 2001, and a seeding rate of four seed /row foot was used. The cultivar in trial 1 was Sure Grow 215 BR and the cultivar in trial 2 was Delta Pine 451 BR. All primary tillage, fertilization, weed, and insect control were provided by the grower. Temik 15 G and DiSyston 15 G were applied in-furrow in appropriate treatments at planting. For Messenger applications, the material was mixed with distilled water immediately prior to spraying and was delivered as a foliar spray (13 gpa total volume) to the two middle rows of each plot using a CO_2-pressurized backpack sprayer with a hand-held boom and two nozzles (8002) per row. All plots were sampled for nematodes at planting, in June and July, and at harvest. Root galling severity due to the nematode was rated from six plants in each plot immediately after harvest. In addition to root-knot nematode, Texas root rot (*Phymatotrichopsis omnivora*) was also found in the test site, so the percent of plants showing symptoms of this disease was also recorded. Seedcotton was harvested from the two middle rows of each plot with a two-row plot picker, and lint was calculated at 35%.

In the growth chamber trial, Stoneville 4892 BR was planted on 7 February 2001 into pots containing 500 cm^3 of sterilized fine sandy loam soil. Pots were placed into a growth chamber, and plants were maintained at a photoperiod of 16 hours of daylight and temperatures of 30°C daytime and 27°C at night. Messenger applications were made at either the second true leaf on 9 February (early) or two weeks after the two-leaf stage on 5 March (late). Plants were inoculated with ~5,000 root-knot nematode eggs, collected from stock tomato cultures, at either the time of planting or on 15 March, after Messenger treatment. A completely randomized experimental design was used, and treatments were replicated ten times (10 pots per treatment). Treatment and nematode inoculation timings and Messenger rates are listed in Table 1. Messenger applications were made with a backpack sprayer using CO_2 as the propellant. Distilled water was used for all applications and the material was delivered in a total volume of 10 gpa.

For treatments 1, 2, 4, 5, 7, 8, 13, and 14 (Table 3), the following physiological measurements were recorded on 27 March 2001: photosynthesis ($\mu mol/m^2/sec$); leaf temperature (°C); transpiration (as $mol/m^2/sec/$); stomatal conductance ($\mu mol/cm^2/sec$); and leaf intercellular CO_2 (ppm).

The experiment was terminated on 10 April 2001. Cotton plant heights, nodes per plant, and dry plant weights were recorded. Nematodes were extracted from the total volume of soil in each pot by semi-automatic elutriation and centrifugal flotation. Intact root systems were washed free of soil and 10 egg masses were arbitrarily removed and

placed in vials to determine the fecundity of individual females. The entire root mass was extracted using NaOCl to free eggs from egg masses that were attached to the roots. NaOCl was also used in the vials to free eggs from the handpicked egg masses. Nematodes (second-stage juveniles) and eggs per root mass were counted under a stereoscopic microscope, and juvenile and egg numbers were transformed by log (x+1) for statistical analysis.

RESULTS AND DISCUSSION

Lafayette County, Messenger Trial 1

Root-knot nematodes were detected in all plots at planting, and numbers were similar among treatments (Table 4). There were no differences in nematode numbers among treatments in June, although the numbers declined following treatment 1 which had received Messenger two weeks prior to sampling. There were no differences in the number of eggs found at mid-season (July) among treatments. Nematode numbers were highest at mid-season in some treatments that received DiSyston (treatments 9 and 11) and in treatment 3 that received Temik. Both nematodes and eggs increased substantially in all plots by harvest. There were no differences among treatments in the number of nematodes that were found at harvest. Root galling was moderately severe in all treatments (Table 5). Galling was greatest after treatment 9 (DiSyston + 4 Messenger applications) and least severe after treatment 7 (Temik + 3 early Messenger applications). Texas root rot was most severe in treatment 1 (Temik + 4 Messenger applications), but this was most likely due to variability of this disease in the test site. There were no differences among treatments in lint yield. Messenger application has no significant effect for galling or yields with any treatment.

Lafayette County, Messenger Trial 2

There were no clear trends of Messenger effects on nematode population densities throughout the season (Table 6), and populations increased in all treatments. Multiple applications of Messenger resulted in slightly lower nematode numbers at harvest (October) than single applications, and nematode reproduction, as measured by the number of eggs in harvest samples, was lower where multiple applications were made. Three applications of Messenger, with the first initiated at the 3^{rd}-leaf stage, resulted in the lowest number of eggs at harvest. There were no differences among treatments in root-galling severity or the percent of plants showing Texas root rot and lint yield was not significantly affected by treatments (data not shown).

Growth Chamber Study Results

No significant differences in photosynthesis, transpiration, leaf temperature, stomatal resistance, and intercellular CO_2 was found among Messenger treatments or nematode inoculation treatments although photosynthesis and stomatal resistance were slightly lower and intercellular CO_2 was slightly higher in Messenger-treated plants (data not shown).

When nematodes were added at planting, a single application of Messenger at 2.23 oz/acre lowered nematode reproduction (Table 7). Total eggs that were extracted from the cotton roots following this treatment were lower than all other treatments. In addition, the number of eggs that were produced by individual adult females was lower, indicating that Messenger adversely affected the reproductive capability of the females. The number of juveniles that were recovered from the soil following this treatment was also numerically lower than in other treatments. Two applications of Messenger or a single early application at 4.46 oz/acre tended to follow this same trend. Juveniles, total eggs, and eggs per female were slightly, although not significantly, lower than the control. When nematode inoculation was delayed until after Messenger was applied to the plants, only the 4.46 (early) application resulted in lower numbers of juveniles than the control (Table 8). None of the treatments resulted in lower numbers of eggs or eggs per female when inoculation with nematodes was delayed.

Control plants that did not receive either Messenger or nematodes were tallest (Table 9). When nematodes were applied at planting, Messenger resulted in a numerical, although not statistically significant, increase in plant height compared with nematode-infested plants that did not receive the material. A single application of Messenger either early or late, and two applications of the material to nematode-infested plants provided a numerical increase in the number of stem nodes. There were no differences among treatments in plant weight. When nematodes were added later in the experiment, no trends in plant height, nodes, or weight were apparent (data not shown).

PRACTICAL APPLICATION

Although the novel mode of action of Messenger and its biorational nature make this material extremely interesting, significant efficacy for suppression of nematode damage will be needed before Messenger can be recommended to growers. Also, there was no significant effect on yield. The lower nematode reproduction in Messenger-treated plants in the growth chamber study is encouraging. Further study will be needed to determine if rates and timing of Messenger can be found that are efficacious in the field for root-knot management in cotton.

Table 1. Rates and timing of applications of nematicide and Messenger treatments. Gin City, AR, 2001. (Trial 1).

			Messenger application timing			
Treatment	Messenger rate	At-plant treatment	2-leaf	Pin-head	First bloom	3 wk after first bloom
	(oz/acre)	(lb/acre)				
1	2.25	Temik 3.5	X	X	X	X
2	2.25	Temik 3.5	X	X	X	
3	2.25	Temik 3.5		X	X	X
4	none	Temik 3.5				
5	2.25	Temik 7	X	X	X	X
6	2.25	Temik 7	X	X	X	
7	2.25	Temik 7		X	X	X
8	none	Temik 7				
9	2.25	DiSyst.6.5	X	X	X	X
10	2.25	DiSyst.6.5	X	X	X	
11	2.25	DiSyst.6.5		X	X	X
12	none	DiSyst.6.5				

Table 2. Rates and timing of applications of nematicide and Messenger treatments. Gin City, AR, 2001. (Trial 2).

			Messenger application timing			
Treatment	Messenger rate	At-plant treatment	2-leaf	Pin-head	First bloom	3 wk after first bloom
	(oz/acre)	(lb/acre)				
1	untreated	Disyston 5				
2	untreated	Temik 5				
3	2.25	Temik 5	X	X	X	
4	2.25	Temik 5		X	X	X
5	2.25	Temik 5		X	X	
6	2.25	Temik 5			X	X
7	2.25	Temik 5		X		
8	2.25	Temik 5			X	
9	2.25	Temik 5				X

Table 3. Timing and rate of Messenger and timing of nematode inoculation of cotton in growth chamber tests.

Timing and Messenger rate			Nematode inoculation timing		
None	2 leaf	2 leaf + 2 weeks	None	At planting	5 March
---------------- (oz/acre) ----------------					
X			X		
X				X	
X					X
	2.23		X		
	2.23			X	
	2.23				X
	2.23	2.23	X		
	2.23	2.23		X	
	2.23	2.23			X
		2.23	X		
		2.23		X	
		2.23			X
	4.46		X		
	4.46			X	
	4.46				X

Table 4. Population density of *Meloidogyne incognita* juveniles and eggs at various sampling times. Gin City, AR. 2001. (Trial 1).

Treatment	*M. incognita* juveniles				*M. incognita* eggs	
no.	May	June	July	October	July	October
	---------------------------- (#/500 cm^3 soil) ----------------------------					
1	189	38	341	1,200	1,036	1,164
2	114	265	190	1,000	1,358	1,088
3	38	76	720	1,300	370	824
4	455	341	493	1,500	1,428	1,036
5	720	303	303	1,150	600	2,161
6	455	303	114	1,300	1,302	1,652
7	379	151	152	1,400	2,212	918
8	455	190	341	1,300	609	2,006
9	493	303	720	2,250	900	1,377
10	493	76	190	1,000	321	1,324
11	76	227	758	1,450	997	1,636
12	644	152	379	1,950	646	851
LSD(0.05)	480	283	NS[z]	NS	NS	NS
CV (%)	110	121	119	81	175	78

[z] NS = not significant

Table 5. Root-galling severity, percent of plants showing Texas root rot symptoms, and cotton yield. Gin City, AR. 2001. (Trial 1).

Treatment no.	Root gall severity	Texas root rot	Lint
		(%)	(lb/acre)
1	2.6	56	864.3
2	2.3	22	898.7
3	2.5	17	873.0
4	2.4	36	930.3
5	2.9	36	900.3
6	2.3	36	862.9
7	2.0	31	909.1
8	2.5	28	846.4
9	3.1	33	838.6
10	2.9	35	831.0
11	2.6	17	942.2
12	2.5	36	828.5
LSD (0.05)	0.8	28	NS[z]
CV (%)	27	75	13

[z] NS = not significant

Table 6. Population density of root-knot nematode juveniles and eggs at various sampling times. Gin City, AR. 2001. (Trial 2).

Treatment	*M. incognita* juveniles				*M. incognita* eggs	
no.	May	June	July	October	July	October
	(#/500 cm^3 soil)					
1	265	303	265	1,350	1,267	1,273
2	114	76	114	850	421	1,555
3	189	227	341	800	976	317
4	151	265	455	950	967	800
5	303	0	341	950	609	1,759
6	76	227	606	1,000	661	411
7	227	38	379	1,350	873	1,079
8	720	76	152	1,100	1,191	1,053
9	189	76	303	750	1,903	1,064
LSD (0.05)	458	266	419	797	1,539	1,105
CV (%)	158	159	109	68	134	92

Table 7. Number of root-knot nematode juveniles per pot, eggs per plant, and eggs per adult female when nematodes were added at planting (before Messenger treatment).

Messenger timing and rate	Root-knot juveniles	Root-knot eggs	Nematode eggs
(oz/acre)	[#/pot (500 cm^3 soil)	(#/root system)	(#/adult female)
None applied (control)	2,989 a[z]	22,152 a	318 a
Early (2.23)	881 a	1,690 b	149 b
Early (2.23)+late (2.23)	1,205 a	6,988 ab	261 ab
Late (2.23)	2,975 a	18,461 a	382 a
Early (4.46)	1,668 a	4,007 ab	304 ab

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

Table 8. Number of root-knot nematode juveniles per pot, eggs per plant, and eggs per adult female when nematodes were added after Messenger treatment (March 15).

Messenger timing and rate	Root-knot juveniles	Root-knot eggs	Nematode eggs
(oz/acre)	[#/pot (500 cm^3 soil)	(#/root system)	(#/adult female)
None applied (control)	807 a[z]	15,976 a	229 a
Early (2.23)	366 a	16,919 a	204 a
Early (2.23)+late (2.23)	549 a	18,252 a	222 a
Late (2.23)	2,099 a	13,714 a	238 a
Early (4.46)	130 b	2,626 a	230 a

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

Table 9. Cotton plant height, weight, and number of stem nodes when nematodes were added at planting (before Messenger treatment).

Messenger timing and rate	Plant height	Stem nodes	Plant top weight
(oz/acre)	(cm)	(#)	(g)
No Messenger; no nematodes (control)	35.6 a[z]	10.0 a	3.49 a
No Messenger (control)	29.5 b	8.4 b	2.37 a
Early (2.23)	31.4 ab	9.2 ab	3.02 a
Early (2.23)+late (2.23)	30.3 b	9.4 ab	2.99 a
Late (2.23)	31.6 ab	9.3 ab	2.96 a
Early (4.46)	32.3 ab	8.9 b	2.71 a

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

MORPHOMETRIC VARIATION OF RENIFORM NEMATODE GEOGRAPHIC POPULATIONS FROM COTTON-GROWING REGIONS IN THE UNITED STATES

Paula Agudelo, Robert T. Robbins, and James M. Stewart[1]

RESEARCH PROBLEM

Reniform nematode (*Rotylenchulus reniformis*, Linford & Oliveira 1940) is considered the most damaging nematode in many cotton-producing areas of the southeastern United States. The diversity of this nematode in the U.S., however, has not been studied. The objective of this research was to measure the morphometric variation among thirteen populations from different cotton-growing regions.

BACKGROUND INFORMATION

Management practices of *R. reniformis* in cotton include the use of nematicides and rotation with nonhost crops. The most effective and profitable means of control would be the use of crop resistance, but no commercial upland cotton cultivars with resistance to reniform nematode are available. For resistant cultivars to be developed, breeders need to know if differences exist among populations of nematodes for preferred host range and reproduction and other information concerning the life cycle of the nematode. Unfortunately, information on the genetic variability among nematode populations for these parameters does not exist. This study is part of a research project to characterize diversity among reniform nematode populations based on their morphometric characteristics, their reproduction on selected hosts, and on nuclear and mitochondrial molecular markers.

---

[1] Graduate assistant and professor, Plant Pathology Department, Fayetteville; and professor, Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

Thirteen geographic populations from the main cotton regions where reniform nematode has been reported were included in this study as follows: Alabama (2), Arkansas (2), Florida (1), Georgia (1), Louisiana (1), Mississippi (1), North Carolina (1), South Carolina (1), and Texas (1). In addition, Hawaii (2) was included because it is the origin of the first report of the reniform nematode (Linford and Oliveira, 1940) and represents a more tropical environment than the other locations. Specimens for measuring were extracted from soil by the centrifugal flotation technique (Jenkins, 1964) and mounted in water. The main morphological characters (body length, stylet length, vulva position, spicule length, tail length, length of hyaline portion of tail, dorsal oesophageal-gland orifice position, excretory pore position, maximum width, oesophageal length, anal width, ratios a, b, c and c') were measured on 20 immature females and 20 adult males from each population. Multivariate analysis of variance (MANOVA) was used to determine if significant differences existed among populations. The DISCRIM procedure in SAS version 8.2 was used to perform discriminant analysis. Canonical variable scores were also generated and plotted to indicate how populations differed.

RESULTS AND DISCUSSION

The MANOVA indicated that significant differences exist across populations. The first two canonical variables were generated and plotted for both the immature female and the male data. Tables 1 and 2 interpret the canonical variables in their correlation to the original morphological characters. For females, canonical variable 1 is most highly correlated with body length, vulva position, and excretory pore, while canonical variable 2 is mostly defined by stylet, dorsal oesophageal gland orifice, and oesophageal length. For males, canonical variable 1 is most highly correlated to body length, excretory pore, and anal width, while canonical variable 2 is defined by a combination of body length, spicule, tail length, oesophageal length, and maximum body width.

The plot of the means of the first two canonical variables for females (Fig. 1) illustrates how the population from Hawaii (HWP) differs from the others in terms of the first canonical axis. The populations from Pine Bluff, Arkansas (ARP) and Mississippi (MS) differ from the others in terms of the second canonical axis, and are highly similar to each other. Figure 2, a plot of the mean canonical variable scores for the male, illustrates how the Hawaiian population (HWP) also differs from the others in terms of the first axis. Additionally, the population from Limestone, Alabama (ALL) differs from the others on the second canonical axis.

There was considerable fluctuation of size and shape within all the populations. This polymorphism of reniform nematode has been documented for populations in Japan (Nakasono, 1983) and also is consistent with variation reported within populations from Florida, Louisiana, and Texas (Lehman and Inserra, 1989). Overlapping morphometric values in our results suggest a more diverse composition of the reniform

populations in Hawaii covering a wider range of body sizes than is found in the populations from the continental U.S. The notably larger body size (body length >500 m) that we observed in the Hawaiian populations has been reported only from Cape Verde Islands (Germani, 1978) and in the original description of the species based on a Hawaiian population (Linford and Oliveira, 1940). Studies on population genetics should further elucidate the composition of populations of reniform nematode present in the U.S.

PRACTICAL APPLICATIONS

The development of cotton cultivars with wide genetic resistance to reniform nematode depends upon knowledge of and availability to the range of genetic diversity present within the nematode itself. Also, the development of effective management strategies is directly related to the ecological significance of the morphological variations of *R. reniformis* and their correlation with the genetic diversity of the nematode.

LITERATURE CITED

Germani, G. 1978. Caractères morpho-biométriques de trois espècies ouest-africanes de *Rotylenchulus* Linford&Oliveira 1940 (Nematoda:Tylenchida). Revue de Nématologie 1:241-50.

Jenkins, W.R. 1964. A rapid centrifugal-flotation method for separating nematodes from soil. Plant Disease Reporter 48:692.

Lehman, P.S. and R.N. Inserra. 1989. Morphometric variation of *Rotylenchulus parvus* and *Rotylenchulus reniformis* populations in the southern United States. Soil and Crop Science Society of Florida, Proceedings 49:220-226.

Linford, M.B. and J.M. Oliveira. 1940. *Rotylenchulus reniformis*, nov.gen., n.sp., nematode parasite of roots. Proceedings of the Helminthological Society of Washington 7:35-42.

Nakasono, K. 1983. Studies on morphological and physio-ecological variation of the reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940 with an emphasis on differential geographical distribution of amphimictic and parthenogenetic populations in Japan. Bulletin of the National Institute of Agricultural Sciences, Japan 38:4-67.

Table 1. Correlations between the first two canonical variables and the original variables in immature females. The highlighted values correspond to the characters that contribute the most to distinguishing populations.

	Pooled within canonical structure	
Variable	Can1	Can2
Stylet	0.292833	**-0.426942**
Body length	**0.807854**	0.178108
Vulva	**0.747700**	0.246445
Tail length	0.319306	-0.110217
Hyaline portion	0.155569	0.142758
Dorsal oesoph. gl.	0.153402	**0.369677**
Excretory pore	**0.702242**	-0.102214
Max. width	0.480224	-0.298169
Oesophagus	0.621896	**0.473667**
Anal width	0.377200	-0.234497

Table 2. Correlations between the first two canonical variables and the original variables in adult males. The highlighted values correspond to the characters that contribute the most to distinguishing populations.

	Pooled within canonical structure	
Variable	Can1	Can2
Stylet	0.388348	0.013193
Body length	**0.586365**	**0.681958**
Spicule	0.242949	**0.393726**
Tail length	-0.066639	**0.467467**
Hyaline portion	-0.139429	0.073713
Excretory pore	**0.646651**	0.046112
Max. width	0.166736	**0.459137**
Oesophagus	0.377026	**0.404948**
Anal width	**0.591245**	-0.092283

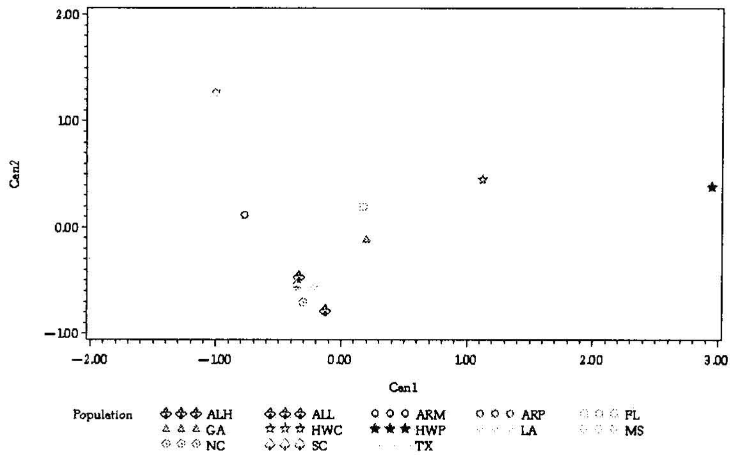


Fig. 1. Plot of the means of canonical variables for the immature female. (ALH: Alabama-Huxford, ALL: Alabama-Limestone, ARM: Arkansas-Mississippi Co., ARP: Arkansas-Pinebluff, Fl: Florida, GA: Georgia, HWC: Hawaii-Cowpea, HW: Hawaii-Pineapple, LA: Louisiana, MS: Mississippi, NC: North Carolina, SC: South Carolina, TX: Texas).

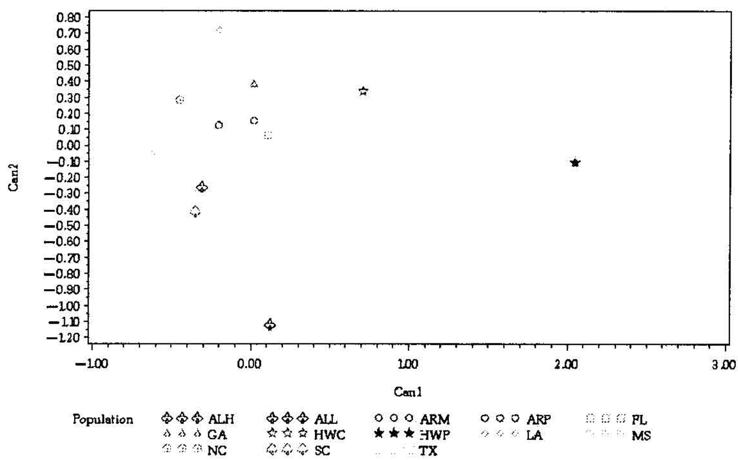


Fig. 2. Plot of the means of canonical variables for the immature female. (ALH: Alabama-Huxford, ALL: Alabama-Limestone, ARM: Arkansas-Mississippi Co., ARP: Arkansas-Pinebluff, FL: Florida, GA: Georgia, HWC: Hawaii-Cowpea, HW: Hawaii-Pineapple, LA: Louisiana, MS: Mississippi, NC: North Carolina, SC: South Carolina, TX: Texas).

HYBRIDIZATION OF EXOTIC GERMPLASM WITH UPLAND COTTON AS THE FIRST STEP IN TRANSFER OF RENIFORM NEMATODE RESISTANCE

Nilesh Dighe, James M. Stewart, and Robert T. Robbins

RESEARCH PROBLEM

Surveys of agricultural areas in several countries have shown that the reniform nematode (*Rotylenchulus reniformis*) is a widespread and persistent pest (Luc et al., 1990). In upland cotton (*Gossypium hirsutum*) the reniform nematode is now considered a serious problem throughout the southern United States (Heald and Robinson, 1990). Cotton yield loss due to this pest may range from 10% to 25% and can be as high as 50% in some situations (Davis and Cummings, 1998). Kirkpatrick and Robbins (1998) reported that, under drought stress, losses caused by reniform nematode in cotton may approach 50%. No commercial cultivar of upland cotton has been reported to have resistance to reniform nematode (Wang, 2001). The objectives of this project are to 1) make hybrids between diploid cotton germplasm resistant to reniform nematode and upland cotton as the first step in trait transfer; and 2) develop molecular markers genetically linked to nematode resistance to aid in following trait introgression.

BACKGROUND INFORMATION

Resistances to reniform nematodes have been found in A-genome diploid cottons (Carter, 1981; Yik and Birchfield, 1984; Robbins and Stewart, 1996). Robbins and Stewart (1996) identified a number of sources of resistance to the reniform nematode in the secondary germplasm pool, especially within *G. arboreum* (A2), *G. herbaceum* (A1), and *G. longicalyx* (F1), the last of which appears to be immune to this nematode. These sources of resistance are diploid species; therefore, the material must be genetically enhanced for use in tetraploid commercial upland cotton. Advances in genetic research methodology have made possible the dissection and analysis of plant genomes at the molecular level. Random Amplified Polymorphic DNA (RAPD) markers

[1] Graduate assistant and professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; and professor, Plant Pathology Department, Fayetteville.

have been used to rapidly identify loci linked to genes or genomic regions of interest by bulked segregant analysis (Michelmore et al., 1991). Techniques like bulk segregant analysis assist in finding resistant-linked molecular markers that can subsequently be used in progeny selection without specific screening for reniform nematode resistance.

RESEARCH DESCRIPTION

Several strategies are being pursued simultaneously using nematode-resistant diploid cotton. The resistant diploid cotton, including the most resistant plants from an F_2 population of reniform nematode-resistant *G. arboreum* X susceptible *G. arboreum* F_1 hybrid, are being crossed with high-performance upland cottons (which are susceptible to reniform nematodes). In our first approach the resistant diploid is crossed directly with tetraploid upland cotton. The resulting hybrid is expected to be a sterile triploid and requires extensive additional manipulation before introgression into cotton can proceed. In another approach, D-genome wild species are crossed with the A-genome lines that are resistant to the reniform nematodes. A successful hybridization would result in a diploid AD hybrid that, upon having its chromosome number doubled, would be directly compatible with upland cotton. A third approach involves hybridization of a 2(ADD) hexaploid genetic stock with the resistant A-genome species. Success in this approach would yield a hybrid directly compatible with cotton without the need to double the chromosome number. Because most of these crosses will not develop on the mother plant, the pollinated ovules are placed on culture medium for *in ovulo* embryo culture to obtain hybrid embryos (Stewart and Hsu, 1978).

For identifying molecular markers (RAPDs) associated with reniform resistance, bulk segregant analysis was used. DNA was extracted from the ten most resistant and ten most susceptible plants from a segregating F2 population (100 plants) from a cross between a reniform nematode resistant Asiatic line (*G. arboreum*) and a highly susceptible line. DNAs from each group of ten plants were pooled into resistant and susceptible bulks. Random primers were used to perform polymerase chain reactions (PCR) on these two bulked DNA samples. The PCR products from each primer/sample were separated by electrophoresis and examined to detect DNA polymorphism associated with resistance.

RESULTS

Several crosses between resistant A-genome cotton and D-genome *Gossypium aridum* were attempted to create a synthetic AD hybrid. The maternal Asiatic plants have retained a few bolls that were not placed into ovule culture. These bolls have enlarged and are currently in the filling stage of development. A limited number of cross-pollinations have been made between resistant diploid Asiatic cotton and one of three other parental lines including a 2(ADD) hexaploid genetic line and two elite

upland cotton lines. Since these crosses result in empty seeds or will not develop naturally on the plant, the fertilized ovules were placed on a defined culture medium 3 days after pollination. The culture flasks subsequently proved to be contaminated by fungal spores. This approach to obtain hybrids is continuing with improved methods to control microbial contamination.

Identification of molecular markers genetically linked to reniform nematode resistance in Asiatic cotton is in progress. The DNA bulks from the resistant and susceptible plants have been screened with 100 random, 10-nucleotide base primers, thus far. Among these a few RAPD markers have been detected that appear to be associated with the bulked DNA sample from nematode resistant plants. The association of these markers with resistance will be confirmed by testing their presence or absence in individual plants from the F2 segregating population.

PRACTICAL APPLICATION

The need for genetic resistance to the reniform nematode is widely recognized. The first step in transferring resistance from exotic germplasm, such as the Asiatic cottons, into upland cotton is to obtain hybrids between these. The current test for resistance to reniform nematodes requires in excess of two months, is labor intensive, and is subject to wide variation. One or more molecular markers closely associated with resistance could be used in marker-assisted selection to greatly simplify the introgression and breeding of resistance in elite cultivars. This research is continuing.

ACKNOWLEDGMENTS

The financial support of the Delta and Pine Land Company for this research project is gratefully acknowledged.

LITERATURE CITED

Carter, W.W. 1981. Resistance and resistant reaction of *Gossypium arboreum* to the reniform nematode, *Rotylenchulus reniformis*. J. Nematol. 13:368-374.

Davis, R.F., and T.D. Cummings. 1998. Reniform nematode management in cotton with Temik® and crop rotation. (http://www.griffin.peachnet.edu/caes/cotton/rer/pg65.htm).

Heald, C.M., and A.F. Robinson. 1990. Survey of current distribution of *Rotylenchulus reniformis* in the United States. J. Nematol. 22:695-699.

Kirkpatrick, T.L., and R.T. Robbins. 1998. Nematodes of cotton in Arkansas. FSA7523-2M-4-98RV.

Luc, M., R.A. Sikora, and J. Bridge. 1990. Plant parasitic nematodes in subtropical and tropical agriculture. p. 629. CAB International, Wallingford, UK.

Michelmore, R.W., I. Paran, and R.V. Kesseli. 1991. Identification of markers linked to disease resistance genes by bulk segregant analysis: A rapid method to detect markers in specific genomic regions using segregating populations. Proc. Natl. Acad. Sci. (USA) 88:9828-9832.

Robbins, R.T., and J.McD. Stewart. 1996. Russian Society of Nematologists. Russian J. Nematol. (Nematology Symposium Abstract Index) (http://www.scri.sari.ac.uk/rjn/robbins2.htm)

Stewart, J.McD. and C.L. Hsu. 1978. Hybridization of diploid and tetraploid cottons through *in ovulo* embryo culture. J. Hered. 69:404-408.

Wang, K.-H. 2001. Departmental newsletter, University of Florida. Publication Number EENY-210.

Yik, C.-P., and W. Birchfield. 1984. Resistant germplasm in *Gossypium* species and related plants to *Rotylenchulus reniformis*. J. Nematol. 16:146-153.

FIELD TEST OF A NEW COTTON PETIOLE MONITORING TECHNIQUE

Derrick M. Oosterhuis, Dennis L. Coker, and Robert S. Brown[1]

RESEARCH PROBLEM

The conventional fourth-node petiole sampling approach has not consistently allowed clear detection of the onset of K deficiency. The work of Bednarz and Oosterhuis (1996) indicated that lower main-stem node petioles showed pending K deficiencies sooner than upper main-stem node petioles. Therefore, the objective of this study was to observe the effect of soil nutrient status/fertilizer regime and developing boll load size (reflected in lint yield) on petiole N and K status from two positions in the canopy (fourth and eighth main-stem node from the terminal).

BACKGROUND INFORMATION

In 1999, conventional and modified petiole sampling procedures were compared in field tests at ten Cotton Research Verification Trial (CRVTs) sites on farms in Arkansas. The results showed that the lower petiole (8^{th} main-stem node) did indeed show a drop in K status before the conventionally sampled 4^{th} node. However, it was still not possible to show that this was actually indicating a K deficiency or just a large drain on plant K supply due to the developing boll load. This was because all the fields used were highly fertilized for optimal yields.

Potassium (K) deficiencies in cotton are frequently observed in cotton fields during the middle to later parts of the growing season. These symptoms occur concurrently with reduced root growth and a developing boll load which serves as the dominant sink for available K (Oosterhuis, 1995). Previous research at the University of Arkansas (Bednarz and Oosterhuis, 1996; Oosterhuis and Steger, 1998; Coker and Oosterhuis, 2000) has evaluated the petiole sampling program with particular respect to plant physiological factors influencing plant response to deficiencies. Results showed that the boll load was a major driving force influencing petiole nutrient levels and that

---

[1] Distinguished professor, research specialist, and research assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville.

petioles lower in the canopy, closer to the developing boll load, may be more sensitive to plant nutrient levels. Therefore, analysis of these petioles will more clearly show the development of a pending K deficiency such that timely remedial action can be taken.

RESEARCH DESCRIPTION

Replicated field plots arranged in a split-split design with high and low soil-K, well-watered and water-deficit conditions were established at Rohwer and Clarkedale. Eight treatment combinations of well-watered (W) or dryland (D) conditions, high soil-K (H) or low soil-K (L) were arranged in a split-split plot design with five or six replications. Each plot consisted of four rows 40 feet long (50 feet at Clarkedale), spaced 38 inches apart. At Rohwer, cultivar Suregrow 125 was planted into a moderately well-drained Hebert silt loam on 5 May 2001. At Clarkedale, cultivar Suregrow 747 was planted into a well-drained Calloway silt loam on 9 May 2001. Granular KCl fertilizer was hand broadcast to designated plots at Clarkedale on 26 April and at Rohwer on 25 April 2001 according to recommendations (Sabbe, 1998). Beginning at first flower, 10 to 15 petioles from main-stem nodes 4 and 8 were sampled weekly. Upon collection, the petioles were promptly dried at 60°C, ground to pass a 2-mm screen, and submitted to the Arkansas Agricultural Diagnostic Laboratory for nutrient analysis. Final lint yield and components of yield were determined by mechanically harvesting the two center rows of each plot and by hand-picking a 1-m length of each of two yield rows and counting the number of bolls.

RESULTS AND DISCUSSION

Replicated Field Experiment at Rohwer

This study was terminated on 20 June 2001 due to a severe hail storm event that occurred on 27th of May. An insufficient plant population was obtained after the plots had been replanted on the 4th of June.

Replicated Field Experiment at Clarkedale

Rainfall amounts were greater and events more frequent throughout the boll development stage, particularly compared to the previous two seasons at Clarkedale (see page 12).

Main-stem Node Petiole NO_3-N and K

Overall at Clarkedale, petiole NO_3-N measured in nodes 4 and 8 tended to decrease with the progression of boll development (Fig. 1). Node 4 petiole NO_3-N appeared to increase sharply in each of the four primary treatments between the first and

second week after first flower (FF) followed by a continuous decline through four weeks after FF. We did not observe the same amount of fluctuation in node 8 petiole NO_3-N with the progression of sampling events. Beginning at FF, petiole NO_3-N was significantly lower ($P \leq 0.05$) in node 8 versus node 4 petioles under high soil-K, well-watered, or dryland conditions. We observed similar differences from petioles collected at the second and third week after FF under high or low soil-K, well-watered, or dryland conditions. The node 8 petiole NO_3-N levels at 2 and 3 weeks after FF were near deficient, while node 4 petiole NO_3-N levels appeared to be fully adequate according to current Extension recommendations.

Two different treatment interactions were observed for the level of petiole NO_3-N at various sampling dates (data not shown). At 2, 3, and 4 weeks following FF, we observed a significant interaction ($P \leq 0.05$) for water x main-stem node. At 1, 2, and 3 weeks following FF, there was a significant interaction ($P \leq 0.05$ and $0.05 < P \leq 0.1$) for soil-K level x main-stem node. These observations seemed to indicate that water deficits and low soil-K levels (together or separately) can increase the difference between node 4 and 8 NO_3-N levels during the peak boll development stage.

Potassium deficiency symptoms were apparent in mid- to upper-canopy leaves beginning at FF under the high and, more consistently, under the low soil-K levels. The concentration of K was significantly greater ($P \leq 0.05$) in node 4 compared to node 8 petioles under the well-watered, high, or low soil-K treatments at all four sampling stages (Fig. 2). These observations were very similar to what we found the previous season at the Rohwer and Clarkedale locations. Petiole K concentration was also significantly higher ($P \leq 0.05$) at node 4 versus node 8 at FF, and 2, 3, and 4 weeks following FF under the high or low soil-K levels and dryland conditions. We found significantly higher ($0.05 < P \leq 0.1$) petiole K concentration in node 4 compared to node 8 petioles at FF plus one week under the high or low soil-K levels and dryland conditions. According to current Extension recommendations, petiole-K concentrations were inadequate for optimal production in all of our primary treatments beginning at FF and this was indicated best by sampling node 8 as compared to node 4 petioles.

A significant ($P \leq 0.05$) water x main-stem node interaction for petiole-K concentration was observed at FF plus one week and at four weeks ($0.05 < P \leq 0.1$) following FF (data not shown). Water deficit appeared to minimize the difference in petiole-K concentration between nodes 4 and 8 at one week after FF. On the other hand, the difference in node 4 versus node 8 petiole-K concentration was increased at 4 weeks after FF by water-deficit conditions. We also observed a significant ($P \leq 0.05$) soil K x main-stem node interaction at three weeks after FF. Apparently, petiole-K concentration differences between nodes 4 and 8 were reduced considerably under low soil-K as compared to high soil-K conditions.

As found the previous season, node 4 and 8 petiole P and S concentrations showed similar patterns as those observed for nutrient-K among the four primary treatments at Clarkedale in 2001 (data not shown).

Yield Versus Main-stem Node-K

Figure 3 shows a regression of node 4 and 8 petiole-K concentration plotted against lint yield under *well-watered* conditions at 2, 3, and 4 weeks following FF. Data collected from the high and low soil-K treatments were individually plotted. There appeared to be a stronger relationship for node 8 compared to the node 4 position (for sampling) and petiole-K concentration response in relation to lint yield. A regression of petiole-K concentration at nodes 4 and 8 was plotted against lint yield under *dry-land* conditions at 2, 3, and 4 weeks following FF (Fig. 4). The regression values showed a numerically stronger relationship between lint yield and node 8 petiole-K concentration as compared to node 4 petiole-K concentration under the *dryland* conditions.

PRACTICAL APPLICATION

Our results have shown that soil and plant water, and soil-K status can interact with the availability of petiole NO_3-N and K at different main-stem nodal positions (for sampling). At Clarkedale, collection of node 8 appeared to be better than node 4 position petioles for indication of a pending N shortage under *well-watered* or *water stress* conditions and for pending P, K, and S deficiencies under *well-watered* or *dryland, high* or *low* soil-K conditions. The relationship between petiole-K concentration and lint yield appeared to be noticeably stronger at main-stem node 8 compared to node 4, especially under *well-watered* conditions. Cotton producers should take into account the plant moisture status (besides soil nutrient levels and apparent boll loads) when monitoring nutrient levels in petioles during the flowering and boll development stages. Perhaps sampling node 4 and 8 petioles would be the most accurate way to monitor and ameliorate pending NO_3-N and K deficiencies during the critical flowering and boll development stages.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Larry Fowler at the Delta Branch Station who participated in this study, and to Cotton Incorporated for financial assistance.

LITERATURE CITED

Bednarz, C.W., and D.M. Oosterhuis. 1996. Partitioning of potassium in the cotton plant during the development of a potassium deficiency. J. Plant Nutr. 19 (12):1629-1638.

Coker, D.L., and D.M. Oosterhuis, 2000. Potassium partitioning in the cotton plant as influenced by soil and foliar potassium fertilization under water deficit stress. *In*: D.M. Oosterhuis (ed.). Proceedings 2000 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 198:81-88.

Oosterhuis, D.M. 1995. Potassium nutrition of cotton with particular reference to foliar fertilization. pp. 133-146. *In*: G.A. Constable and N.W. Forrester (eds.). Proc. World Cotton Research Conference. CSIRO, Brisbane, Australia.
Oosterhuis, D., and A. Steger. 1998. Physiological research on potassium nutrition in cotton. *In:* D. M. Oosterhuis and J.M. Stewart (eds.). Proc. 1998 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 188:111-114.
Sabbe, W. 1998. Cotton. p. 40-41. *In:* S. Chapman (ed.). Soil Test Recommendation Guide. University of Arkansas Agricultural Experiment Station.

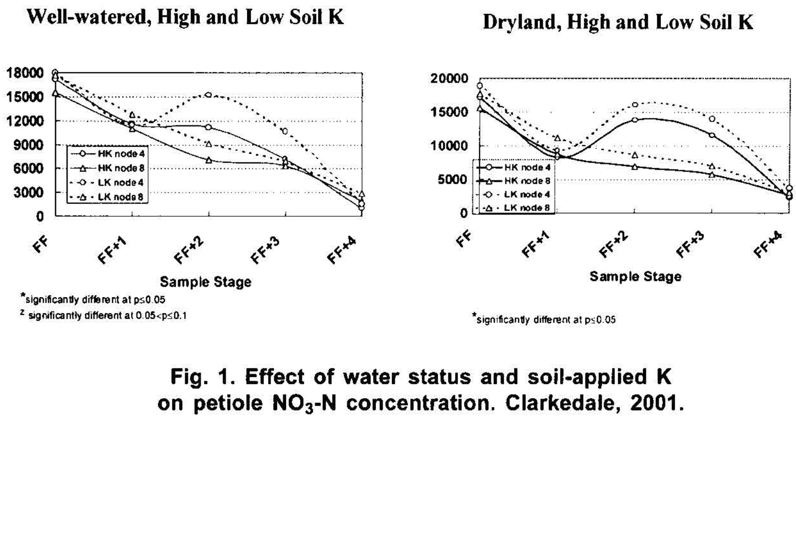


Fig. 1. Effect of water status and soil-applied K on petiole NO_3-N concentration. Clarkedale, 2001.

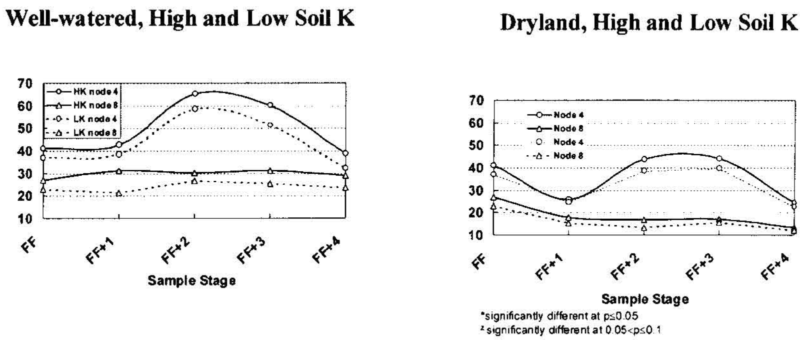
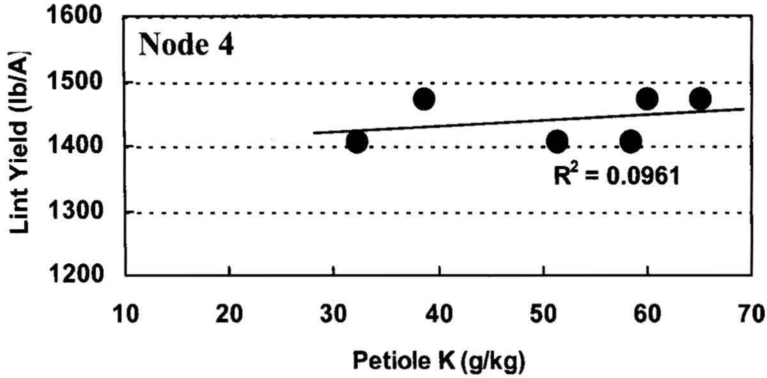


Fig. 2. Effect of water status and soil-applied K on petiole-K concentration. Clarkedale, 2001.



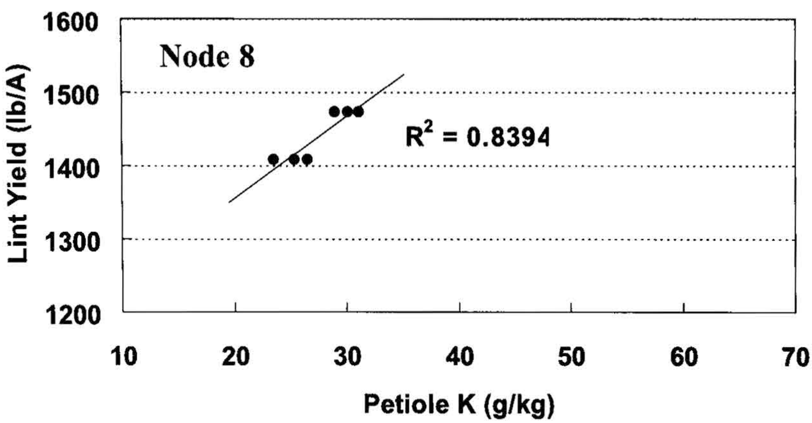
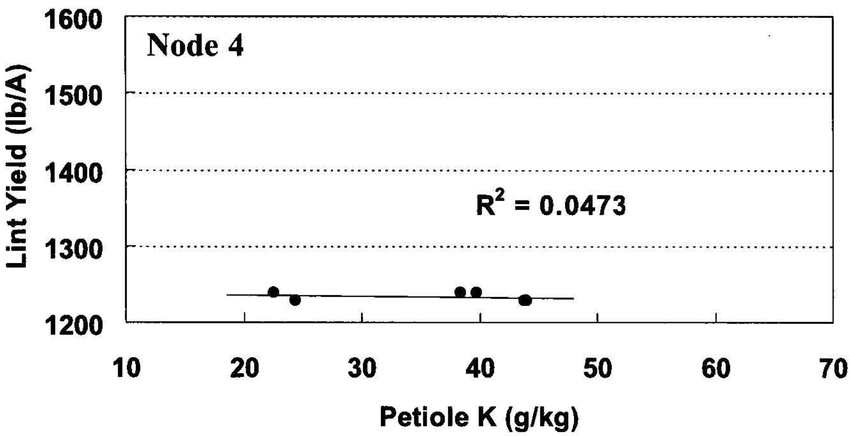


Fig. 3. Lint yield versus node 4 or 8 petiole-K concentration at 2, 3, and 4 weeks after FF with or without preplant, soil-appled K fertilizer under well-watered conditions. Clarkedale, 2001.



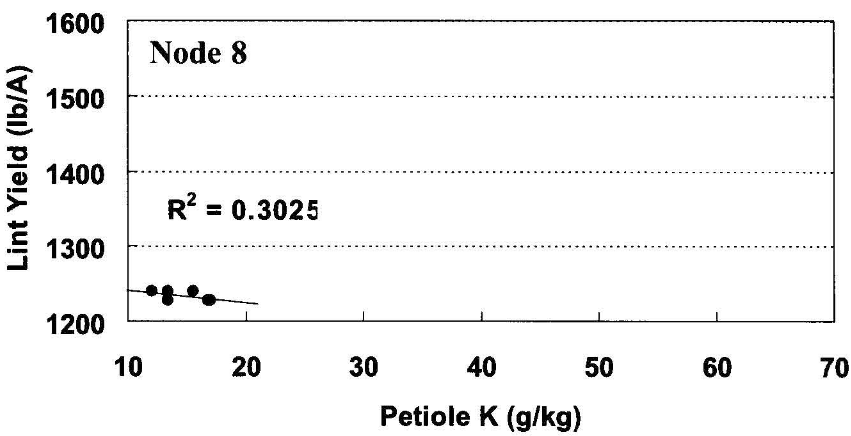


Fig. 4. Lint yield versus node 4 or 8 petiole-K concentration at 2, 3, and 4 weeks after FF with or without preplant, soil-appled K fertilizer under dryland conditions. Clarkedale, 2001.

RESPONSE OF DRYLAND AND IRRIGATED COTTON TO POTASSIUM FERTILIZATION

Dennis L. Coker, Derrick M. Oosterhuis, and Robert S. Brown[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) fiber yield and fiber elongation, strength, and micronaire depend on properly managed potassium (K) nutrition. Widespread K deficiencies have been noted in Arkansas beginning at first flower and persisting as the developing bolls exert a greater demand on plant K resources. Information is lacking about the management details of K fertilization practices for maximum production profitability when water is limiting under irrigated or rainfed systems. The principal objective for this study was to evaluate the effect of water-deficit stress and K deficiency on the final yield components of field-grown cotton.

BACKGROUND INFORMATION

Modern cotton cultivars have greater total K requirements compared to earlier cultivars and the K uptake window to satisfy those requirements has been compressed (Varco, 2000). Factors that interfere with the strong source-sink relationship of K in cotton will directly influence the efficiency of K use and the potential for high lint yields (Oosterhuis, 1995). Although K may be taken up in luxury amounts by the cotton plant prior to peak demand, K deficiencies may occur late in the growing season when the large developing boll load becomes the dominant sink for available K. Yield and economic advantages have been realized by timely foliar applications of K to supplement soil-applied K and to correct K deficiencies (Oosterhuis, 1999). Field studies conducted over a five-year period on foliar K fertilization of irrigated cotton showed that the maximum yield benefit occurred from applications made between one and three weeks after first bloom (Weir, 1999). However, the impact of mid-season water-deficit stress on the efficiency of foliar K uptake and yield response to foliar K feeding remains unclear.

---

[1] Research specialist, distinguished professor, and research assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

Cotton growth, K partitioning, and lint yield under limited water and K inputs were studied in 1999 in a field environment at Rohwer (Coker and Oosterhuis, 1999) and in 2000 at Clarkedale and Rohwer (Coker and Oosterhuis, 2000). The following information reflects the same study continued in 2001 at Clarkedale. Eight treatment combinations of well-watered (W) or dryland (D) conditions, high soil-K (H) or low soil-K (L), and with foliar-applied K (F) or without foliar-applied K (N) were arranged in a split-split plot design with five replications. Each plot consisted of four rows 50 ft long at Clarkedale, spaced 38 inches apart. At Clarkedale, cultivar Suregrow 747 was planted into a well-drained Calloway silt loam on 9 May 2001. Preplant granular KCl fertilizer was hand broadcast to designated plots at Clarkedale on 26 April according to University of Arkansas soil test recommendations (Sabbe, 1998). Foliar KNO_3 was applied for four consecutive weeks starting one week after first flower with a CO_2-pressurized backpack sprayer. Beginning at the pinhead square (PS) stage, the water status of the soil profile in each plot was monitored using screen-cage thermocouple psychrometers buried at a depth of 24-cm. The plant-water status of all treatments was monitored using end-window thermocouple psychrometers starting at PS. Growth, dry matter, photosynthesis, and K concentration in organ tissues were measured at key phenological stages [PS, first flower (FF), first flower + 3 weeks (FF+3), and first flower + 5 weeks (FF+5)]. Final lint yield and components of yield were determined by mechanically harvesting the two center rows of each plot and also by hand-picking a 1-m length of each of two yield rows and counting the number of bolls.

RESULTS

Lint yields were numerically greater from all treatment combinations compared to the previous season at Clarkedale (Table 1). Rainfall amounts were greater and more evenly dispersed throughout the boll development stage compared to the previous season at Clarkedale and likely contributed most to the observed yield differences.

Overall, the trends in cotton yield response to soil-applied or foliar-applied K in 2001 were similar to previous seasons at either Rohwer or Clarkedale. Foliar K had no significant ($p \leq 0.05$) effect on lint yield under either level of soil K and well-watered or dryland conditions in 2001 at Clarkedale. However, we did observe a 4.5% increase in lint yield, across both locations and three seasons, in response to foliar-applied K under low soil-K, but not high soil-K conditions. Lint yield tended to increase numerically in response to foliar-applied K under irrigated or dryland conditions in 2001 at Clarkedale. We did not observe any noticeable differences between irrigated or dryland lint yield response to application of foliar-K from an average across the two locations and three seasons. Lint yield response to soil-applied K tended to be slightly negative under dryland conditions but numerically positive under irrigated conditions at Clarkedale in 2001. Across both locations and three growing seasons, soil-applied K

increased the mean lint yield by 5% under well-watered conditions and decreased lint yield by 3% under dryland conditions.

PRACTICAL APPLICATION

The 2001 growing season seemed to contrast with the previous two seasons in which extreme hot and dry conditions throughout the peak boll-filling stage appeared to limit gains in lint yield from foliar-K feeding under well-watered or dryland conditions. At Rohwer, lint yield did not respond to foliar K under either water regime where upper-medium to high soil-K levels were measured at planting. At Clarkedale, soil-K resources fell into the marginal to medium range of existing recommendations and foliar-K added to lint yield under dryland or well-watered conditions, particularly in plots where no K was applied to the soil.

Thus far, our studies have shown that the preplant soil-K status should be strongly considered when making decisions about foliar-K fertilization and that response to foliar-K feeding will differ little between irrigated and dryland cotton. Lint yield significantly improved in response to added soil-K at Rohwer under well-watered conditions during the 2000 season and there was a trend for numerically higher lint yield in response to soil-applied K under irrigated conditions for other seasons and locations. However, under dryland conditions there has not been a noticeable response to soil-applied K across seasons and locations. Therefore, it appears that use of preplant soil-applied K may be particularly important for maximum economic yield from cotton under irrigated conditions, and the use of foliar-applied K (supplementing soil-K resources) can be equally beneficial to cotton lint yield under dryland or irrigated conditions in the Mississippi Delta region of Arkansas.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Soil Test and Research Board and IMC Global.

LITERATURE CITED

Coker, D.L., and D.M. Oosterhuis. 1999. Soil and foliar potassium fertilization of water deficit stressed cotton. *In:* W. Sabbe (ed.). Arkansas Soil Fertility Studies 1999. University of Arkansas Agricultural Experiment Station Research Series 471:76-80. Fayetteville.

Coker, D.L., and D.M. Oosterhuis. 2000. Yield response to soil and foliar fertilization of water-deficit-stressed cotton. *In:* R.J. Norman and S. Chapman (eds.). Arkansas Soil Fertility Studies 2000. University of Arkansas Agricultural Experiment Station Research Series 480:78-83.

Oosterhuis, D. 1995. Potassium nutrition of cotton in the USA, with particular reference to foliar fertilization. p. 133-146. Proc. of the World Cotton Res. Conf., Brisbane, Australia.
Oosterhuis, D. 1999. Foliar fertilization. p. 26-29. *In:* P. Dugger and D. Richter (eds.) Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.
Sabbe, W. 1998. Cotton. p. 40-41. *In:* S. Chapman (ed.). Soil Test Recommendation Guide. University of Arkansas Agricultural Experiment Station.
Varco, J.J. 2000. No-tillage cotton responds to potassium fertilization on high CEC soils. p. 21-23. *In:* D. Armstrong (ed.). Better Crops With Plant Food. Potash & Phosphate Institute, Norcross, GA.
Weir, B.L. 1999. Effect of foliar applied potassium on cotton in the San Joaquin Valley of California. p. 1307-1309. *In:* P. Dugger and D. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Table 1. Mean lint yield response of field-grown cultivar 'SG 125' over two seasons and cultivar 'SG 747' from one season to mid-season foliar K and preplant soil-applied K averaged over the water, soil-K, and foliar-K treatments, respectively. Rohwer, 1999 and 2000; Clarkedale, 2000 and 2001.

	Lint yield					
	Rohwer		Clarkedale			
Treatment	1999	2000	2000	2001	Mean	Change
	---------- (lb/A^{-1}) ----------					[lb/A (%)]
Avg. over water[z]						
High soil-K, no foliar-K	1135	1123	948	1359	1141	
High soil-K, with foliar-K	1133	1116	956	1342	1137	none
Low soil-K, no foliar-K	1113	1088	887	1287	1094	
Low soil-K, with foliar-K	1153	1074	985[y]	1359	1143	+49(4.5%)
Avg. over soil-K[z]						
Well-watered, no foliar-K	1366	1452	1241	1434	1373	
Well-watered, with foliar-K	1394	1448	1292	1446	1395	+22(1.6%)
Dryland, no foliar-K	882	758	593	1212	861	
Dryland, with foliar-K	894	742	649	1255	885	+24(2.8%)
Avg. over water and soil-K						
No foliar-K	1126	1105	917	1323	1118	
With foliar-K	1143	1094	970	1350	1139	+21(2%)
Avg. over foliar-K						
Dryland, high soil-K	847	724	640	1228	860	
Dryland, low soil-K	929	776	602	1239	887	-27(3%)
Well-watered, high soil-K	1421	1514	1264	1473	1418	
Well-watered, low soil-K	1338	1386[y]	1269	1407	1350	+68(5%)
Water X soil-K	–[x]	–[x]	–[w]	–[w]		
Avg. over water and foliar-K						
High soil-K	1134	1119	952	1350	1139	
Low soil-K	1133	1081	936	1323	1118	+21(1.9%)

[z] No significant ($p \leq 0.05$) interactions observed between main effects.
[y] Significant at $p \leq 0.05$ for the paired treatments.
[x] Significant at $p \leq 0.05$ for treatment interaction.
[w] No interaction.

FIELD EVALUATION OF FOLIAR-APPLIED FERTILIZERS ON THE GROWTH AND YIELD OF COTTON

Dennis L. Coker, Derrick M. Oosterhuis, and Robert S. Brown[1]

RESEARCH PROBLEM

Proper plant nutrition for optimal crop productivity in cotton requires that nutrient deficiencies be avoided. However, nutrient deficiencies often occur for a variety of reasons, most of which can be rectified by timely application of the deficient nutrient. In crop production, this usually entails a soil application prior to planting, or foliar applications may be appropriate after canopy closure or when a specific nutrient is urgently required. Foliar fertilization may lead to less concern about ground- and surface-water contamination, with nitrates in particular, and less scrutiny of the use of commercial fertilizers. This is particularly important because of current attention being focused on environmental protection. The increased use of foliar fertilizers in cotton production in the last decade is due in part to changes in production philosophy. The change to cotton cultivars which fruit in a shorter period of time and mature earlier has placed greater emphasis on understanding plant uptake and utilization of nutrients. Current crop monitoring techniques also focus attention on plant development and make it easier to combine concomitant foliar fertilization because of the large number of aerial applications that are already made for pest control. There is, however, only a limited understanding of foliar fertilizer use by the cotton plant and the effect on the physiology of the cotton plant has not been clearly documented. The objective of this study was to evaluate the benefits and effect of foliar-applied fertilizers on mid-season petiole nutrient concentrations, growth, and yield of field-grown cotton.

BACKGROUND INFORMATION

Due to its indeterminate growth and sympodial fruiting habit, cotton (*Gossypium hirsutum* L.) is very responsive to nitrogen (N) and potassium (K) fertility manage-

[1] Research specialist, distinguished professor, and research assistant, Crop, Soil, and Environmental Sciences Department, Fayetteville.

ment. Nitrogen is used in large quantities throughout the life cycle of the cotton plant (Bassett et al., 1970), but difficulties arise in maintaining an adequate balanced supply during the vegetative and reproductive stages of growth. Oosterhuis (1999) concluded that this was partly due to the decreasing ability of the root system to meet the increasing requirements of the developing boll load. Cotton-fiber yield and fiber elongation, strength, and micronaire depend on properly managed K and boron (B) nutrition. Widespread K deficiencies have been noted in Arkansas beginning at first flower and persisting as the developing bolls exert a greater demand on plant K resources. Yield and economic advantages have been realized by timely foliar applications of K to supplement soil-applied K and to correct K deficiencies (Coker and Oosterhuis, 2000; Weir, 1999).

RESEARCH DESCRIPTION

Currently available commercial fertilizers were tested in two field experiments. The studies were planted into a Calloway silt loam at the Delta Branch Station, Clarkedale, in northeast Arkansas. Treatments in both studies consisted of (1) a control with no added foliar fertilizer, and (2) individual foliar fertilizers or plant growth regulator (mepiquat chloride) applied according to recommended rates. The foliar applications were applied with a CO_2 backpack sprayer in 10 gallons of water starting at pinhead square or first flower and continued at 2, 3, and 4 weeks after first flower. The experimental design for either study was a randomized complete block with 6 replications. Cotton cv. Suregrow 747 was planted on 9 May at approximately 55,000 seed/acre. Two weeks after planting, all plots were thinned to a uniform plant population of 3 plants/row foot. The plot size consisted of four 38-inch rows, each 50 feet long. Pre- and post-plant fertilization, irrigation, weed control, and insect control were managed according to current University of Arkansas recommendations.

Petioles were sampled and analyzed at the University of Arkansas Agricultural Diagnostic Laboratory at Fayetteville to follow the effects of the foliar fertilizers. Components of yield were determined at harvest by hand-sampling the bolls from two meters of row from the two center rows of each plot. Lint yield was determined by mechanically harvesting the two center rows of each plot at 60% open boll. Fiber quality (HVI) was determined using 120 g of sub-sampled lint from the hand-harvested bolls.

RESULTS AND DISCUSSION

Lint Yield and Fiber Quality (Supplemental N, K Study)

Treatment comparisons of open boll number, boll weight, gin turnout, and lint yield did not show clear trends or significant differences (P=0.05) (Table 1). Previous studies have shown that foliar-applied N fertilizers did not consistently improve cotton

yields depending on how favorable the seasonal growing conditions were (Oosterhuis and Gomez, 2001). Other studies have shown that the beneficial effect on lint yield from mid-season foliar-applied N and K fertilizers appear to be governed primarily by soil nutrient availability (McConnell et al., 1999; Coker and Oosterhuis, 2000) and fruit load (Oosterhuis and Bondada, 2001). Fiber micronaire, strength, length, uniformity, and elongation from the untreated check were not significantly (P=0.05) different compared to the foliar-applied urea, Tricert, Agri-Gro, Helena Chemical products, or KNO_3 (Table 2).

Petiole Nutrients (Supplemental N, K Study)

We found considerable variation between replications and between treatments for the level of petiole nutrients at three (Table 3) and five weeks (Table 4) after first flower. Petiole P concentration was significantly (P=0.05) higher in response to foliar-applied Tricert-K compared to the control at three weeks after first flower. Petiole K and S concentrations tended to be numerically greater following one application of Tricert-K versus the control and were significantly higher (P=0.05) compared to the P concentration in petioles collected from the urea treated plots. At five weeks after first flower, petiole P, K, and S concentrations were higher (P=0.05) following three applications of Tricert-K compared to the untreated check. These observations gave us indication that the plant canopy was effectively absorbing the foliar-applied Tricert-K product thereby raising the potential to increase yield by maintaining an adequate supply of nutrients for the rapidly developing boll load.

Lint Yield and Fiber Quality (Supplemental Foliar Nutrient Study)

We did not observe significant differences (P=0.05) in open boll number, boll weight, gin turnout, and lint yield between the non-treated control plots and those that received mid-season applications of foliar-applied LOAD (Stoller Enterprises, Inc., 7% B and 0.004% Mo) or mepiquat chloride (Table 5). This lack of yield response to our supplemental, mid-season B product could be explained in part by the high levels of B shown in the pre-season soil test analysis, ie. 1.9 lb. B/acre. As with the 2001 supplemental N and K study, fiber micronaire, strength, length, and uniformity from the untreated check were not significantly (P=0.05) different compared to the foliar-applied LOAD products or mepiquat chloride (Table 6).

PRACTICAL APPLICATION

The primary objective of our studies was to evaluate the benefit from supplemental foliar-applied N, K, and B fertilizers on cotton lint yield and fiber quality. Overall, lint yield and fiber quality did not respond significantly to our supplemental foliar fertilizers or mepiquat chloride applied during the 2001 growing season. This was partly due

to near sufficient levels of nutrients for irrigated cotton in our soils at planting time. Rainfall amounts during the 2001 growing season were more frequent throughout the boll development stage, compared to the previous two seasons at Clarkedale (see page 12); therefore, favorable weather reduced plant stress during the boll development period. Very light mid-season insect pressure also helped to minimize plant stress as well as aiding greater square and boll retention.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of Stoller Enterprises, Inc., Tessenderlo Kerley, Inc., Agri-Gro Marketing, Inc., Helena Chemical Company, Agrotain International LLC, and SQM North America. We thank Larry Fowler for his contribution toward management inputs for this research.

LITERATURE CITED

Bassett, D.M., Anderson, W.D., and Werkhoven, C.H.E. 1970. Dry matter production and nutrient uptake in irrigated cotton (*Gossypium hirsutum* L.). Agron. J. 62:299-303.

Coker, D.L., and D.M. Oosterhuis. 2000. Yield response to soil and foliar fertilization of water-deficit-stressed cotton. *In:* R.J. Norman and S. Chapman (eds.). Arkansas Soil Fertility Studies 2000. University of Arkansas Agricultural Experiment Station Research Series 480:78-83.

McConnell, J.S., W.H. Baker, B.S. Frizzell, and C.S. Snyder. 1999. Foliar nitrogen fertilization of cotton in southeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 1999 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 193:171-177.

Oosterhuis, D.M. 1999. Foliar fertilization. pp. 26-29. *In:* P. Dugger and D. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Oosterhuis, D.M., and Bondada, B.R. 2001. Yield response of cotton to foliar nitrogen as influenced by sink strength, petiole, and soil nitrogen. J. Plant Nutr. 24:413-422.

Oosterhuis, D.M., and Gomez, S.K. 2001. Summary of CoRoN™ studies in Arkansas. pp. 537-539. *In:* P. Dugger and D. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Weir, B.L. 1999. Effect of foliar applied potassium on cotton in the San Joaquin Valley of California. pp. 1307-1309. *In:* P. Dugger and D. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Table 1. Yield component response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar fertilizer sprays applied at pinhead square (PS) or 2, 3, and 4 weeks after first flower (FF). Clarkedale, 2001.

	Components of yield			
Treatment	Open bolls	Boll weight	Gin turnout	Lint yield
	(# m^{-2})	(g $boll^{-1}$)	(%)	(lb $acre^{-1}$)
Control	88 abc[z]	4.57 ab	41.1 a	1541 a
Urea (23-0-0), 1.1 gal/A @ FF+2,3, and 4 weeks	87 abc	4.73 ab	41.1 a	1522 a
Urea (23-0-0), 1.1 gal/A + Agrotain[y] @ FF+ 2,3, and 4 weeks	90 abc	4.69 ab	40.8 ab	1516 a
Urea (23-0-0), 4.4 gal/A + Agrotain @ FF+ 2,3, and 4 weeks	85 bc	4.69 ab	41.4 a	1524 a
Trisert CB (26-0-0), 1 gal/A @ FF+2,3, and 4 weeks	95 a	4.5 b	39.8 b	1505 a
Trisert CB (26-0-0), 1gal/A + Agrotain @ FF+ 2,3, and 4 weeks	82 c	4.88 a	40.7 ab	1544 a
Agri-Gro, 32 oz/A @ FF+ 2,3, and 4 weeks	89 abc	4.51 b	40.2 ab	1531 a
HM9951, 1 qt/A @ PS	85 bc	4.85 ab	40.7 ab	1588 a
HM9849, 2 qt/A @ PS	85 bc	4.63 ab	40.7 ab	1525 a
KNO_3 , 10 lb prod./A @ FF+2,3, and 4 weeks	92 ab	4.55 ab	40.4 ab	1524 a
Trisert-K (5-0-20-13S), 2 gal/A @ FF+2,3, and 4 weeks	86 bc	4.76 ab	40.2 ab	1511 a
$LSD_{(0.05)}$	8	0.36	1.3	NS[x]

[z] Numbers followed by the same letter within a column are not significantly (P=0.05) different.
[y] 0.14% ai of urea applied.
[x] NS = non significant (P=0.05).

Table 2. Fiber quality (HVI) response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar fertilizer sprays applied at pinhead square (PS) or 2, 3, and 4 weeks after first flower (FF). Clarkedale, 2001.

	Fiber quality				
Treatment	Micronaire	Strength	Length	Uniformity	Elongation
		(g tex^{-1})	(in)	(%)	(%)
Control	4.15 ab[z]	29.4 ab	1.14 a	83.9 ab	8.48 ab
Urea (23-0-0), 1.1 gal/A @ FF+2,3, and 4 weeks	4.15 ab	28.8 abc	1.12 ab	83.6 ab	8.23 b
Urea (23-0-0), 1.1 gal/A + Agrotain[y] @ FF+ 2,3, and 4 weeks	4.22 a	29.5 a	1.13 ab	84.3 a	8.32 ab
Urea (23-0-0), 4.4 gal/A + Agrotain @ FF+ 2,3, and 4 weeks	3.88 bc	29.1 abc	1.15 a	83.9 ab	8.47 ab
Trisert CB (26-0-0), 1 gal/A @ FF+2,3, and 4 weeks	3.78 c	27.9 c	1.13 ab	83.5 ab	8.37 ab
Trisert CB (26-0-0), 1gal/A + Agrotain @ FF+2,3, and 4 weeks	4.03 abc	28.9 abc	1.14 ab	84.0 a	8.40 ab
Agri-Gro, 32 oz/A @ FF+2,3, and 4 weeks	3.85 bc	28.1 bc	1.11 b	82.9 b	8.48 ab
HM9951, 1 qt/A @ PS	4.12 ab	28.9 abc	1.14 a	83.8 ab	8.45 ab
HM9849, 2 qt/A @ PS	4.25 a	29.3 abc	1.15 a	83.9 ab	8.55 a
KNO_3, 10 lb prod./A @ FF+2,3, and 4 weeks	3.93 abc	28.7 abc	1.13 ab	83.7 ab	8.45 ab
Trisert-K (5-0-20-13S), 2 gal/A @ FF+2,3, and 4 weeks	3.78 c	28.7 abc	1.14 ab	83.9 ab	8.40 ab
$LSD_{(0.05)}$	0.33	1.4	0.03	1.05	0.31

[z] Numbers followed by the same letter within a column are not significantly (P=0.05) different.
[y] 0.14% ai of urea applied.

Table 3. Petiole nutrient concentration at first flower plus three weeks (FF3) of furrow-irrigated, field-grown cotton cv. 'SG 747' that received foliar fertilizer sprays at pinhead square (PS) or 2, 3, and 4weeks after first flower (FF). Clarkedale, 2001.

Treatment	FF3 petiole nutrient concentration			
	NO_3-N	P	K	S
	(μg g^{-2})	(μg g^{-2})	(mg g^{-1})	(μg g^{-2})
Control	9397 a[z]	4591 b	49.8 bc	1662 a
Urea (23-0-0), 1.1 gal/A @ FF2, 3, and 4 weeks	8115 ab	4698 b	47.3 c	1413 bc
Urea (23-0-0), 1.1 gal/A + Agrotain[y] @ FF2, 3, and 4 weeks	6983 ab	4892 ab	47.7 c	1394 c
Urea (23-0-0), 4.4 gal/A + Agrotain @ FF2, 3, and 4 weeks	5355 b	5151 ab	49.8 bc	1407 bc
Trisert CB (26-0-0), 1 gal/A @ FF2, 3, and 4 weeks	9241 a	4935 ab	50.7 abc	1614 ab
Trisert CB (26-0-0), 1gal/A + Agrotain @ FF2, 3, and 4 weeks	9429 a	4917 ab	54.8 ab	1639 a
Agri-Gro, 32 oz/A @ FF2, 3, and 4 weeks	8552 ab	5037 ab	54.5 ab	1630 a
HM9951, 1 qt/A @ PS	9485 a	4797 ab	55.8 ab	1705 a
HM9849, 2 qt/A @ PS	8652 ab	5017 ab	56.7 a	1585 abc
KNO_3 , 10 lb prod./A @ FF2, 3, and 4 weeks	8929 a	4714 b	50.0 abc	1550 abc
Trisert-K (5-0-20-13S), 2 gal/A @ FF2, 3, and 4 weeks	9059 a	5414 a	55.0 ab	1755 a
$LSD_{(0.05)}$	3392	619	6.7	210

[z] Numbers followed by the same letter within a column are not significantly (P=0.05) different.
[y] 0.14% ai of urea applied.

Table 4. Petiole nutrient concentration at first flower plus five weeks (FF5) of furrow-irrigated, field-grown cotton cv. 'SG 747' that received foliar fertilizer sprays at pinhead square (PS) or 2, 3, and 4 weeks after first flower (FF). Clarkedale, 2001.

Treatment	FF5 petiole nutrient concentration			
	NO_3-N	P	K	S
	(µg g^{-2})	(µg g^{-2})	(mg g^{-1})	(µg g^{-2})
Control	9397 a[z]	4591 b	49.8 bc	1662 a
Control	1256 a[z]	1520 b	22.8 de	1064 b
Urea (23-0-0), 1.1 gal/A @ FF2, 3, and 4 weeks	1154 a	1877 ab	24.8 bdce	941 b
Urea (23-0-0), 1.1 gal/A + Agrotain[y] @ FF2, 3, and 4 weeks	871 a	1974 ab	24.0 cde	933 b
Urea (23-0-0), 4.4 gal/A + Agrotain @ FF2, 3, and 4 weeks	1018 a	1777 b	28.8 ab	943 b
Trisert CB (26-0-0), 1 gal/A @ FF2, 3, and 4 weeks	1274 a	1738 b	22.3 e	960 b
Trisert CB (26-0-0), 1gal/A + Agrotain @ FF2, 3, and 4 weeks	1188 a	1854 ab	26.3 abcde	1017 b
Agri-Gro, 32 oz/A @ FF2, 3, and 4 weeks	745 a	2069 ab	24.5 bcde	980 b
HM9951, 1 qt/A @ PS	879 a	1849 ab	26.5 abcde	1038 b
HM9849, 2 qt/A @ PS	715 a	1886 ab	27.7 abc	927 b
KNO_3, 10 lb prod./A @ FF2, 3, and 4 weeks	1167 a	1918 ab	27.2 abcd	1105 b
Trisert-K (5-0-20-13S), 2 gal/A @ FF2, 3, and 4 weeks	947 a	2394 a	30.8 a	1324 a
$LSD_{(0.05)}$	740	591	4.8	180

[z] Numbers followed by the same letter within a column are not significantly (P=0.05) different.
[y] 0.14% ai of urea applied.

Table 5. Yield component response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar-applied fertilizer or mepiquat chloride (PIX) at pinhead square (PS), first flower (FF), 2 weeks following first flower (FF2), and 4 weeks following first flower (FF4). Clarkedale, 2001.

Treatment	Components of yield			
	Open bolls	Boll weight	Gin turnout	Lint yield
	(# $2m^{-1}$)	(g $boll^{-1}$)	(%)	(lb $acre^{-1}$)
Control	88 abc[z]	4.57 ab	41.1 a	1541 a
Control	174 a[z]	3.81 a	42.7 a	1103 a
LOAD, 1.0 gal/A @ FF	174 a	3.71 a	43.0 a	1063 a
LOAD, 1.0 gal/A @ FF + 0.5 gal/A @ FF2	168 a	3.70 a	42.7 a	1050 a
LOAD, 2.0 gal/A @ FF	173 a	3.89 a	42.9 a	1104 a
PIX, 8 oz/A @ FF, FF2, and FF4	175 a	3.91 a	41.8 a	1100 a

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

Table 6. Fiber quality (HVI) response of furrow-irrigated, field-grown cotton cv. 'SG 747' to foliar-applied fertilizer or mepiquat chloride (PIX) at pinhead square (PS), first flower (FF), 2 weeks following first flower (FF2), and 4 weeks following first flower (FF4). Clarkedale, 2001.

Treatment	Fiber quality			
	Length	Strength	Uniformity	Micronaire
	(in.)	(g tex^{-1})	(%)	
Control	1.11 a[z]	29.3 a	83.1 a	3.92 a
LOAD, 1.0 gal/A @ FF	1.12 a	29.4 a	83.3 a	3.80 a
LOAD, 1.0 gal/A @ FF + 0.5 gal/A @ FF2	1.10 a	28.6 a	83.0 a	4.05 a
LOAD, 2.0 gal/A @ FF	1.10 a	28.5 a	83.2 a	3.93 a
PIX, 8 oz/A @ FF, FF2, and FF4	1.12 a	29.0 a	83.5 a	3.85 a

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

EVALUATION OF SOIL AND FOLIAR FERTILIZATION STUDIES WITH BORON IN ARKANSAS

Derrick M. Oosterhuis, William C. Robertson, J. Scott McConnell, Robert S. Brown and Dennis L. Coker[1]

RESEARCH PROBLEM

Boron (B) is routinely applied in commercial cotton production as soil- and foliar-applications irrespective of soil B status. However, this recommendation was based largely on research conducted 30 years ago, and there has been no recent work to substantiate this with modern cultivars and production practices. Furthermore, there is only a limited understanding of B use by the cotton plant and the effect on the physiology of the cotton plant has not clearly been documented. The objective of this study was to evaluate yield response of soil- and foliar-applied boron at low and high soil-nitrogen levels. In a companion study the effect of boron deficiency on the growth of the cotton plant was characterized (Oosterhuis and Zhao, 2001).

BACKGROUND INFORMATION

Boron (B) is an essential element required by cotton for optimal growth and development. Current production recommendations in Arkansas call for initial preplant soil applications of 1.0 lb to 2.0 lb B/acre and two to six foliar applications of 0.1 lb to 0.2 lb B/acre. This is based largely on research conducted by Miley (1966), Baker et al. (1956), and Maple and Keogh (1963). Recently, reports of yield response to soil or foliar applications of B have been inconsistent. For example, Howard and Gwathmey (1998), Abaye et al. (1998), and Heitholt (1992) reported no yield response to B utilizing non-buffered spray solutions, whereas Howard and Gwathmey (1998) observed that buffering B spray solutions to pH 4.0 increased yields relative to buffering to pH 6.0.

---

[1] Distinguished professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; extension agronomist - cotton, University of Arkansas Cooperative Extension Service, Little Rock; associate professor, Crop, Soil, and Environmental Sciences Department, Southeast Research and Extension Center, Monticello; research assistant and research specialist, Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

The study has been conducted for three years at three locations across the state (northeast, central, and southeast Arkansas). The locations, cultivars used, planting dates, and initial soil-B level (SBL) are presented in Table 1.

Fayetteville and Rohwer locations were on University Experiment Stations and were conducted utilizing small plot studies. Nitrogen rates for the low- and high-N treatments were 50 and 100 units, respectively. County locations were conducted utilizing large plots/strips in producer fields. Treatments were replicated at all locations. Soil-applied B consisted of 1.0 lb B/acre and foliar-B applications consisted of three 0.2 lb B/acre applications 1, 2, and 4 weeks after first flower. 'Buffer Xtra Strength', manufactured by Helena Chemical, was used to buffer spray solution to a pH of 4.0 to 5.0.

RESULTS

In general, soil- or foliar-B treatments had only small non-significant affects on lint yields, and in only one out of ten field trials was a significant yield advantage recorded (Table 2). In general at Clarkedale and in Desha/Jefferson and St. Francis Counties, the B treatments had no significant effect on yield. In Rohwer, significant differences were observed in the irrigated study in 1999 with B increasing yields in the low N plots, but no significant differences were observed in the dryland study and the high N plots of the irrigated study. Buffered foliar applications did not significantly affect lint yield (data not shown, see Oosterhuis et al., 2001).

PRACTICAL APPLICATION

Results of this three-year study indicated that soil- or foliar-applied fertilizer B may not have been necessary for obtaining high cotton yields. There were no positive responses to applied soil-B or foliar-B in the high N soil level in any of the locations. There was only one situation where the low N treatments responded to applied B. No positive responses were observed to buffered spray solutions of B at either of the two locations. These results should be interpreted in relation to initial soil B status. This study indicates that the application of additional B as a routine procedure may not be necessary.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the Arkansas Soil Test Research Program.

LITERATURE CITED

Abaye, A.O., M.M. Alley, and C.W. Adcock. 1998. Influence of nitrogen and boron interactions on the production of cotton. p. 676. *In:* P.Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Baker, J.D., H.G. Gauch, and W.M. Dugger. 1956. Effects of boron on the water relations of higher plants. Plant Physiol. 31:89-94.

Heitholt, J.J. 1992. Effect of boron on cotton boll retention when applied to soil or foliage. p. 1088. *In:* P.Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Howard, D.D., and C.O. Gwathmey. 1998. Evaluation of buffered foliar applied boron and potassium for no-tillage cotton. p. 654. *In:* P.Dugger and D.A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Maples, R., and J.L. Keogh. 1963. Effects of boron deficiency on cotton. Arkansas Farm Research. 12(4):5.

Miley, W.N. 1996. Relationship of boron to nutrient element uptake and yield of cotton on selected soils in Arkansas. PhD Dissertation, Louisiana State University.

Oosterhuis, D.M., W.C. Robertson, J.S. McConnell, and D. Zhao. 2001. Characterization of boron use by cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2000 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 198:72-76.

Oosterhuis, D.M., and D. Zhao. 2001. Effect of boron deficiency on the growth and carbohydrate metabolism of cotton. pp. 166-167. *In:* W.J. Horst et al. (eds.). Plant Nutrition – Food Security and Sustainability of Agroecosystems. Kluwer Academic Publishers, Dordrecht, Netherlands.

Table 1. The locations, cultivars used, planting dates (PD), and initial soil B level (SBL).

	1999			2000			2001		
Location	Cultivar	PD	SBL	Cultivar	PD	SBL	Cultivar	PD	SBL
Fayetteville	SG 125	June 4	0.5 lb	SG 747	May 12	0.5 lb	----	----	----
Desha Co.	ST BXN47	May 14	----	----	----	----	----	----	----
St. Francis Co.	PM 1560BG	May 11	----	PM 1218BG/RR	May 21	0.6 lb	----	----	----
Rohwer	ST 474	May 14	0.1 lb	----	----	----	----	----	----
Jefferson Co.	----	----	----	DP 451B/RR	May 9	1.6 lb	DP 451B/RR	May 11	3.2
Clarkedale	----	----	----	----	----	----	SG 747	May 8	1.9

Table 2. Effect of soil- and foliar-B application on cotton yields for test locations in Arkansas in 1999 and 2000.

	Fayetteville irrigated		Clarkedale	Desha Co. irrigated	Jefferson Co. irrigated[z]		St. Francis Co. irrigated		Rohwer irrigated		Rohwer dryland	
Treatment	1999	2000	2001	1999	2000	2001	1999	2000	1999	2000	1999	2000
	[lint yield (lb/acre)]											
High N-control	1173	1348	965	1187	1063	1003	986	—[y]	1432	—[x]	883	---
High N-soil B	1149	1462	921	1196	1041	909	955	1291	1466	---	942	---
High N-foliar B	1181	1302	911	1209	1041	953	944	1250	1420	---	945	---
Low N-control	1236	1296	998	---	---	---	---	---	721	---	896	---
Low N-soil B	1072	1352	961	---	---	---	---	---	1024	---	963	---
Low N-foliar B	1044	1392	902	---	---	---	---	---	1037	---	929	---
LSD(0.05)	NS[w]	NS	NS	NS	NS	NS	NS	NS	184	---	NS	---

[z] Field oversprayed with 1 lb B/acre three weeks after the first flower.
[y] Treatment not included.
[x] Hail destroyed the study.
[w] NS = Non significant (P= 0.05)

VARIETAL RESPONSES OF COTTON TO NITROGEN FERTILIZATION[1]

J. Scott McConnell, William H. Baker, and Robert C. Kirst, Jr.[2]

RESEARCH PROBLEM

Growth and yield response of cotton (*Gossypium hirsutum* L.) varieties to nitrogen (N) fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985). New varieties, both genetically engineered and traditional, are continually introduced into Mississippi Delta production systems. Advantages of these new varieties include enhanced pest resistance, superior lint quality, faster maturity, and other new characteristics. The objective of this study was to determine the responses of new varieties to N fertilization.

BACKGROUND INFORMATION

Development and release of new cotton cultivars have increased the diversity of cotton in the Delta. Varieties now available for use in the Delta may possess genetically engineered traits for pest resistance as well as superior yield, rapid maturity, and improved fiber properties. The genetic variability of currently available varieties indicates that crop growing practices, such as fertilization, might differ to achieve optimal yields. Optimizing N fertilization for individual cotton varieties is a possible way of tailoring production practices to achieve optimal economic returns.

RESEARCH DESCRIPTION

Evaluation of responses of cotton varieties to N fertilization began at the Southeast Branch Experiment Station in 1989 (McConnell et al., 1993). The varieties tested

[1] This manuscript was reprinted from: N.A. Slaton (ed.). *Wayne E. Sabbe Arkansas Soil Fertility Studies 2001*. University of Arkansas Agricultural Experiment Station Research Series 490:22-23.

[2] Associate professor, Crop, Soil, and Environmental Sciences Department, Southeast Research and Extension Center, Monticello; associate professor, Arkansas State University, Jonesboro; and research specialist, Southeast Research and Extension Center, Monticello.

change as new varieties are introduced into the Delta region. Four years of data, 1997 through 2000, are available from the current test. Varieties under evaluation from 1997 to 1999 were Deltapine 20, Deltapine 5415, Stoneville 474, and Nucot 32B. Deltapine 20 was replaced with Deltapine 747, a rapid-maturing variety, for the 2000 growing season. Fertilizer treatments ranged from 0 to 150 lb urea-N/acre in 50 lb N/acre increments. The N fertilizer treatments were split applied. These tests were furrow-irrigated.

The measurements taken on the cotton varieties included seedcotton yield, lint fraction, plant height, and plant population. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was a randomized complete block. Differences among treatments were identified by least significant differences (LSD) calculated at the α=0.05 level of probability.

RESULTS

The N fertilizer rate that tended to produce near optimal seedcotton yields for all four varieties and over all years was 100 lb N/acre (Table 1). The N fertilization rate necessary to produce maximal yield was 100 lb N/acre for Deltapine 20 and Stoneville 474. Although a trend of higher yield was observed with greater N rates, the differences were not significant (P=0.05) from the 100-lb N/acre treatment. In 1998, Stoneville 474 yields declined when N was increased from 100 to 150 lb N/acre. Yield trends with Deltapine 5415 and Nucot 32B differed slightly from the two faster-maturing varieties. A trend of increasing yield with more N was observed for Deltapine 5415 and Nucot 32B but the differences were not always significantly greater than the 100-lb N/acre treatment.

PRACTICAL APPLICATION

The results from this test are preliminary, and final conclusions should not be drawn from these data. The yield response of all cultivars seemed to maximize near 100 lb N/acre. Generally, yields did not increase significantly with N rates above 100 lb N/acre.

LITERATURE CITED

Maples, R. and M. Frizzell. 1985. Effects of varying rates of nitrogen on three cotton cultivars. University of Arkansas, Agricultural Experiment Station Bulletin 882, Fayetteville.

McConnell, J.S., W.H. Baker, D.M. Miller, B.S. Frizzell, and J.J. Varvil. 1993. Nitrogen fertilization of cotton cultivars of differing maturity. Agron. J. 85:1151-1156.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

Table 1. Lint yields of four cotton varieties – Deltapine 20 (DP20), Stoneville 474 (ST474), Deltapine 5415 (DP5415), and Nucot 32B (NU32B) – grown with 0, 50, 100, and 150 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, during 1998 and 1999. Deltapine 747 (DP 747), Stoneville 474 (ST 474), Deltapine 5415 (DP 5415), and Nucot 32B (NU32B) were used in 2000.

	Varieties			
N-Rate	DP 20	ST 474	DP 5415	NU 32B
lb N/acre	---------- lb lint/acre ----------			
1998				
0	687	691	548	615
50	992	1,130	1,049	1,084
100	1,097	1,321	1,241	1,216
150	1,218	1,247	1,159	1,217
$LSD_{(0.05)}$=104				
1999				
0	726	686	609	614
50	1,021	1,022	1,000	1,026
100	1,145	1,255	1,156	1,246
150	1,207	1,393	1,213	1,298
$LSD_{(0.05)}$=118				

	Varieties			
N-Rate	DP 747	ST 474	DP 5415	NU 32B
lb N/acre	---------- (lb seedcotton/acre) ----------			
2000				
0	1,822	1,304	1,284	1,496
50	2,709	2,528	2,473	2,775
100	3,107	3,419	3,044	3,120
150	3,227	3,469	3,259	3,390
$LSD_{(0.05)}$=165				

[z] Lint yield may be estimated by dividing the seedcotton yield by 3.

LONG-TERM IRRIGATION METHODS AND NITROGEN FERTILIZATION RATES IN COTTON PRODUCTION: THE LAST FIVE YEARS[1]

J.S. McConnell and R.C. Kirst, Jr.[2]

RESEARCH PROBLEM

Nitrogen (N) management and irrigation management are two very important aspects of successful cotton (*Gossypium hirsutum* L.) production. The interactions of N fertilizer and irrigation are not well documented under the humid production conditions of southeast Arkansas (McConnell et al., 1988). The objectives of these studies were to evaluate the growth, development, and yield of intensively-managed cotton grown on soils previously treated with different rates of soil-applied N fertilizer that resulted in different levels of residual soil N under several irrigation methods.

BACKGROUND INFORMATION

Over- and under-fertilization may result in delayed maturity and reduced yield, respectively (Maples and Keogh, 1971). Adequate soil moisture is also necessary for cotton to achieve optimal yields. If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn et al., 1981).

RESEARCH DESCRIPTION

Studies were conducted at the Southeast Branch Experiment Station on an Hebert silt loam soil. Five irrigation methods were used from 1988 to 1993, but only three have been used since 1993 (Table 1). Six different total N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested with different application timings used for the higher (90 to

---

[1] This manuscript was reprinted from: N.A. Slaton (ed.). *Wayne E. Sabbe Arkansas Soil Fertility Studies 2001*. University of Arkansas Agricultural Experiment Station Research Series 490:24-26.

[2] Associate professor and research specialist, Crop, Soil, and Environmental Sciences Department, Southeast Research and Extension Center, Monticello.

150 lb N/acre) N rates. Ten total-N treatments were tested within each irrigation method (Table 2). Nitrogen fertilizer was not applied to the 2000 cotton crop to examine the effects of residual soil N on cotton development. From 1996 to 2000 the experimental design was a split block with irrigation methods as the main blocks. Each treatment was replicated five times.

RESULTS

The method of irrigation that maximized cotton lint yield varied among years. Therefore, the method of irrigation appeared to be less important than irrigation usage (Table 3). Generally, lint yield increased with increasing N rate (Table 2). The N treatments that usually resulted in the greatest lint yields were applications of 60 to 150 lb N/acre, depending upon the irrigation treatment and year. Exceptions were found for the 150-lb N/acre treatment (75 lb N/acre PP and 75 lb N/acre FS), which was found to decrease lint yield in some irrigation blocks. The yields of the High Frequency Irrigation block were significantly influenced by verticillium wilt during some years. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N rate.

In 2000, cotton response to the residual N seemed to mirror the N-fertilizer rates applied in previous years. Presumably, as the residual N is consumed by subsequent crops, residual soil N will have less impact on cotton development and yield.

PRACTICAL APPLICATIONS

Irrigated cotton was generally found to be higher yielding than cotton grown under dryland conditions unless verticillium wilt affected the crop. Fertilizer N requirements of cotton for maximal yield tended to be greater under irrigated production than under dryland production. Fertilizer N requirements of cotton for maximal yield tended to be greater for furrow-irrigated cotton than for center-pivot irrigated cotton. Residual soil N was sufficient the first year to maintain cotton yields when previous years of N-fertilization were above 60 to 120 lb N/acre.

LITERATURE CITED

Guinn, G., J.R. Mauney, and K.E. Fry. 1981. Irrigation scheduling effects on growth, bloom rates, boll abscission and yield of cotton. Agron. J. 73:529-534.

Maples, R. and J.G. Keogh. 1971. Cotton fertilization studies on loessial plains soils of eastern Arkansas. University of Arkansas, Agricultural Experiment Report Series 1943. Fayetteville.

McConnell, J.S., B.S. Frizzell, R.L. Maples, and G.A. Mitchell. 1988. Relationships of irrigation methods and nitrogen fertilization rates in cotton production. University of Arkansas, Agricultural Experiment Station Report Series 310. Fayetteville.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods.

Irrigation methods	Duration	Tensiometer threshold	Tensiometer depth	Water applied
		(cbar)	------- (inches)	------
High frequency center-pivot	Planting to PB[z]	35	6	0.75
High frequency center-pivot	PB to Aug. 15	35	6	1.00
Furrow flow	Until Aug. 15	55	12	Not precise
Dryland	Not irrigated	--	--	--

[z] PB = Peak bloom

Table 2. Cotton lint yield response to ten nitrogen (N) fertilization treatments under three irrigation methods from 1996 to 1999, and seedcotton yield response to residual soil N from previous N treatments in 2000.

N Rate					
PP[z]	FS[z]	FF[z]	HF[y]	FI[y]	DL[y]
---------	(lb/acre)	------------	----------------------	(lb/acre)	----------------------
1996					
75	75	0	1315	1630	1067
50	50	50	1411	1543	1116
30	60	60	1331	1572	1078
60	60	0	1383	1522	1035
40	40	40	1431	1576	1174
45	45	0	1382	1495	1050
30	30	30	1440	1527	1059
30	30	0	1461	1633	1059
15	15	0	1309	1167	1048
0	0	0	979	868	752
$LSD_{(0.05)}$			114	251	155
1997					
75	75	0	1491	1739	1682
50	50	50	1491	1679	1777
30	60	60	1384	1576	1867
60	60	0	1528	1547	1629
40	40	40	1491	1751	1799
45	45	0	1507	1582	1615
30	30	30	1420	1368	1754
30	30	0	1477	1457	1338
15	15	0	1157	1102	1067
0	0	0	1086	764	683
$LSD_{(0.05)}$			156	207	217

continued

Table 2. Continued.

N Rate					
PP[z]	FS[z]	FF[z]	HF[y]	FI[y]	DL[y]
--------- (lb/acre) ------------			---------------------- (lb/acre) ----------------------		
1998					
75	75	0	1230	1519	767
50	50	50	1154	1495	721
30	60	60	1096	1520	777
60	60	0	1185	1281	641
40	40	40	1237	1490	816
45	45	0	1259	1410	837
30	30	30	1413	1437	883
30	30	0	1226	1331	779
15	15	0	1195	1107	712
0	0	0	1116	817	589
$LSD_{(0.05)}$			161	220	171
1999					
75	75	0	1595	1533	656
50	50	50	1468	1431	788
30	60	60	1467	1463	706
60	60	0	1552	1405	636
40	40	40	1545	1587	783
45	45	0	1445	1454	756
30	30	30	1406	1203	740
30	30	0	1446	1280	791
15	15	0	1105	847	799
0	0	0	1057	677	605
$LSD_{(0.05)}$			169	257	NS
2000[x]					
75	75	0	2968	2161	1245
50	50	50	3034	2126	1295
30	60	60	3138	2223	1255
60	60	0	2783	1923	1186
40	40	40	2882	1999	1382
45	45	0	2753	1951	1233
30	30	30	2541	2003	1314
30	30	0	2784	1885	1182
15	15	0	2329	1665	1312
0	0	0	2643	1677	1027
$LSD_{(0.05)}$			280	203	157

[z] Pre-plant (PP), first square (FS), and first flower (FF).
[y] High frequency (HF), furrow irrigated (FI), and dryland (DL).
[x] Lint yield may be estimated by dividing the seedcotton yield by 3 (i.e., gin turnout of 33%).

Table 3. Lint yield response of cotton to four irrigation methods from 1996 to 1999, and seedcotton yield in 2000.

Method	1996	1997	1998	1999	2000
	----------------------------		(lb/acre)	----------------------------	
High frequency center-pivot	1344	1400	1211	1401	2801
Furrow-flow	1463	1458	1341	1288	1961
Dryland	1057	1521	750	728	1242
$LSD_{(0.05)}$	108	99	129	120	248

NITROGEN FERTILIZATION OF ULTRA-NARROW-ROW COTTON[1]

J.S. McConnell, R.C. Kirst, Jr., R.E. Glover, and R. Benson[2]

RESEARCH PROBLEM

Recent developments in cotton (*Gossypium hirsutum* L.) production technology in the Mississippi Delta include drill planting cotton. Ultra-narrow-row (UNR) cotton is a low-input production system designed to maximize economic returns. However, research that provides information on production parameters in UNR cotton is scant. Optimal nitrogen (N) fertilization rates in UNR cotton are unknown. The objectives of these studies were to determine how UNR cotton responds to N fertilization.

BACKGROUND INFORMATION

Technology development for UNR cotton production has increased recently. It has long been known that plants grown in very narrow rows intercept and utilize sunlight more efficiently. Potential benefits of UNR cotton production include: reduced production costs, utilization of poorer soils, decreased soil erosion, and utilization of the same equipment for cotton, soybeans, and cereal crops. Potential drawbacks of UNR cotton include: increased weed pressure in low-stand areas; different equipment requirements from conventionally row-spaced cotton (precision drill planter, finger stripper harvester); and lint quality may decline. Varietal differences, fertility requirements, effect of planting date, and other parameters for optimal growth and yield of UNR cotton are unknown.

---

[1] This manuscript was reprinted from: N.A. Slaton (ed.). *Wayne E. Sabbe Arkansas Soil Fertility Studies 2001*. University of Arkansas Agricultural Experiment Station Research Series 490:27-29.

[2] Associate professor and research specialist, Crop, Soil, and Environmental Sciences Department, Southeast Research and Extension Center, Monticello; research specialist and research associate, Northeast Research and Extension Center, Keiser.

RESEARCH DESCRIPTION

A pilot study to evaluate UNR response to N fertilization was conducted in 1997. Fertilizer treatments of 100 lb urea-N/acre, 100 lb Meister-N/acre, 50 lb urea-N/acre, and 0 lb N/acre were strip-applied with a fertilizer buggy just prior to squaring.

The test was expanded in 1998 to include N-rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre. The test design was randomized complete block with 8 replications. Nitrogen fertilizer treatments were applied as the crop reached the true two-leaf stage. The test was further expanded in 1999 to include a second study site at the Northeast Research and Extension Center (NEREC) near Keiser, Arkansas, with identical treatments.

Measurements taken on the UNR cotton included cotton lint yield, plant height, plant population, boll load, and boll weight. All data were analyzed using the Statistical Analysis System (SAS). Differences among treatments were identified using least significant differences (LSD) calculated at the α=0.05 level of probability.

RESULTS

In the 1997 pilot study, UNR cotton fertilized with either 50 or 100 lb N/acre, regardless of N source, did not differ in lint yield (Table 1). Boll loads and boll weights were not significantly different for the UNR cotton that received N fertilizer. Cotton receiving no N fertilizer produced significantly lower yield, boll load, and boll weight than cotton that received N fertilizer.

The results of the first year (1998) of the expanded study correlated well with the pilot study. The N fertilization rate necessary to produce maximal yield, boll load, and boll weight was 50 lb N/acre (Table 2). Although trends of higher numerical lint yields were observed with the greater N rates, the differences were generally not significantly different from the 50-lb N/acre treatment. Plant height increased with increasing N fertilization up to 100 lb N/acre.

Results from 1999 at SEBES indicated that severe drought conditions masked the impact of N fertilization of cotton (Table 4). Nitrogen fertilization of conventionally row-spaced cotton has been shown to be ineffective under severe water deficit (McConnell et al., 1998). The N treatments were not found to significantly affect any of the measured parameters.

Results from the NEREC were similar to the first year at SEBES. Maximal yields were achieved with only 25 lb N/acre. Plant height significantly increased in treatments up to 75 lb N/acre. No significant differences among N rates were observed in either the plant populations or boll loads at the NEREC.

PRACTICAL APPLICATION

The preliminary responses of UNR cotton to N fertilization treatments indicates that the N required for maximal yield will be less than for cotton grown in convention-

ally spaced rows. Yields were not found to increase with N rates above 50 lb N/acre. Additionally, the 50-lb N/acre treatment usually maximized both the boll load and boll weight at SEBES. The parameters measured in these studies indicated that the N fertilization management of UNR cotton may be substantially different from conventionally grown cotton.

LITERATURE CITED

McConnell J.S., W.H. Baker, and R.C. Kirst, Jr. 1998. Yield and petiole nitrate concentrations of cotton treated with soil-applied and foliar-applied nitrogen. J. Cotton Sci. 2:143-152.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

Table 1. Seedcotton yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with 0, 50, and 100 lb urea-N/acre and with 100 lb N (Meister)/acre at the Southeast Branch Experiment Station near Rohwer, AR, in 1997.

N Rate	Seedcotton yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(inches)	(plants/acre)	(boll/acre)	(g/boll)
100(M)[z]	2,938	24.9	115,360	393,675	3.36
100	,3008	31.3	140,368	392,869	3.44
50	3333	29.9	108,099	416,263	3.58
0	1529	20.4	118,587	242,820	2.87
$LSD_{(0.05)}$	1099	6.1	NS[y]	119,875	0.38

[z] Meister N.

[y] NS = not significant (P=0.05).

Table 2. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with 0, 25, 50, 75, 100, and 125 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, from 1998 to 2000.

N Rate	Seedcotton yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(inches)	(plants/acre)	(boll/acre)	(g/boll)
1998					
125	1060	27.5	153,074	349,710	3.31
100	1033	30.5	168,199	327,928	3.39
75	1034	26.3	160,334	341,844	3.30
50	899	24.4	175,460	321,273	3.12
25	745	20.4	177,275	278,921	2.93
0	468	19.9	171,225	191,796	2.84
$LSD_{(0.05)}$	153	4.2	NS	48,066	0.28
1999					
125	700	10.6	130,687	264,400	2.70
100	638	11.4	139,763	253,077	2.55
75	598	12.8	157,914	223,863	2.76
50	548	12.1	148,233	230,950	2.45
25	547	11.4	140,368	233,863	2.41
0	474	12.2	150,048	191,796	2.49
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
2000					
125	648	25.5	107,091	271,055	2.67
100	527	23.7	104,671	232,333	2.46
75	482	22.8	113,326	218,417	2.41
50	384	18.9	98,621	182,115	2.34
25	335	18.8	114,784	183,239	1.98
0	310	17.6	117,982	147,628	2.22
$LSD_{(0.05)}$	110	2.9	NS	40,124	2.94

Table 3. Lint yield, plant height, plant population, and boll load of cotton grown in ultra-narrow rows with 0, 25, 50, 75, 100, and 125 lb urea-N/acre at the Northeast Research and Extension Center near Keiser, AR, in 1999.

N Rate	Lint yield	Plant height	Plant population	Boll load
(lb N/acre)	(lb/acre)	(inches)	(plants/acre)	(boll/acre)
125	989	20.7	212488	341,499
100	1004	20.4	261816	333,910
75	958	23.7	239049	314,938
50	965	20.4	292171	417,387
25	883	17.5	250432	394,621
0	608	16.7	250432	318,732
$LSD_{(0.05)}$	267	2.7	NS	NS

SPATIAL YIELD ANALYSIS IN NORTHEAST ARKANSAS FIELDS

Sreekala G. Bajwa and Earl Vories[1]

INTRODUCTION

Precision agriculture is implemented through five major steps namely, data collection, knowledge discovery (information extraction), management decision making, variable rate application, and evaluation. Many new methods have evolved in the past decade for collecting within-field variability data from the field. Variable-rate control systems and machineries have been developed for site-specific application of agricultural inputs. Nonetheless, not much progress has been made in knowledge discovery and knowledge-based decision-making areas. One major reason for this lack of progress is that we do not know the yield functions that relate yield to all the factors that affect yield. The final yield is affected by a complex system of soil, crop, weather, and operational parameters and their interacted effects. The second major drawback is the quality of the data collected from the field. Grid sampling from every 2 to 10 acres of land does not provide a clear picture of the actual variability in a field. Therefore, it is necessary to use high-quality (high-resolution) data for research and to develop methods for knowledge discovery from the field data and guidelines to use this information for developing field management decisions. Research shows that availability of high-density and high-quality data on spatial variability of yield-limiting factors within a field is valuable, and the use of this data to manage the field site-specifically will tremendously increase the yield profitability from a field (Bullock et al., 1998).

In Arkansas, some growers have adopted some of the precision agricultural practices such as soil-grid sampling, precision land leveling, and yield monitoring. Recently, apparent electrical conductivity of soil collected using VERIS soil mapping equipment was also collected by a few growers and researchers. The VERIS data were reported as a good indicator of soil physical and chemical properties and a good estimator of yield-limiting variability factors such as soil texture, Ca, Mg, K, and CEC in

[1] Assistant professor, Department of Biological and Agricultural Engineering, Fayetteville; and associate professor, Department of Biological and Agricultural Engineering, Northeast Research and Extension Center, Keiser.

claypan, Mississippi Delta, and deep loess-hill soils (Kitchen et al., 2000). However, most of the field data collected by growers were not processed or used for making any site-specific management decisions. This study was undertaken with the general objective to gather and synthesize some of the spatial data collected by growers in northeast Arkansas. The specific objectives were to study whether VERIS data represent the spatial variability in yield and yield-limiting soil fertility factors.

RESEARCH DESCRIPTION

The experimental data included VERIS data on soil apparent electrical conductivity and soil fertility data collected on a grid basis. The data were collected from the Wildy Farms located in Mississippi County in northeast Arkansas. The farm consisted of 6405 acres of cotton. Two fields, namely Field 7 (27.4 acres) and Field 66N (70 acres), were selected for the study mainly because of the availability of past data starting from 1998. Both farms were under continuous corn irrigated by center-pivot irrigation systems. Soil fertility data were obtained from both fields by soil sampling on a 100 m grid and analyzing the soil samples in a laboratory. The apparent electrical conductivity ($EC_{a)}$ of the soil was measured using a VERIS soil mapping system that is a direct-contact soil EC_a meter. The VERIS shallow represents the EC_a for the top 33 cm of soil and VERIS deep represented the EC_a for the top 100 cm of soil. The soil electrical conductivity measurements are strongly correlated to water content (Fritz et al., 1999) and have long been used to identify contrasting soil properties in the geological and environmental fields (Lund et al., 1999). The distance between successive passes of VERIS data varied from 15 to 20 m. The yield data were collected at the end of the season with a yield monitor. The yield monitor data were calibrated to lint yield using the actual total lint yield from the field with the software program called AGRIPLAN.

Initially, the spatial distribution of yield and VERIS data was compared by matching the krigged surface generated from the respective point data. The different data sets used in this study were collected at different resolutions. The soil grid data were collected on 100 m grid. The distance between adjacent passes of VERIS data was approximately 20 m and that for yield data was approximately 10m. Therefore, the field data were processed using two different schemes, namely scheme 1and scheme 2. In scheme 1, buffer zones of 10 m radius were selected around the soil sampling point at 100 m spacing (Fig. 1). The VERIS and yield data that fell in the buffer area were averaged and aggregated with soil-test data for that point. Since the VERIS data were collected at 15 to 20 m distance between adjacent passes, a grid scheme with 15 m horizontal size and 15 to 20 m vertical size was manually laid out centering VERIS data (Fig. 2) in scheme 2. The yield data and VERIS data were averaged over this 15- to 20-m grid and aggregated with each other. The aggregated data were used to study the spatial distribution and correlation of yield with VERIS and soil fertility measures.

RESULTS AND DISCUSSION

Correlation analysis of soil fertility factors with respect to VERIS data showed strong correlation of soil fertility factors such as P, Ca, Mn, S, Mg, Zn, B, organic matter, cation exchange capacity (CEC), and pH with both VERIS shallow and deep (Table 1 and 2). Other minerals such as copper, manganese, and iron were poorly correlated to VERIS measures of soil electrical conductivity. This result showed that VERIS could be used as a measure of several of the soil fertility factors. Correlation analysis between soil fertility factors and yield did not show any consistent patterns over the three years. In different years, the yield-limiting factors appeared to change. The trends between yield and soil fertility factors also seemed to change over the years. In some years, yield may show a positive trend with respect to a particular soil factor. In some other years, it may show a negative trend. For example, organic matter revealed iron content of the soil showed a positive correlation with yield in 1999, indicating higher yields in areas of high iron content. In 1998 and 2001, iron content showed a negative correlation with yield, showing lower yields in areas with high iron content. This vacillating trend is an indication of the complexity of the combined effects of different parameters acting on crop and causing yield variations.

In both field 7 and field 66N, the spatial variation in yield (Fig. 3) did not match with the spatial variations in VERIS (Fig. 4) on visual observation. The yield pattern in field 7 showed some similarity to VERIS surface in 1998 (Fig. 3C and 4). Correlation analysis between VERIS and yield data showed contradictory results between scheme 1 and scheme 2 especially in Field 7 (Table 3). Scheme 1 showed a significant correlation in 1999 and a very strong correlation (0.63 and 0.78) in 2001 between yield and VERIS data. However, the higher resolution analysis in scheme 2 resulted in a poor correlation in 1999 and 2001 and a strong correlation in 1998. Such contradictory correlation coefficients resulting from the two schemes show the importance of data resolution in obtaining reliable results. Low-resolution of the soil data may be one reason for the wavering trend between yield and soil parameters observed in Table 1 and 2.

The results from this study show that VERIS data are a good indicator of soil fertility. However, VERIS may or may not indicate the spatial variations in yield. The critical task is to investigate why VERIS and various fertility measures did not show a consistently good correlation with yield. This may be due to the fact that some factors that were not considered in this study had influenced how different fertility measures affected yield. We need to investigate what additional soil-based or weather-based factors could have caused these variations in the yield. We also need to identify the dominating or delimiting soil factors from an array of fertility measures based on their estimated impact on yield in a given year. Such accurate analysis, as indicated by Bajwa et al. (2001), requires field data collected at relatively high resolution.

CONCLUSIONS

This study found that the VERIS data were a good indicator of soil fertility measures such as P, Ca, Mg, CEC, etc. However, various fertility measures and VERIS data did not show any consistent correlation with spatial yield. Data resolution is found to be a critical factor that influenced the accuracy and reliability of spatial analysis results.

LITERATURE CITED

Bajwa, S.G., L. Tian, D. Bullock, K. Sudduth, N. Kitchen, and H. Palm. 2001. Soil characterization in agricultural fields using hyperspectral image data. ASAE paper no. 01-1106, St. Joseph, MI: ASAE.

Bullock, D.G., D.S. Bullock, E.D. Nafziger, T.A. Peterson, P. Carter, T. Doerge, and S. Paszkiewicz. 1998. Does variable rate seeding of corn pay? Agronomy Journal 90:830.

Fritz, R.M., D.D. Malo, T.E. Schumacher, D.E. Clay, C.G. Carlson, M.M. Ellsbury, and K.J. Dalsted. 1999. Field comparison of two soil electrical conductivity measurement systems. *In:* P.C. Robert, R.H. Rust, and W.E. Larson (eds.). Proc. Fourth International Conference of Precision Agriculture, American Society of Agronomy, Madison, EWI, pp. 1211-1217.

Kitchen, N.R., K.A. Sudduth, and S.T. Drummond. 2000. Characterizing soil chemical and physical properties influencing crop yield using soil electrical conductivity. *In:* Proc. of Second International Geospatial Information in Agriculture and Forestry Conference, 10-12 January, Lake Buena Vista, Florida.

Lund, E.D., P.E. Colin, D. Christy, and P.E. Drummond. 1999. Applying soil electrical conductivity technology to precision agriculture. *In:* P.C. Robert, R.H. Rust, and W.E. Larson (eds.). Proc. Fourth International Conference of Precision Agriculture, American Society of Agronomy, Madison, EWI, pp. 1089-1100.

Table 1. Correlation analysis of soil fertility factors with respect to yield and VERIS data in Field 66N.

Soil fertility factors	VERIS-s	VERIS-d	Yield98	Yield99
Phosphorus	0.56	0.35	0.13	-0.20
Potassium	-0.10	-0.07	-0.07	-0.04
Calcium	0.71	0.51	0.30	-0.05
Magnesium	0.72	0.46	0.24	0.01
Sulfur	0.34	0.18	0.08	-0.06
Zinc	0.50	0.52	0.22	-0.31
Boron	0.76	0.50	0.16	-0.06
Organic matter	0.72	0.59	0.22	-0.10
pH	0.58	0.34	0.23	0.17
CEC	0.70	0.51	0.32	-0.12

Table 2. Correlation analysis of soil fertility factors with respect to yield and VERIS data in Field 7.

Correlation factors	VERIS-s	VERIS-d	Yield98	Yield99	Yield 01
Phosphorus	0.39	0.42	-0.45	0.25	-0.06
Potassium	-0.28	0.08	-0.32	-0.25	0.21
Calcium	0.71	0.51	-0.16	0.59	0.14
Magnesium	0.74	0.50	-0.19	0.51	0.17
Sulfur	0.67	0.43	-0.19	0.21	0.32
Zinc	0.21	0.07	-0.37	0.13	-0.16
Iron	-0.03	-0.05	-0.35	0.35	-0.48
Manganese	0.04	0.14	0.27	-0.47	0.51
Copper	0.22	0.15	-0.24	0.42	0.46
Organic matter	0.33	0.21	-0.46	0.47	0.01
pH	-0.23	-0.28	-0.20	0.35	-0.54
CEC	0.80	0.60	0.16	0.55	0.31

Table 3. Correlation between yield data and VERIS data, analyzed using two schemes.

		Scheme 1		Scheme 2	
Fields	Yield-year	VERIS shallow	VERIS deep	VERIS shallow	VERIS deep
Field 7	1998	-0.21	-0.35	-0.53	-0.50
	1999	0.47	0.44	0.10	0.05
	2001	0.63	0.78	0.17	0.25
Field 66N	1998	0.09	0.28	0.09	0.09
	1999	0.19	0.12	0.12	0.09

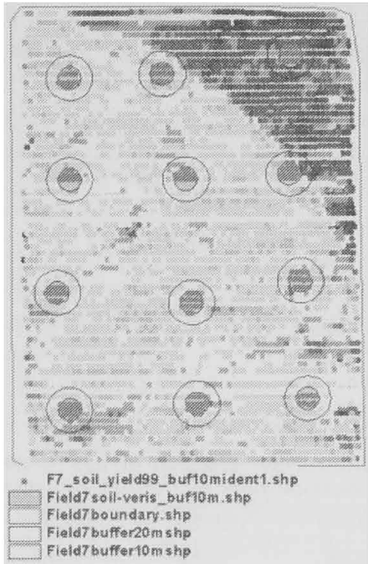


Fig. 1. Data analysis scheme 1. In this scheme, soil data collected over 100 m grid were analyzed with respect to VERIS and yield data averaged over 10 m buffer radius around the sampling location.

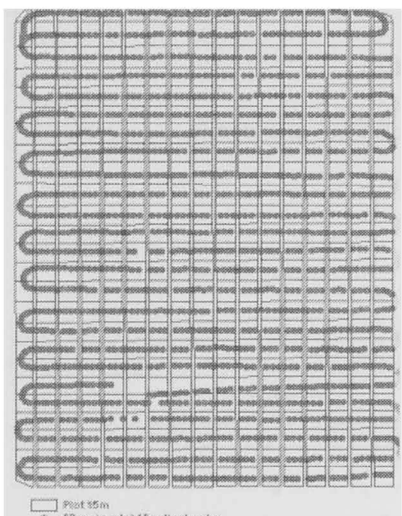
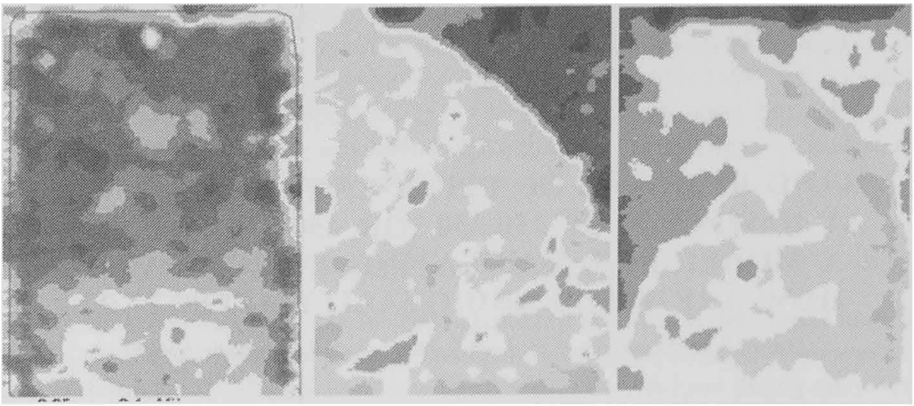
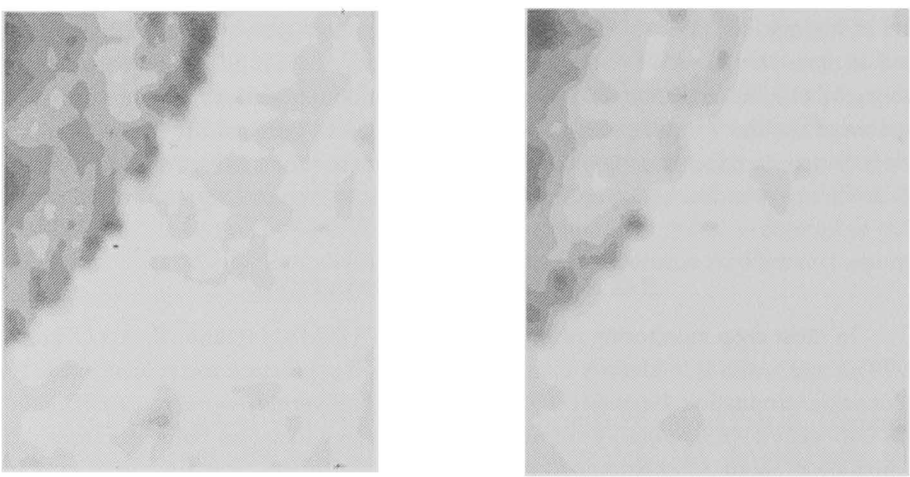


Fig. 2. Data analysis scheme 2. In this scheme, yield and VERIS data were analyzed over a 15 by 20 m grid laid around VERIS data. Both VERIS and yield data were averaged over the grid and aggregated for further analysis.



(A) (B) (C)

Fig. 3. Spatial distribution of yield from (A) 2001, (B) 1999, and (C) 1998 from Field 7. Yield surfaces were developed from yield monitor data by krigging interpolation.



(A) (B)

Fig. 4. Spatial distribution of VERIS data in Field 7. (A) VERIS deep, and (B) VERIS shallow.

HAND REMOVAL OF UPPER-CANOPY SQUARES AT NAWF=5 PLUS 250,350, OR 450 HEAT UNITS AS A MODEL FOR SIMULATING INSECT DAMAGE: HOW ARE YIELD AND QUALITY AFFECTED?

Derrick M. Oosterhuis, Robert S. Brown, and Dennis L. Coker[1]

RESEARCH PROBLEM

Cotton is a perennial with an indeterminate growth habit and will continue to produce fruit as long as the season persists. However, these late-season bolls are often small in size, low in fiber quality, costly to protect, and provide a good food source for insects. COTMAN, a crop- monitoring program for cotton, uses the concept of 350 heat units after anthesis of the last effective flower population at NAWF=5 for termination of insecticide applications. At this time in the cotton-growing season, insects can feed on fruit above NAWF=5 without decreasing yields. This allows growers to save money by eliminating costly end-of-season insecticide applications without the fear of decreased yields. This ongoing study was designed to confirm the hypothesis that insect damage to upper-canopy (above NAWF=5) squares results in improved partitioning of carbon to lower developing bolls which may increase cotton yields and quality.

BACKGROUND INFORMATION

In most crop monitoring programs, such as COTMAN (Danforth and O'Leary, 1998), a major aim is to identify the last effective boll population and project a date for insecticide termination. Bagwell (1995) showed that bollworm *Helicoverpa zea* (Boddie) and boll weevil *Anthonomus grandis* Boheman damage to cotton bolls decreases dramatically at about 350 heat units after anthesis. This finding was supported by Kim (1998), who showed increased resistance of the boll wall to penetration at NAWF=5 plus about 350 heat units. This phenomenon is made use of in COTMAN for decisions about late-season termination of insecticide applications at 350 heat units after NAWF=5. Research and field observations have indicated that terminating insecticide use at 350

[1] Distinguished professor, graduate assistant, and research specialist, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

heat units after physiological cutout (NAWF=5) results in a higher yield than when terminating earlier or later than 350 heat units, however, more research is needed to confirm this. The ongoing objective of this five-year study was to investigate the effect of different times of upper-canopy square removal after NAWF=5 on subsequent first-position boll weights at the NAWF=5 main-stem node, lint yields, and quality. A second objective was to determine the amount of carbohydrates translocated to lower bolls following upper canopy fruit removal.

RESEARCH DESCRIPTION

Field experiments were conducted at Clarkedale in northeast Arkansas from 1998 to 2001 to test the effects of late-season fruit removal. Cotton (*Gossypium hirsutum* L.) cultivar Suregrow 125 was planted into a Dubbs-Dundee silt loam during early May each year. Rows were spaced 0.9 m apart and plots were 4 rows wide with a plant density of 10 plants per meter. All plots received fertilizer and pesticide applications following the cotton production recommendations for Arkansas and were furrow irrigated as needed. The experiment was arranged in a randomized complete block design with four treatments and four to six replications depending on the year. Treatments consisted of: 1) control with no fruit removal, 2) hand removal of all fruit above NAWF=5 at NAWF=5 plus 250 H.U., 3) hand removal of all fruit above NAWF=5 at NAWF=5 plus 350 H.U., and 4) hand removal of all fruit above NAWF=5 at NAWF=5 plus 450 H.U.

Taggings of 20 to 30 white flowers per plot were made at the first-fruiting position of the main-stem node at NAWF=5. Treatments were applied when sufficient heat units were accumulated after physiological cutout for the various treatments. Three days following fruit removal, ^{14}C was used to label upper-canopy leaves for determining the amount of carbon eventually translocated to the first-position bolls at NAWF=5. At final harvest, 10 tagged bolls at NAWF=5 were collected in order to determine boll weight and fiber quality. Lint yields were determined from mechanical harvest assuming a standard gin turnout of 38%.

RESULTS

The following four-year field study has investigated the impact that fruit removal at varying heat units after physiological cutout had on yield, boll development, and quality of cotton in Arkansas. One growth chamber study in 1998 and two field studies in 2000 and 2001 were also conducted to determine the amount of carbohydrate partitioned to lower developing bolls following removal of fruit at the different treatment times. The data in this paper will summarize the yield and boll data from the 2001 season with an accompanying four-year average of yield and average boll weight. Results from the 1998 growth chamber study and the 2000 field study evaluating ^{14}C-carbohydrate partitioning will also be discussed. The carbohydrate partitioning data from the 2001 field study is currently being analyzed and will not be included in this paper.

Lint Yields

Results from 1998 to 2001 have shown no clear trends for significantly increasing lint yields from the removal of late-season fruit (Table 1). However, the data support COTMAN and show that yields are not significantly reduced and possibly even sometimes are increased from the removal of upper-canopy fruit above NAWF=5 once physiological cutout (Oosterhuis et al., 1999) occurs. In 2001, lint yields were numerically the highest in the control plots where upper-canopy fruit (above NAWF=5) was not removed (Table 1). Despite the control, the NAWF=5 plus 350 heat-unit treatment represented the highest lint yields of the three fruit-removal treatments tested. These results support concepts presented in COTMAN about insecticide termination at NAWF=5 plus 350 heat units and help support the data from the 1998 field study in which fruit removal at NAWF=5 plus 350 heat units significantly improved lint yields compared to the control. Removing ftuit earlier than 350 heat units probably increased the total amount of carbohydrate partitioned to lower bolls without the concern of insects harming the bolls at NAWF=5, which would typically not be completely developed yet.

Boll Weights at NAWF=5

In 2001, all fruit removal treatments resulted in a greater weight of first-position NAWF=5 bolls compared to the control with the NAWF=5 plus 250 heat-unit treatment resulting in a significant increase (Table 2). No significant differences occurred between treatments for increasing first-position boll weight at NAWF=5 when averaged over the four-season span from 1998 to 2001 (Table 2). However, all ftuit-removal treatments resulted in numerically higher boll weights than the control treatment where no fruit was removed. The control resulted in the lowest boll weights at NAWF=5 because, in theory, carbohydrates were used to fill the unwanted upper-canopy fruit instead of being translocated to lower harvestable bolls still developing. Boll weight at NAWF=5 was increased the most where upper-canopy fruit was removed at NAWF=5 plus 350 and 450 heat units (Table 2). These boll data support the results from past research by Kim and Oosterhuis (1998), which indicates that boll weight at NAWF=5 was increased the most when fruit was removed at 350 heat units after NAWF=5.

Fiber Quality

No significant differences were noticed with respect to improved length, strength, length uniformity, or micronaire of cotton fiber from first position NAWF=5 bolls (Table 3). Fiber length and strength are usually determined more by genetics than the environment, and therefore no drastic changes were anticipated following the late-season fruit removal treatments. However, micronaire could have been slightly impacted from the removal of upper-canopy ftuit and eventual translocation of additional sugars. The 250, 350, and 450 heat-unit treatments did show numerically higher micronaire values

than the control treatment with no fruit removal, but this difference was not significant (Table 3). Removal of upper-canopy fruit at 250 heat units past physiological cutout represented the treatment with the best fiber quality. All measured fiber parameters were numerically increased when fruit was removed at 250 heat units compared to the other treatments.

^{14}C Translocation

In 1998, a growth chamber study was conducted in Fayetteville, AR, to determine the amount of carbohydrate translocated to the developing boll load following fruit removal at different heat units after physiological cutout (NAWF=5). Those data indicated that a greater amount of ^{14}C was translocated to the boll at NAWF=5 when fruit was removed at 350 heat units (Table 4). This movement of ^{14}C helps clarify why lower bolls are larger if upper-canopy fruit is removed, which consequently was observed from this study. A similar technique was used in the field in 2000 at Clarkedale to provide additional information on carbon movement to lower bolls following fruit removal after NAWF=5. Results from this study indicated that of the CO_2 fixed by the leaf, a numerically higher percent of ^{14}C-assimilate was translocated to the boll when fruit was removed at NAWF=5 + 350 H.U. compared to the control with no fruit removal (Table 5). Of this assimilate translocated to the first position boll at NAWF=5, a significantly greater amount was stored in the boll wall for the 350 heat-unit treatment (Table 5). The 2001 study was conducted in both Fayetteville and Clarkedale to repeat the last year's measurements. Due to adverse weather in Clarkedale, no measurements were possible. However, we successfully carried out the experiment in Fayetteville and the data are currently being analyzed for carbon fixation and translocation.

PRACTICAL APPLICATION

Overall, the field experiments conducted from 1998 to 2001 have shown evidence of increased boll weight of NAWF=5 bolls, however there has not been a clear yield trend. Yield results from the 2001 field data at Clarkedale were inconsistent with the field data from the 1998 season, but supported the COTMAN concept of insecticide termination at 350 heat units after NAWF=5. However, the results still indicated that removing late-season fruit did not significantly lower lint yields and lint quality was not affected either. In 2001, boll weight of first-position bolls was increased ($P \leq 0.05$) when fruit was removed at NAWF=5 plus 250 heat units, with boll weight being numerically increased by all fruit removal treatments in comparison to the control where no fruit was removed. This can be explained by improved translocation of carbohydrates from upper-canopy leaves where fruit was removed to lower developing bolls below the area of fruit removal. Previous field and growth-chamber studies have indicated that removing fruit, especially at 350 heat units after NAWF=5 is reached, can increase

the amount of carbohydrate to lower bolls. It can be concluded that removing upper-canopy fruit increases translocation to lower developing bolls and will increase the size of the last effective boll population. However, more research is needed to determine if yields can be consistently enhanced by removal of this fruit.

LITERATURE CITED

Bagwell, R.D. 1995. Monitoring the cotton plant for insecticide effects and late-season termination. Ph.D. Dissertation, University of Arkansas, Fayetteville.

Danforth, D.M. and P.F. O'Leary (eds.). 1998. COTMAN expert system. University of Arkansas Agricultural Experiment Station, Fayetteville. Published Cotton Incorporated, Raleigh, NC. 198 pp.

Kim, M. 1998. Changes in the cotton fruit wall in relation to COTMAN insecticide termination rules. M.S. Thesis, Fayetteville, Arkansas.

Kim, M., and D. M. Oosterhuis. 1998. Effect of upper-canopy square removal before and after NAWF=5 plus 350 heat units on carbon partitioning from upper-canopy leaves to bolls lower in the canopy. *In:* D.M. Oosterhuis (ed.). Proc. 1998 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 188:174-176.

Oosterhuis, D.M., F.M. Bourland, and W.R. Robertson. 1999. Cutout defined by crop development. University of Arkansas, Cooperative Extension Service, Little Rock. Cotton Comments 98-7.

Table 1. Effect of upper-canopy fruit removal at varying heat units (H.U.) after physiological cutout on lint yields. Clarkedale, AR.

Treatment	2001 Lint yields	4-year average (98-01)
	(lb/acre)	
Control	1216 a[z]	1236 a
NAWF=5 + 250 H.U.[y]	1180 a	1273 a
NAWF=5 + 350 H.U.	1190 a	1224 a
NAWF=5 + 450 H.U.	1147 a	1245 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 2. Average weight of first-position bolls at NAWF=5 following removal of upper-canopy fruit at different heat units past physiological cutout. Clarkedale, AR.

Treatment	2001 Boll weight	4-year average (98-01)
	------- (g/boll) -------	
Control	4.63 b[z]	4.34 a
NAWF=5 + 250 H.U.[y]	5.22 a	4.50 a
NAWF=5 + 350 H.U.	5.02 ab	4.61 a
NAWF=5 + 450 H.U.	4.99 ab	4.62 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 3. Fiber quality of first-position bolls at NAWF=5 following removal of upper-canopy fruit at different heat units past physiological cutout. Clarkedale, AR. 2001.

Treatment	Length	Uniformity	Strength	Micronaire
	(inches)	(%)	(g/tex)	
Control	1.15 a[z]	83.6 ab	30.2 a	3.9 a
NAWF=5 + 250 H.U.[y]	1.17 a	84.4 a	30.5 a	4.2 a
NAWF=5 + 350 H.U.	1.16 a	83.3 b	29.9 a	4.2 a
NAWF=5 + 450 H.U.	1.15 a	83.5 ab	29.8 a	4.1 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 4. Translocation of ^{14}C from upper-canopy leaves to NAWF=5 bolls following upper-canopy fruit removal. Fayetteville, AR. 1998.

Treatment	Boll weight	^{14}C translocated
	(g)	(%)
Control	3.3[z]	1.8
NAWF=5 + 250 H.U.[y]	3.8	75.4
NAWF=5 + 350 H.U.	2.8	44.4
NAWF=5 + 450 H.U.	0.9	63.2

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

Table 5. Total $^{14}CO_2$ fixation by main-stem leaves positioned three nodes above the NAWF=5 main-stem node and percent ^{14}C-assimilate translocated into the first-position boll at NAWF=5 two days after leaf labeling. Clarkedale, AR, 2000.

Treatment	Leaf $^{14}CO_2$ fixation	^{14}C-assimilate transported to boll		
		Boll	Boll wall	Seedcotton
	(dpm mg^{-1} DW)	---------------------- (%) ----------------------		
Control	40.4 a[z]	17.2 a	1.4 b	15.8 a
NAWF=5 + 350 H.U.[y]	19.5 a	21.4 a	3.8 a	17.6 a

[z] Treatment means within a column followed by the same letter are not significantly different ($P \leq 0.05$).

[y] Represent approximate heat unit values after cutout at which squares were removed.

GLYPHOSATE AND PYRITHIOBAC (STAPLE™) COMBINATIONS IN ROUNDUP READY™ COTTON

Marilyn R. McClelland, Jim L. Barrentine, and Oscar C. Sparks[1]

RESEARCH PROBLEM

The Roundup Ready™ (glyphosate-tolerant) system has provided cotton producers versatility in their weed management programs and allows the reduction of soil-applied herbicides in some situations. However, glyphosate (Roundup UltraMax™, Touchdown I.Q.™, Glyphomax™, and others) does not have residual activity, and some weeds, such as the morningglory species, are difficult to control with glyphosate alone. Staple™ (pyrithiobac) appears to be a good choice as a tank-mix partner for glyphosate because it does have some residual activity and is active on pitted and entireleaf morningglories. The objective of this research was to determine if adding Staple to glyphosate would increase weed control in Roundup Ready cotton and provide residual control lacking in glyphosate alone.

BACKGROUND INFORMATION

Glyphosate programs without residual, soil-applied herbicides can be used effectively under some conditions, although application timing is important and some weeds are difficult to control with glyphosate alone. Studies have been conducted to determine if applying Staple with glyphosate can enhance weed control over that with glyphosate alone (Reynolds et al., 1998; Webster and Baughman, 1998). Miller et al. (1999) reported that pyrithiobac increased control of barnyardgrass, hemp sesbania, and pitted morningglory over that with low rates of glyphosate (0.188 lb active ingredient [ai]/acre). However, sicklepod, smooth pigweed, and entireleaf morningglory were controlled equally by all treatments. Entireleaf morningglory and common cocklebur were controlled as well with two applications of glyphosate at 1 lb ai/acre as with sequential treatments of Staple plus glyphosate (Webster and Baughman, 1998). A combination package of Staple and glyphosate (Staple Plus™) was introduced by

[1] Senior research associate, professor/head, and graduate assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

DuPont in 2000. Gillham et al. (2001) claimed that studies in 2000 showed that control with the mixture was better than control with either herbicide alone, although comparisons with sequential glyphosate treatments were not reported.

RESEARCH DESCRIPTION

Two sets of experiments were conducted. The first set, glyphosate formulation experiments, was conducted in 2001 at Marianna and Fayetteville, AR, to evaluate single applications of Staple with four glyphosate formulations. The experiment at Marianna was a randomized complete block (RCB) design with 13- by 40-ft plots and four replications. Cotton (Paymaster 1218BR) was planted 14 May, and postemergence (POST) treatments were applied 6 June (two-leaf cotton, ~one-leaf weeds). At Fayetteville, fourteen species – cotton (Paymaster 1218BR), soybean (Roundup Ready), barnyardgrass, seedling johnsongrass, large crabgrass, sunflower, velvetleaf, sicklepod, hemp sesbania, prickly sida, entireleaf and pitted morningglory, smooth pigweed, and Palmer amaranth – were planted in a multispecies design in 6.5-ft wide plots. Treatments were applied 6 July (one-leaf cotton stage). Glyphosate formulations were Roundup™ (no surfactant), Roundup Ultra™, and Roundup UltraMax™ at 0.75 lb ai/acre, and Touchdown™ at 0.56 lb acid equivalent/acre. Each formulation was applied alone and with Staple (0.031 lb ai/acre).

The second set of experiments, Staple Plus experiments, were conducted in 2000 and 2001 at Marianna and Fayetteville to evaluate Staple Plus (Staple + Roundup without surfactant) programs. Paymaster 1218 Roundup Ready cotton was planted in mid-May. Each experiment was an RCB design with four replications. Plots were 13 by 40 ft. at Marianna and 3 by 27 ft at Fayetteville. Treatments, rates, and timing are shown in Table 1.

Standard field-plot techniques were used. Plots were rated for weed control and cotton injury, and cotton yield was taken at Marianna in 2001. Data were analyzed by analysis of variance, and means were separated with Fisher's protected LSD at the 0.05 level of probability.

RESULTS

Formulation Experiments

Glyphosate formulations generally did not differ in activity in the formulation experiments (data not shown), and only data for Staple with Roundup Ultra and Touchdown are shown (Table 2). The benefits of adding Staple to glyphosate were evident with these single-application treatments. Control of prickly sida (*Sida spinosa*), morningglory species (*Ipomoea lacunosa* and *I. hederacea* var. *integriuscula*), pigweed species (*Amaranthus palmeri* and *A. hybridus*), and annual grasses (*Digitaria*

sanguinalis, *Eleusine indica*, and *Brachiaria platyphylla)* at 4 weeks after treatment (WAT) at Marianna was 89 to 100% with all treatments. By 13 WAT, however, control with glyphosate alone was significantly lower for all species. Control with glyphosate alone also declined at Fayetteville for most species as weed regrowth and late emergence occurred (Table 3). Because of good soil moisture and high temperatures, plant growth and herbicide activity were rapid, and control was evident even by 1 WAT. Regrowth of species was rapid as well, and weed control had declined by 4 WAT.

In the Staple Plus experiments, cotton was injured slightly by Staple applied preemergence (PRE) alone or with fluometuron (Fig. 1). Although early symptoms (3 to 7 DAT) included slight chlorosis, injury at 2 WAT manifested primarily as stunting. No visual injury was noted later in the season except at Marianna in 2000 from Staple + fluometuron PRE *fb* a full rate of Staple postemergence [12% at 6 weeks after late over-the-top (LOT) treatment]. Seedcotton yield (Marianna 2001) did not differ among treatments (data not shown).

Prickly sida control was 95% at 2 WAT with all treatments (Fig. 2). By 7 WAT, control with Roundup Ultra alone was lower than control with treatments containing pyrithiobac. The decline was due to decreased control at Marianna (72% at 7 WAT), whereas control at Fayetteville did not differ among treatments (data not shown).

Staple Plus applied alone LOT gave the poorest morningglory control initially at both Fayetteville and Marianna (Fig. 3). By 7 WAT, control had increased with single LOT applications and decreased with early over-the-top (EOT) applications. Morningglories treated at EOT apparently had sufficient regrowth to avoid complete shading from the growing cotton, whereas those treated at LOT were further shaded by the cotton. Control also declined with Roundup Ultra applications and was lower than treatments in which Staple or Staple Plus was applied LOT. For this difficult-to-control species, the residual activity of Staple helped maintain control later into the season.

Pigweed species were controlled 99 to 100% at 2 weeks after LOT treatments and 96% at 7 WAT (data not shown). Miller et al. (1999) reported 98 to 100% control at 7 WAT with sequential applications of Roundup Ultra alone or with single or sequential applications of Roundup Ultra + Staple.

Annual grass was controlled 100% at 2 weeks after LOT treatments with all treatments (data not shown). At 7 weeks after LOT treatments, control was 93% except with the sequential application of Roundup Ultra, which gave only 84% at Marianna. Staple, although generally weak on grasses, appeared to have enough residual activity to help maintain grass control. At Fayetteville, however, control was 100% with Roundup Ultra alone, and later-emerging grass was shaded by the cotton canopy.

PRACTICAL APPLICATION

Adding Staple to glyphosate postemergence (Staple Plus), or applying Staple preemergence prior to glyphosate application, may be advantageous for difficult-to-control species such as morningglories, especially with high-density infestations and

with single applications prior to late post-directed or layby treatments. The cost of the additional Staple will have to be balanced with the benefits of possible increased and residual control from Staple and will depend on the species and density of weeds present or anticipated in the crop.

LITERATURE CITED

Gillham, L., S. Williams, A. Yang, and J Claus. 2001. Weed control in Roundup Ready cotton with Staple Plus. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (vol. 2) p. 1222.

McClelland, M. 1998. Roundup Ready cotton weed control systems. *In:* D. Oosterhuis (ed.). Proc. Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 188:134-136.

Miller, C., C. Wilson, and J. Milligan. 1999. Evaluation of Roundup Ultra/Staple combinations for total postemergence weed control in Roundup Ready cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (vol. 1) p. 742-743.

Reynolds, D., C. Rowland, R. Cobill, and K. Bloodworth. 1998. Evaluation of Staple use in transgenic cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (vol. 1) p. 846.

Webster, E. and T. Baughman. 1998. Strategies for Staple use in cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. (vol. 1) p. 842.

Table 1. Treatments in Staple Plus experiments, Marianna and Fayetteville, 2000-2001.

Treatment designation	Herbicide[z]	Rate	Application timing[y]
		(lb ai/acre)	
St/fl	Staple +	0.031 +	PRE *fb*
St LOT	fluometuron *fb*	0.94 *fb*	
	Staple +	0.063 +	LOT
	Assure (quizalofop)	0.063	
St/fl	Staple +	0.031 +	PRE *fb*
St+ LOT	fluometuron *fb*	0.94 *fb*	
	Staple Plus	0.031 + 0.75	LOT
St	Staple *fb*	0.031 *fb*	PRE *fb*
St+ LOT	Staple Plus	0.031 + 0.75	LOT
St+ EOT	Staple Plus	0.031 + 0.75	EOT
St+ LOT	Staple Plus	0.031 + 0.75	LOT
St+ EOT/LOT	Staple Plus	0.031 + 0.75	EOT *fb* LOT
RU/RU	Roundup Ultra(Max)	0.75	EOT *fb* LOT

[z] Staple = pyrithiobac + NIS (surfactant); Staple Plus + pyrithiobac + glyphosate + NIS; *fb* = followed by.

[y] PRE = preemergence; EOT = cotyledon- to 3-leaf; LOT = 4-leaf cotton.

Table 2. Control of prickly sida, morningglory species (pitted and entireleaf), and annual grasses at 4 and 13 weeks after treatment (WAT) at 2-leaf cotton and seedcotton yield, Marianna, 2001.

	Prickly sida		Morningglory spp.		Annual grass		Lint
Treatment[z]	4 WAT	13 WAT	4 WAT	13 WAT	4 WAT	13 WAT	yield
	----	----	----	(%)	----	----	(lb/acre)
St + RU	100 a[y]	98 a	96 a	87 ab	99 a	92 a	1518 a
St + TD	100 a	100 a	95 ab	94 a	98 a	92 a	1424 a
RU	89 b	40 b	88 c	69 b	96 a	92 a	1467 a
TD	89 b	53 b	91 bc	70 b	96 a	85 b	1480 a

[z] St = Staple; RU = Roundup UltraMax; TD = Touchdown. RU and TD are glyphosate formulations.

[y] Means for each species at each rating followed by the same letter do not differ by LSD 0.05.

Table 3. Control of prickly sida, entireleaf morningglory, barnyardgrass, and sicklepod at 1 and 4 weeks after treatment (WAT) at 2-leaf cotton, Fayetteville, 2001.

	Prickly sida		Entireleaf morningglory		Barnyardgrass		Sicklepod	
Treatment[z]	1 WAT	4 WAT	1 WAT	4 WAT	1 WAT	4 WAT	1 WAT	4 WAT
	----	----	----	----	(%)	----	----	----
St + RU	100 a[y]	98 a	96 a	87 ab	99 a	92 a	83 a	93 a
St + TD	100 a	100 a	95 ab	94 a	98 a	92 a	80 a	87 a
RU	89 b	40 b	88 c	69 b	96 a	92 a	88 a	62 b
TD	89 b	53 b	91 bc	70 b	96 a	85 b	82 a	60 b

[z] St = Staple; RU = Roundup UltraMax; TD = Touchdown. RU and TD are glyphosate formulations.

[y] Means for each species at each rating followed by the same letter do not differ by LSD 0.05.

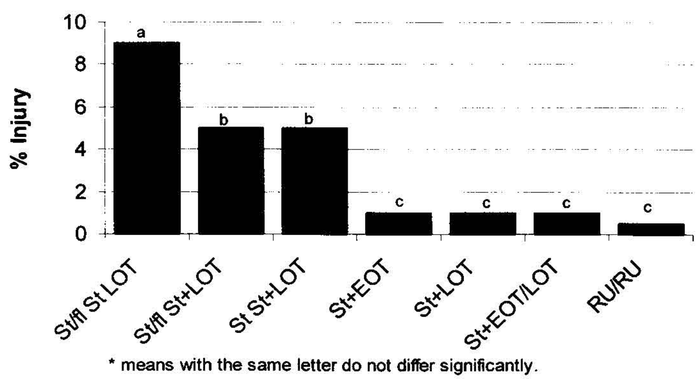


Fig. 1. Cotton injury 2 wks after LOT applications, mean of 2000 and 2001, Fayetteville and Marianna, AR (treatments listed in Table 1).

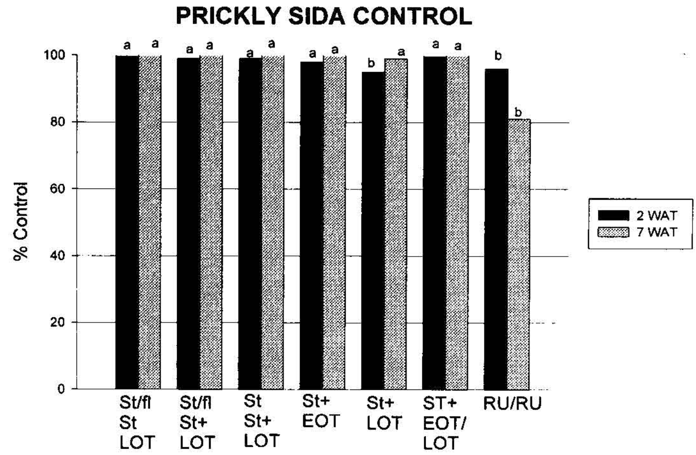


Fig. 2. Prickly sida control 2 and 7 weeks after LOT treatment (WAT), mean of 2000 and 2001, Fayetteville and Marianna, AR (treatments listed in Table 1).

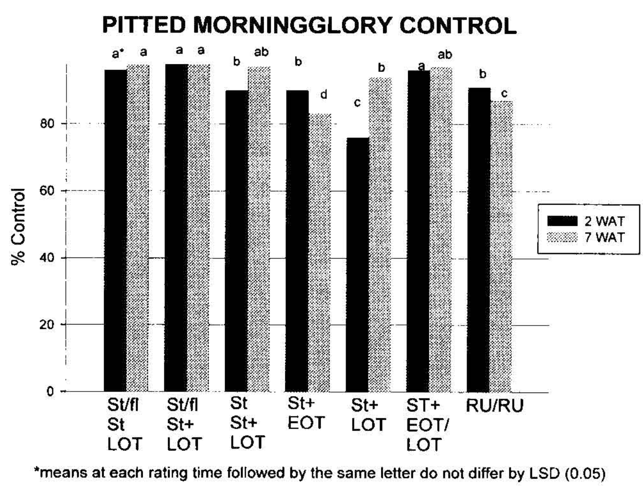


Fig. 3. Pitted morningglory control 2 and 7 weeks after LOT treatments (WAT), mean of 2000 and 2001 at Fayetteville and Marianna, AR (treatments listed in Table 1).

BIOLOGY AND CONTROL OF YELLOW NUTSEDGE IN COTTON

Frank E. Groves and Kenneth L. Smith[1]

RESEARCH PROBLEM

Yellow nutsedge (*Cyperus esculentus*) is a problem weed in cotton (*Gossypium hirsutum*) that escapes most weed control programs. Postemergence herbicide applications are required for season-long control. The physiological characteristics of yellow nutsedge inhibit the absorption and translocation of herbicides so application timing is critical. This research tests the hypothesis that the direction of carbohydrate flow in yellow nutsedge influences susceptibility to many herbicides and that carbohydrate flow fluctuates with plant growth stages. The primary goals of this research are (1) to identify optimal herbicide application timing and herbicide combinations for yellow nutsedge control in cotton; and (2) determine if control is influenced by a correlation between herbicide application timing and carbohydrate flow toward tubers.

BACKGROUND INFORMATION

Yellow nutsedge has been listed among the most troublesome weeds in the world. Found in all 50 states, it has been responsible for significant crop losses (Holm et al., 1977; Wills, 1985). In 2000, there were 5,121,478 ha of cotton grown in the US with 18% infested with the *Cyperus* species. This level of infestation reduced cotton yield by 8.3% (Byrd, 2001). In the 2000 growing season, 384,465 ha of cotton were grown in Arkansas with 5.2% infested with the *Cyperus* species. This weed caused a 6% yield loss in the state (Byrd, 2001).

Stoeller and Woolley (1983) reported that yellow nutsedge utilizes a complex underground network of rhizomes, basal bulbs, and tubers to produce vegetative and reproductive growth. Individual yellow nutsedge tubers have been reported to sprout up to three times. Tuber viability must be diminished to ensure against resprouting (Stoeller and Wax, 1973). Application timings that coincide with basipetal translocation have increased herbicide efficacy in other species (Wilson et al., 2001; Ficke and Sosebee,

---

[1] Research specialist and extension weed scientist, Southeast Research and Extension Center, Monticello.

1981). Wills (1971) reported carbohydrate concentration in various parts of purple nutsedge (*C. rotundus*) was affected by maturity. Little has been reported on carbohydrate levels and translocation during the life cycle of yellow nutsedge.

RESEARCH DESCRIPTION

Two studies were conducted to evaluate the control of yellow nutsedge in glyphosate-tolerant cotton in Rohwer, Arkansas. Cotton cultivar DP451BRR was planted 5 June 2001 in 0.96-m rows on a Hebert silt loam soil. The plots contained a natural population of yellow nutsedge. The study design was a complete randomized block, replicated four times. The first study evaluated metolachlor alone preplant (PP) and preemergence (PRE) at 1.12 kg ai/ha and postemergence in combination with or followed by glyphosate at 1.12 kg ai/ha or trifloxysulfuron at multiple application rates and timings. The second study evaluated norflurazon at 1.12 kg ai/ha preplant incorporated (PPI) followed by 1.12 kg ai/ha PP. Norflurazon was observed followed by glyphosate at 1.12 kg ai/ha or trifloxysulfuron at multiple application rates and timings.

In the fall of 2001 a greenhouse study was conducted to test a possible correlation between carbohydrate content and growth stage of yellow nutsedge. Two-leaf through nine-leaf plants were harvested and the study was replicated ten times. At harvest the plants were separated into rhizomes, tuber, shoot, old leaves, and young leaves. The samples were then weighed, bagged, and frozen. All samples will be analyzed for carbohydrate content using high performance liquid chromatography (HPLC).

These studies will be repeated in 2002. The efficacy of three herbicides (metolachlor, trifloxysulfuron, and glyphosate) will also be investigated in a greenhouse study conducted in Monticello, AR, in the spring of 2002. Treatments will occur at each leaf stage to determine the correlation between plant growth stage and herbicide efficacy based upon carbohydrate content.

RESULTS

Metolachlor PP offered 71% control of yellow nutsedge at 35 days after treatment (DAT; data not shown). Increased control was achieved with early-postemergence (EP) treatments influenced by herbicide and rates. Trifloxysulfuron applied alone, in combination with metolachlor, or following metolachlor provided greater than 80% control at 21 DAT. Sequential postemergence applications provided greater than 85% control. Trifloxysulfuron at 13.0 g ai/ha EP fb 19.0 g ai/ha mid-postemergence (MP) provided greater than 85% control at 35 DAT. MSMA at 1.12 kg ai/ha MP and metolachlor at 1.12 kg ai/ha in combination with trifloxysulfuron at 13.0 g ai/ha EP fb trifloxysulfuron at 19.0 g ai/ha MP provided 89% control at 35 DAT. Season-long control was achieved with sequential applications of trifloxysulfuron at 13.0 g ai/ha EP fb 32.0 g ai/ha late-postemergence (LP). This resulted in 94% control at 21 DAT. The addition of metolachlor

EP did not improve control over the sequential applications of trifloxysulfuron alone. Norflurazon evaluated at 2.24 kg ai/ha applied PPI or at 1.12 kg ai/ha in a split PPI/PRE application offered 82% control at 35 DAT. An EP application of glyphosate alone provided 73% control at 21 DAT. An EP tank-mix of trifloxysulfuron at 13.0 g ai/ha and glyphosate improved control to 81%. However, when these treatments followed a PPI application of norflurazon the level of control exceeded 90%. Norflurazon PPI fb trifloxysulfuron EP fb trifloxysulfuron at 19.0 g ai/ha MP offered 95% control. Sequential applications of glyphosate EP and MP provided 92% control at 35 DAT. Norflurazon PPI fb glyphosate or trifloxysulfuron EP fb trifloxysulfuron at 32.0 g ai/ha LP provided 94% control at 21 DAT. The same control was achieved with trifloxysulfuron at 13.0 or 19.0 g ai/ha EP fb trifloxysulfuron at 32.0 g ai/ha LP. Trifloxysulfuron in combination with glyphosate EP fb trifloxysulfuron at 13.0 g ai/ha LP resulted in 72% control.

PRACTICAL APPLICATION

These studies were conducted to evaluate the efficacy of herbicides with different modes of action at various application rates and timings on yellow nutsedge. Although glyphosate provides excellent control of pigweed (*Amaranthus*) and small-seeded annuals, morningglory (*Ipomoea*) and *Cyperus* species continue to be problematic weeds. Trifloxysulfuron promises greater than 80% control when applied EP, MP, or LP following an EP treatment. Similar control may be achieved with glyphosate following a PPI or PP treatment.

The data from these studies will be used to develop protocols for future tests and may also allow producers to treat yellow nutsedge in the most effective rates and timings.

LITERATURE CITED

Byrd, J.D., Jr. 2001. Report of the 2000 cotton weed loss committee. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1207-1210.

Ficke, W.E. and R.E. Sosebee. 1981. Translocation and storage of 14-C labeled total nonstructural carbohydrates in honey mesquite. J. Range Manage. 34:205-208.

Stoeller, E.W., and J.T. Woolley. 1983. The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal bulb formation. Weed Sci. 31:148-152.

Stoeller E.W., and L.M. Wax. 1973. Yellow nutsedge shoot emergence and tuber longevity. Weed Sci. 21:76-81.

Holm, L.G., D.L. Pluckenett, J.V. Pancho, and J.P. Herberg. 1977. The world's worst weeds. Distribution and biology. United Press Hawaii, Honolulu. pp. 125-133.

Wills, G.D. 1985. Description of purple and yellow nutsedge (*Cyperus rotundus* and *Cyperus esculentus*). Weed Tech. 1:2-9.

Wills, G.D. 1971. Sugars, phosphorous, and iron in purple nutsedge. Weed Sci. 20:348-350.

Wilson, R.G., S.D. Kachman, and A.R. Martin. 2001. Seasonal changes in glucose, fructose, sucrose, and fructans in the roots of dandelion. Weed Sci. 49:150-155.

EVALUATION OF TRIFLOXYSULFURON AND PYRITHIOBAC IN TRANSGENIC COTTON WEED CONTROL PROGRAMS

Jeffrey W. Branson, Kenneth L. Smith, and Robin C. Namenek[1]

RESEARCH PROBLEM

Transgenic cotton varieties now account for greater than 60% of the total cotton acreage planted in Arkansas. The Roundup Ready program (glyphosate-tolerant) and the BXN program (bromoxynil-resistant) provide acceptable control of many weeds that decrease cotton yields; however, neither program provides control of all troublesome weeds in Arkansas cotton production. The objectives of this research were to evaluate the contribution of trifloxysulfuron and pyrithiobac to these transgenic weed control programs, and also to compare weed control from applications of trifloxysulfuron and pyrithiobac applied alone at various weed growth stages.

BACKGROUND INFORMATION

Trifloxysulfuron (CGA 362622) is a new sulfonylurea being developed by Syngenta Crop Protection for postemergence use in cotton (Culpepper, 2001). Trifloxysulfuron provides activity on many key weeds in cotton production such as pitted morningglory, Palmer amaranth, sicklepod, and hemp sesbania (Wells, 2000). Use rates are extremely low and range from 0.1 to 0.25 oz/acre (Holloway, 2001). Trifloxysulfuron can be applied over-the-top of cotton as long as it has reached the 3-leaf growth stage. Cotton phytotoxicity is 13% or less following early post applications and 6% or less following post-directed applications. All visible injury dissipates within 14 days after applications under normal growing conditions (Holloway, 2001). Yellowing and stunting can occur following over-the-top applications, but the response dissipates quickly and does not affect yield (Holloway, 2000).

Pyrithiobac (Staple) was registered in the fall of 1995 for postemergence applications in cotton and is also an ALS inhibitor. It was the first herbicide to be registered for

---

[1] Weed science associate, extension weed scientist and research specialist, Southeast Research and Extension Center, Monticello.

postemergence applications in nontransgenic cotton for control of numerous annual broadleaf weeds without risk of crop injury, yield and quality reductions, and maturity delays (Wilcut, 1998).

RESEARCH DESCRIPTION

Field studies were established at Rohwer, Arkansas, during the 2000 and 2001 growing seasons to determine the influence of CGA 362622 and pyrithiobac rates and application timings on weed control and crop safety. The cotton (*Gossypium hirsutum* L.) varieties DP 451 B/RR and BXN 47 were planted on 17-18 May 2000 and on 5 June 2001 in conventional 96-cm rows. The experimental design was a randomized complete block with four replications. Preemergence applications were applied at planting, and postemergence applications were applied over-the-top at the 3- to 4-leaf cotton growth stage. Preemergence and over-the-top applications were applied at a 140 l/ha volume with a CO_2 backpack sprayer equipped with 8002 VS flat fan nozzles. Cotton was grown under normal cultural practices and sprinkler irrigated as needed. Visual evaluations of control included sicklepod (*Senna obtusifolia)*, hemp sesbania (*Sesbania exaltata)*, pitted morningglory (*Ipomoea lacunosa)*, prickly sida (*Sida spinosa)*, and Palmer amaranth (*Amaranthus palmeri*).

RESULTS

Control of Palmer amaranth, sicklepod, and prickly sida was greater than 90% 14 days after preemergence applications of CGA 362622 at 5.3 and 8 g ai/ha and pyrithiobac at 70 g ai/ha (data not shown). At 28 days after preemergence applications, control of all species was similar with both rates of CGA 362622 and pyrithiobac and ranged from 88 to 95%. Crop injury occurred in 2000 following preemergence applications of both herbicides, but injury was greatest following applications of CGA 362622 at 8 g ai/ha and ranged from 35 to 49%. Significant rainfall was received in 2000 immediately following preemergence applications, which may have played a role in the high levels of injury produced. In 2001 injury was less than 15% with both herbicides at all rates.

Postemergence applications of CGA 362622 and pyrithiobac provided similar control of Palmer amaranth and pitted morningglory at all rates, with control ranging from 92 to 100% both years. CGA 362622 at 5.3 and 8 g ai/ha provided greater control of hemp sesbania and sicklepod compared to pyrithiobac. Postemergence control of prickly sida with CGA 362622 was very poor both years, while control with pyrithiobac at 70 g ai/ha was significantly higher compared to CGA 362622.

Roundup Ultra at 0.84 kg ai/ha provided greater than 90% control of Palmer amaranth both years; however, control of prickly sida, pitted morningglory, sicklepod, and hemp sesbania was 90% or less in both years. Roundup Ultra at 0.84 kg ai/ha combined with CGA 362622 at 8 g ai/ha provided greater than 90% control of all spe-

cies. Tank mixes of Roundup Ultra and CGA 362622 applied over-the-top of 3- to 4-leaf cotton produced injury in the form of necrosis, which slowly dissipated. Bromoxynil alone at 0.56 kg ai/ha provided greater than 88% control of pitted morningglory and hemp sesbania; however, control of sicklepod and Palmer amaranth was poor both years. Bromoxynil at 0.56 kg ai/ha combined with CGA 362622 at 8 g ai/ha and pyrithiobac at 70 g ai/ha provided greater than 90% control of all species.

PRACTICAL APPLICATION

Broadleaf weed control continues to be a major concern in cotton production. Advances in plant biotechnology have given rise to a new era in weed control with the glyphosate-tolerant and bromoxynil-resistant cotton varieties. These herbicides provide control of many problematic weeds in cotton production; however, no herbicide on the market provides control of all of the weeds that decrease cotton yield. Trifloxysulfuron and pyrithiobac may provide activity on weeds that are not controlled by glyphosate or bromoxynil.

LITERATURE CITED

Culpepper, A.S. 2001. Comparison of CGA 362622, pyrithiobac, and glyphosate in glyphosate-resistant cotton. Proc. Southern Weed Science Society 54:2.

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

Holloway, J.C. 2001. The effects of CGA-362622 applications on weed control and cotton yield. Proc. Southern Weed Science Society. 54:203.

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

Wilcut J.W. 1998. Influence of pyrithiobac sodium on purple and yellow nutsedge. Weed Science 46:115-119.

ALTERATION OF COTTON PLANT STRESS DYNAMICS BY TARNISHED PLANT BUG FEEDING

Chuck Yates and Phil Tugwell[1]

RESEARCH PROBLEM

The early detection of stress in the cotton crop is essential for efficient management and optimal yield. The objective of this study was to determine the change in the stress dynamics of cotton plants injured by tarnished plant bug [*Lygus lineolaris* (Palisot de Beauvois)] feeding.

BACKGROUND INFORMATION

Boll loading is a major source of stress in the cotton plant because of the sharp increase in plant demand for resources. Boll loading is composed of two components, boll retention and boll filling. Prior to first flower, stress due to boll loading is negligible, but it can be expressed as potential stress. Following first flower, actual boll loading stress quickly accumulates until the carrying capacity of the plant is reached. The carrying capacity of the plant is the fruit load that causes production of new vegetative and reproductive structures to cease. Plant bugs feed on squares during the squaring period of growth. This causes shedding and a resultant alteration of potential stress. The alteration of potential boll loading stress prior to flower leads to a modification of actual boll loading stress after first flower.

RESEARCH DESCRIPTION

The experiment was conducted at Wildy Farms, a commercial farm in northeast Arkansas near Manila. The study consisted of 6 replications of 5 treatments of cultivars Stoneville 4892 BR arranged in a randomized complete block design. Each plot was 25 ft. in length and 4 rows (38-in. spacing) wide. Prior to planting, drip-tape irrigation was placed in-furrow to eliminate water-deficit stress. Each treatment received different

---

[1] Graduate assistant and professor, Entomology Department, Fayetteville.

numbers of tarnished plant bug nymphs (TPB) for three consecutive weeks prior to first flower. Insect treatments were 0, 1, 2, 3, and 4 nymphs per 3 plants, respectively.

During plant development, data on plant growth and fruit retention were collected using COTMAN, SCOUTMAP, and COTMAP. At season's end, 10 plants were selected and each first-position boll was marked for location on the plant and bagged separately. These bolls were then ginned in a one-boll gin. The seeds were counted, and lint and seed weight was recorded on a boll-by-boll basis

RESULTS

Percentage of first position squares shed prior to first flower were 3%, 23%, 26%, 37%, and 53% for treatments 1, 2, 3, 4, and 5, respectively.

The final lint yields for treatments 1, 2, 3, 4, and 5 were 1543, 1365, 1369, 1148, and 1003 lb/acre, respectively.

Individual boll data are being analyzed for their contribution to yield. Also, the plant response to shedding of adjacent bolls on the retained boll is being determined, including effects on fiber length, strength, and micronaire.

Present research is centered on relating the various levels of an estimated pre-flower potential stress created by different TPB densities to the corresponding estimated actual stress plants encountered following first flower.

PRACTICAL APPLICATION

The understanding of *potential* boll loading stress and *actual* boll loading stress will provide the basis for growers and consultants to anticipate the onset of stress and make management decisions to reduce or possibly avoid stress completely.

MORTALITY OF TARNISHED PLANT BUG ADULTS FOLLOWING DIFFERENTIAL EXPOSURE TO CENTRIC, STEWARD AND LEVERAGE IN FIELD CAGES

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

RESEARCH PROBLEM

Evaluating new insecticides for control of tarnished plant bug (TPB) [*Lygus lineolaris* (Palisot de Beauvois)] remains a research priority (Teague et al., 2000; Teague and Tugwell, 1996). In this study, our objective was to examine how activity of several insecticides used against tarnished plant bug declined in the first few hours after a field application. We compared plant bug mortality when bugs were exposed to insecticide sprays immediately after application and 4 hours after application.

RESEARCH DESCRIPTION

The insecticides Steward 1.25 SC (indoxicarb), Centric 40 WG (thiamethoxam), and Leverage 2.7 EC (imidacloprid + cyfluthrin) were evaluated. The experiment was conducted in a commercial cotton field on Wildy Farms located near Leachville in northeast Arkansas with cultivar PSC 355 planted on 30 April 2001. Plots were 4 rows wide and 40 ft long with 10 ft alleys, and they were arranged in a randomized complete block design with 3 replications. Insecticides were applied 24 July using a 4-row electrostatic, high-clearance sprayer calibrated to deliver 13.4 gpa at 28 psi with Turbo Teejet nozzles (TT1002-VP) set on 19-inch spacing to provide 2 nozzles per row. In the center 2 rows of each plot, 6 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 ca. 1 ft from the terminal. The cages were rolled down to the tie and covered with aluminum foil leaving plant terminals exposed. Application began at 8:00 AM immediately following the insecticide application, while the foliage was still wet, the foil was removed, the cage pulled up, and 5 TPB adults (<5 days old) were placed into each of 3 cages. Cages were secured with twist ties. Application of insec-

---

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

ticide and release of bugs were completed in 27 minutes. Four hours later TPB adults were released in the remaining 3 cages in each plot. At 72 hrs following application, plants where bugs had been released 0 hours after spray (HAS) were cut below the cage and taken to the laboratory where TPB mortality was determined. The procedure was repeated for the remaining cages 4 hours later. Mortality data were analyzed with AOV, and means separated with LSD. TPB were obtained from a laboratory colony reared on artificial diet at the USDA-ARS laboratory in Mississippi State, MS.

RESULTS

Significant differences among treatments were observed in both exposure times in cages (Table 1). The new insecticide Centric resulted in highest mortality at 0 and 4 hours after spray. Mortality of >20% was observed in the untreated control in 4-HAS treatments. This higher-than-expected mortality was probably due to high noon-time temperatures during the release period.

PRACTICAL APPLICATION

Plant bug mortality from insecticides that act following ingestion may decline as the spray on foliage evaporates. Persistence varied between products in this test. Growers and crop advisors should be aware that live insects may remain in the field in the first few days following application of insecticides with anti-feedent properties such as Provado (imidacloprid), Centric, or Steward; however, crop injury may not be occurring. To assess insecticide efficacy, crop monitoring of new injury is required. If no new injury is observed, the insecticides have performed their crop protection function.

ACKNOWLEDGMENTS

We thank David and Justin Wildy and their staff at Wildy Farms for their assistance in the study. We also acknowledge Mr. Dale Wells for his support, and Mr. Joe Stewart 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.

REFERENCES

Teague, T.G., and N.P. Tugwell. 1996. Chemical control of tarnished plant bug: Results from field cage studies and laboratory bioassays. *In:* D.A. Richter and J. Armour (eds.). 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. *In:* D.A. Richter and J. Armour (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis TN, pp. 1214-1217.

Table 1. Mean percentage mortality of tarnished plant bug adults observed 72 hrs after release in sleeve cages in cotton. Bugs were released at 0 hrs after spray or 4 hrs after spray (HAS).

		Mortality after 72 hrs	
Treatment/formulation	Rate	Released 0 HAS	Released 4 HAS
Untreated control		4.3 c[z]	22.2 d
Steward 1.25 SC	0.1040	73.7 b	62.2 bc
Centric 40 WG	0.0346	90.1 a	84.4 a
Centric 40 WG	0.0625	95.7 a	82.2 ab
Leverage 2.7 EC	0.0634	85.0 ab	56.1 c
P>F (AOV)		*0.001*	*0.001*
LSD (0.05)		*12.0*	*20.52*

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

LATE-SEASON TARNISHED PLANT BUG INFESTATIONS – WHEN IS THE CROP SAFE?

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

RESEARCH PROBLEM

Economic thresholds (Stern et al., 1959) are used extensively in cotton production for determining when to initiate insecticide applications. Despite their importance in pest management, at some point in the season the crop is no longer susceptible to insects, and thresholds become irrelevant. The crop is beyond its final stage of susceptibility, and subsequent insecticide applications are uneconomical (Pedigo et al., 1986).

The question of when a cotton crop is "safe" from late-season insect pests has been the focus of intense research during the last 20 years (Bernhardt et al., 1986; Bagwell and Tugwell, 1992; Bourland et al., 1992; Zhang et al., 1994; Cochran et al., 1996; O'Leary et al., 1996; Benedict et al., 1997; Torrey et al., 1997; Harris et al., 1997; Cochran et al., 1999). Those previous studies dealt with terminating crop protection for heliothine caterpillars and boll weevils. There has been little research to define termination rules for tarnished plant bug (TPB), a key pest in mid-South cotton.

BACKGROUND

Research efforts have yielded a simple crop monitoring procedure and crop termination rule that allows a decision maker to define the final stage of crop susceptibility for a particular pest. After that point, the decision maker can ignore future infestations of those pests. The process is easily performed using the COTMAN™ system (Danforth and O'Leary, 1998).

To determine the final stage of crop susceptibility in cotton for a specific fruit-feeding insect pest, one must know which fruiting forms are the last to contribute to economic yield – the last effective boll population – and then know when those fruit are reasonably safe. Crop monitoring allows identification of the flowering date of the

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

last effective boll population. This is considered cutout. Physiological cutout (Oosterhuis et al., 1996) takes place as the crop approaches carrying capacity, that point at which terminal growth has slowed and eventually stops because of boll loading (Hearn and Constable, 1984). By monitoring changes in the number of nodes above white flower (NAWF), the decision maker can measure late-season terminal growth and gauge physiological stress brought on by boll loading. With normal crop development, the last effective boll population occurs when the mean NAWF of a field reaches 5 (Wells, 1991; Bourland, 1992). Should physiological cutout be delayed significantly and NAWF=5 not reached prior to the latest possible cutout date, then the last effective boll population is defined based on a seasonal cutout date (Oosterhuis et al., 1996). In the COTMAN system, the latest possible cutout date is calculated based on the probability of accumulating 850 heat units (DD60s) from the date of flowering of the last effective boll population. Seasonal cutout dates are calculated based on local historical weather data from the crop production area.

If cutout date defines the last bolls to be protected, the next question is when are those bolls sufficiently mature that they are safe from insect attack. Research by Bagwell (1992) indicated that at about 350 DD60s after anthesis, injury to a boll by bollworm (*Helicoverpa zea*) and boll weevil (*Anthonomus grandis*) is dramatically reduced. Kim (1998) made measurements of different-aged bolls and found significant increases in resistance of the boll wall to penetration at about 350 DD60s. With these results in hand, researchers hypothesized that infestations occurring after cutout + 350 would not lead to economic loss. This hypothesis was tested in small-plot research trials and then in large-plot, on-farm validation studies. In three years of research across several states and involving 20 small-plot trials, a yield penalty was never observed for terminating insect control after 350 DD60s beyond NAWF=5. Four years of large-plot grower trials compared yields using the COTMAN termination rule to yields using the growers' normal economic thresholds for initiating insecticide applications. In each of the 33 trials, the grower thresholds resulted in additional insecticide applications beyond 350 DD60s, at an additional cost ranging from $7 to $70 per acre. In 32 of 33 trials, insecticide termination at 350 DD60s improved farm profits. Overall, less than two pounds of lint difference on average was observed between termination at 350 DD60s and the grower full-season treatment. An average of $19.62 per acre was spent on insect control with no return to yield (Cochran et al., 1999).

Late-season injury resulting from plant bug feeding on bolls includes damage to lint and seed. Pack and Tugwell (1976) observed as high as a 10% yield reduction from damaged bolls in studies in northeast Arkansas; however, during the time of that research, there were no efficient tools to monitor crop development, and timing of the infestation with regard to crop maturity was not easily quantifiable.

In studies conducted in Mississippi, Horn et al. (1999) examined the incidence and severity of plant bug feeding punctures. In no-choice cage studies, adult bugs were confined on bolls of different ages for 48 hrs. They determined that bolls which had accumulated 250 DD60s were relatively safe from tarnished plant bug injury. The

authors proposed a conservative recommendation of establishing 300 DD60s after cutout as the point at which to terminate insecticides (i.e. insecticide sprays to control future infestations of plant bugs would be unnecessary). Similar no-choice cage tests were conducted in Louisiana, where Russell et al. (1999) evaluated retention of bolls after 72 hrs exposure to 2 TPB adults. They found that TPB did not sufficiently penetrate the boll wall to result in boll abscission if the boll had accumulated >300 DD60s.

The objectives of this study were: 1) to conduct field studies to validate decision rules for defining the final stage of cotton crop susceptibility to tarnished plant bug; and 2) to use standardized procedures to assess plant responses to late-season injury by TPB and to protective sprays in a high yielding production system in the absence of boll weevil, heliothine larvae, and defoliating caterpillar pests.

RESEARCH DESCRIPTION

The experiment was conducted at Wildy Farms, a commercial farm in northeast Arkansas near Manila. The growing season is May through October, and the latest possible cutout date (that date with a 50% or 85% probability of attaining 850 DD60s from cutout) for this production area is 9 August or 31 July, respectively (Zhang et al., 1994; Danforth and O'Leary, 1998).

The cultivar, Stoneville 4892 (a transgenic *Bt* variety with tolerance to the herbicide glyphosate), was seeded on 2 May 2001. Temik 15G (aldicarb) was applied in furrow at planting at 5 lb formulation per acre. The soil was a Routon-Dundee-Crevasse Complex (sand). Sprinkler irrigation was initiated beginning 7 May, and continued at weekly intervals until 21 Aug. Rainfall in May, June, July, August, September, and October was 5.27, 1.33, 2.04, 1.30, 2.67, and 5.82 inches, respectively. Foliar applications of Orthene 90S (acephate) (0.33 lb formulation/acre) were made to control infestations of mirid pests, cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), and TPB on 1 and 27 June and 12 July. Applications were made when mirid counts in drop cloth samples and/or percent square shed approached grower thresholds (1 bug/3ft or pre-flower first-position square shed not to exceed 10%). Defoliants were applied on 19 September (12oz Folex and 4oz Finish/acre) and 25 Sept (4oz Finish + 32 oz Super Boll/acre).

Infestation Treatment

TPB nymphs were released at different times and levels after cutout to compare injury and lint yield of infested plants to plants protected by insecticide. There were 5 infestation treatments: 1) Bug 3, release of TPB nymphs 3 times at weekly intervals beginning August 10, the day after the latest possible cutout date; 2) Bug 2, release of TPB nymphs 2 times weekly, beginning 8 days after the latest possible cutout date; 3) Bug 1, a single release of TPB nymphs made 15 days after the latest possible cutout date; 4) no releases, just the naturally occurring TPB infestation, and 5) protected with insecticide sprays.

In Bug 3, Bug 2, and Bug 1 treatments, 3 to 5 TPB nymphs (3rd instar) were released on every plant on the appropriate date. Plant stand density was approximately 3.5 plants/ft. Nymphs were allowed to walk onto plants from shredded strips of white copy paper. These 0.5-cm wide and 10- to 20-cm long strips are used to line the bottom of rearing boxes, and the bugs rest on them after feeding. Rearing boxes were carried to the field, and a single paper strip was pulled from the box with TPB nymphs clinging to the paper. Excess bugs were brushed off and the paper strips laid across leaves on the top of the plant. Bugs were released during the cool periods of the morning after dew had dried. For the sprayed treatment, Centric 40 WG (thiamethoxam), was applied at 3 ounces/acre using a back-pack sprayer. Plot rows as well as the 2 rows adjacent to the plot were sprayed at 6-day intervals. Details on timing treatments in relation to DD60 accumulation after physiological cutout and the seasonal cutout date are outlined in Table 1.

Each treatment was replicated 3 times. Plots were 2 rows wide, 15 ft long. Plots were separated through the field by 85 ft buffer areas. 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).

Crop Monitoring and TPB Counts

Plants were monitored from the early squaring period through cutout using the COTMAN system. Five consecutive plants in 2 treatment rows were monitored weekly. Prior to first flowers, sampling included measurement of plant height, number of squaring nodes (nodes on which 1st position squares had not yet flowered), and sheds of first-position squares. After first flowers, nodes above white flower were monitored. Beginning on the date of seasonal cutout (9 Aug) the SCOUTMAP component of COTMAN was used to monitor square and boll retention and injury (Tugwell et al., 1999). In this sampling scheme, total squares, small bolls, and large bolls on 10 plants were monitored for retention, and external symptoms of TPB feeding. Total squares were all first-position squares. Small bolls were first-position bolls located on the first 3 sympodial nodes below the white flower (or last squaring node if no flower was present), and large bolls were all first-position bolls located 4 nodes below the last squaring node.

Natural infestations of TPB were monitored outside the treatment plots. Plant bug population density was estimated on 16 and 24 Aug using 10 sweeps of the terminal areas of plants with an 18-inch net. Twelve samples were made through the entire field. Within plots, on these same dates, 10 white flowers in each plot were examined in the late morning just after flowers were open. Any signs of injury were noted, and counts of total numbers of plant bugs/flower were made. For yield determinations, plots were hand harvested 27 Sept, 2 Oct, and 9 Oct. These data, along with other plant and insect monitoring data, were analyzed using ANOVA with mean separation using LSD.

RESULTS

TPB Population Densities

Natural infestations of tarnished plant bugs were surprisingly high during mid-August though September in northeast Arkansas. TPB numbers were considered at treatment level (exceeded economic thresholds) throughout the area, and consequently it was common for growers who were not using plant monitoring for crop termination decisions to apply from 2 to 5 insecticide applications for TPB during late August and early September (Keith Martin, personal communication). At our study site, means of 10.7 and 15.3 bugs per 10 sweeps from plant terminals were recorded on 16 and 24 Aug, respectively, in sweep net sampling taken adjacent to the experiment. Other non-mirid pest species were at inconsequential levels; boll weevil and heliothine numbers were *extremely* low in the production area in the 2001 season and were not a factor in the end-of-season decision making.

Crop Monitoring

Mean number of squaring nodes for each treatment is 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 was apparent that the crop was somewhat late in square initiation, but the rate of squaring node accumulation indicated no significant pre-flower stress after squaring commenced. NAWF values indicated that boll loading appeared to be slightly delayed; however, the crop reached physiological cutout (NAWF=5) prior the latest possible cutout date (9 Aug). Days to cutout among all plots ranged from 89 to 97 days after planting (30 July to 8 Aug). Mean date of physiological cutout for all plots was 3 Aug.

SCOUTMAP data taken following cutout indicated plants had fewer than 4 squaring nodes (NAWF<4) and had between 10 and 11 total sympodial nodes with bolls on 16 Aug. There were no differences in square or boll sheds between treatments exposed to natural infestations of TPB and released bug and sprayed plots although numerically, percent square shed was lowest in sprayed treatments (Table 2). By 23 Aug, these trends continued, but by 30 Aug there were few squares remaining in any treatment. Small boll shed numerically was lower in sprayed plots compared to treatments with released and/or natural bugs. Sheds of all first-position fruiting forms ranged between 43 and 56% by 23 Aug.

Significant differences between infested and the sprayed treatments in TPB injury symptoms were observed for small bolls for the first 2 sample dates and for total fruiting forms for the second sample dates (Table 3). By 30 Aug the trend for lower levels of small boll injury in sprayed plots was still present; however, there were no significant differences. In white flower inspections, numbers of flowers with injury symptoms and counts of TPB/flower indicated significantly higher levels of TPB activ-

ity in unsprayed plots compare to those protected with insecticide (Table 4). By the time of the 23 Aug sample, Bug 3 treatments had received 2 applications of nymphs, and in those plots 100% of all flowers were infested by a bug and were found to have injury symptoms. Casual inspection of plots in late August produced the impression that severe boll injury from TPB feeding had occurred in unsprayed plots, especially in those receiving 2 and 3 applications of bugs. Significant economic damage appeared inevitable to at least one of the senior authors.

Yield

From the mean date of physiological cutout (3 Aug) until the first application of defoliants on 16 Sept, daily temperatures were such that 822 DD60s were recorded. From 9 Aug, the seasonal cutout date, to 16 Sept, total DD60 accumulation was 697. Most plots were over 80% open at the time of defoliation, and all plots had at least 60% open bolls. Yield data indicated no differences between treatments for any harvest date (Table 5).

DISCUSSION

In the Bugs 3 infestation treatment, plant bug feeding was continuous from 150 DD60s following physiological cutout until open bolls were present. All infestation treatments had significantly higher levels of small boll injury, but no differences in yield between sprayed and any TPB infestation level were measured. The crop apparently had passed its final stage of susceptibility to TPB, and protection of those fruiting forms was unnecessary.

In previous boll susceptibility studies with TPB, boll weevil, and bollworm, insects were tested in no-choice environments (Bagwell, 1992; Horn et al., 1999; Russell et al., 1999) and caged on bolls of different ages. Under field conditions, an insect's ovipositional and feeding site preferences are important factors that affect the potential for damage to economically significant boll populations. This is especially true for TPB, a persnickety herbivore that when feeding in cotton, prefers succulent squares to large bolls (Tugwell et al., 1976).

As a cotton crop approaches carrying capacity and is at physiological cutout, the late-season bolls usually are small and low in fiber quality (Bourland et al., 1992). Protection of those upper canopy fruiting forms with late-season insecticide applications is expensive. If those bolls are lost, photosynthates produced by upper canopy source leaves may be translocated to alternate sites such as economically important bolls lower in the canopy. This could act to compensate for loss of yield from the upper bolls. Results from ^{14}C labeling studies by Oosterhuis et al. (2000) indicated that removal of late-season squares after physiological cutout + 350 DD60s improved carbon partitioning to lower developing bolls. When they tested this hypothesis in field trials,

they observed that there were no statistical differences in yields following removal of fruiting forms in the upper canopy; however, in 2 of 3 years, yields were highest numerically where squares had been removed following physiological cutout. In studies by Fife et al. (2000) in Louisiana, removal of upper canopy squares after cutout did not result in increased yields; however, there were no yield reductions.

The elimination of late-season insecticide applications when bolls are no longer susceptible to damage by fruit-feeding insects has been shown to save producers money without adversely impacting yields (Cochran et al., 1999). The lack of yield penalty in literally dozens of validation studies, for the cutout + 350 DD60 control termination rule, seems to correspond to Hearn and Room's (1979) characterization of time-independent response of cotton to loss of fruiting forms: 1) *instantaneous tolerance* – when the damage occurs to fruiting forms that would have shed physiologically anyway; or 2) *instantaneous compensation* – when resources that would have been directed to damaged bolls are directed to the remaining undamaged bolls making them bigger. Pest management specialists and cotton professionals must work to increase recognition among growers and other decision makers that such tolerance and compensation factors do exist in late-season cotton systems, and that recommendations to adopt insect control termination rules are economically and environmentally sound advice.

PRACTICAL APPLICATION

Despite significant, high tarnished plant bug numbers and associated feeding injury, no yield penalty was observed following TPB infestations initiated at 150, 296, or 375 DD60s after physiological cutout. Results from this one season of research indicate that insect control termination rules that have been in use for heliothine caterpillars and boll weevils (cutout +350 DD60s) are more than sufficient for late-season tarnished plant bug management.

ACKNOWLEDGMENTS

We thank David and Justin Wildy and their staff at Wildy Farms for their assistance in the study. We also acknowledge Mr. Dale Wells for his support, and Mr. Joe Stewart and Ms. Gay McCain, USDA, ARS, Mississippi State, MS for providing the tarnished plant bug nymphs.

LITERATURE CITED

Bagwell, R.D. and N.P. Tugwell. 1992. Defining the period of boll susceptibility to insect damage in heat units from flower. 1992 Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 767-768.

Bernhardt, J.L., J.R. Phillips, and N.P. Tugwell, 1986. Position of the uppermost white bloom defined by node counts as an indicator for termination of insecticide treatments in cotton. J. Econ. Entomol. 79:1430-1438.

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.

Benedict, J., C. Correa, R. Huffman, R. Parker, M. Cochran, N.P. Tugwell, P. O'Leary, and S. Hopkins. 1997. Use and validation of COTMAN to termination insecticide application in south Texas. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 2:949-953.

Cochran, M.J., D.M. Danforth, S. Mi, N.P. Tugwell, N.R. Benson, and K.J. Bryant. 1999. Validation and economic benefits of COTMAN insecticide termination rules: Four years of research. *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 193:263-268. Fayetteville.

Cochran, M., D. Danforth, N.P. Tugwell, A. Harris, J. Reed, J. Benedict, R. Leonard, R. Bagwell, O. Abaye, E. Herbert, and P. O'Leary. 1996. A multistate validation of insecticide termination rules based upon the COTMAN plant monitoring system: Preliminary results. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp.1124-28.

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

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.

Fife, J.H., J. Gore, B.R. Leonard, and K.D. Torrey. 2000. Determination of physiological "cut-out" in Louisiana cotton based upon nodes above white flower. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN. Vol 2:969-971.

Harris, F.A., F.T. Cooke Jr., G.L. Andrews, and R.E. Furr, Jr. 1997. Monitoring nodes above white flower as basis for cotton insecticide treatment termination. Mississippi Agric. and Forestry Exp. Stn. Bulletin 1068, Mississippi State, MS.

Hearn, A.B. and G.A. Constable. 1984. Cotton. *In:* P.R. Goldworth and N.M. Fisher (eds.). The physiology of tropical food crops. John Wiley and Sons, Bath, Avon, pp. 495-527.

Horn, T.O., F.A. Harris, J.T. Robbins, and R.E. Furr, Jr. 1999. Influence of boll age on susceptibility to tarnished plant bug injury. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN. pp. 1044-45.

O'Leary, P., A.M. Cochran, N.P. Tugwell, A. Harris, J. Reed, R. Leonard, R. Bagwell, J. Benedict, J. Leser, K. Hake, O. Abye, and E. Herbert. 1996. A multi-state validation of insecticide termination rules based upon the COTMAN plant monitoring system: An overview. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN. pp. 1121-1124.

Oosterhuis, D.M., F.M. Bourland, N.P. Tugwell, and M.J. Cochran. 1996. Terminology and concepts related to the COTMAN crop monitoring system. University of Arkansas Agricultural Experiment Station Special Report 174, Fayetteville.

Oosterhuis, D.M., R.S. Brown, C.T. Allen, and F.M. Bourland. 2000. Effect of insecticide termination at 250, 350, and 450 heat units on carbon partitioning from upper-canopy leaves to the developing boll load. *In:* D.M. Oosterhuis (ed.). Proc. 2000 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 198:113-117. (http://www.uark.edu/depts/agripub/Publications/specialreports/198su12.pdf)

Pedigo. L.P., S.H. Hutchins, and L.G. Higley. 1986. Economic injury levels in theory and practice. Ann. Rev. Entomol. 31:341-368.

Russell, J.S., B.R. Leonard, J. Gore, and G.E. Church. 1999. Cotton boll abscission influenced by tarnished plant bug feeding. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN. pp. 1046-1048.

Stern, V.M., R.F. Smith, R. van den Bosch, and K.S. Hagen. 1959. The integrated control concept. Hilgardia. 29:81-101.

Tugwell, N.P., S.C. Young, B. Dumas, and J.R. Phillips. 1976. Plant bugs in cotton: Importance of infestation time, types of cotton injury, and significance of wild hosts near cotton. University of Arkansas Agricultural Experiment Station Technical Bulletin 227.

Tugwell, N.P., D.M. Danforth, S. Mi, and S. Bradshaw. 1999. SCOUTMAP: COTMAN monitoring technique for monitoring boll shed and insect damage. Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, TN. Vol 2:1230.

Wells, V.D. 1991. Timing of cotton defoliation based upon the upper most white flower as a measure of the maturity of the last effective boll population. M.S. Thesis, University of Arkansas, Fayetteville.

Zhang, J.P., M.J. Cochran, N.P. Tugwell, F. M. Bourland, D. M. Oosterhuis, and D.M. Danforth. 1994. Using long-term weather patterns for targeting cotton harvest completion. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN, p. 1284-1285.

Table 1. Timing of TPB introductions and time of initiating and terminating insecticide sprays in relation to calendar date and stage of crop development.

Infestation treatments	Date of application	DD60s accrued after physiological cutout[z]	DD60s accrued after seasonal cutout date[y,x]
Applied bugs 3	10, 17, 24 Aug	156	19
Applied bugs 2	17, 24 Aug	296	137
Applied bugs 1	24 Aug	375	272
Natural infestation only			
Sprayed[w]	10, 16, 22, 28 Aug	488	356

[z] DD60 accumulation began when a treatment mean reached NAWF=5.

[y] Latest possible cutout date of 9 Aug based on historical probability (50%) for accruing heat units (DD60s) needed for boll maturation.

[x] Daily DD60s = (daily high temperature (°F) +daily low temperatue)/2 – 60.

[w] Centric (3 oz/acre) sprayed on each date with final spray at 488 DD60s after physiological cutout/ or 356 DD60s after the seasonal cutout date.

Table 2. Mean number of nodes above white flower (NAWF), number of sympodial nodes with bolls, total sympodial nodes, percent total square shed, percent small boll shed, percent large boll shed, percent total boll shed, and total percent shed fruiting forms (all first position) observed in plant monitoring observations made following infestation treatments.

Sample date	Infestation treatment	NAWF	No. sympodial nodes with bolls	Total square shed	Small boll shed	Large boll shed	Total boll shed	Total fruiting form shed
				(%)				
16 Aug	Bugs 3	3.4	10.9	45.1	48.9	39.8	42.3	40.2
	Bugs 2	3.3	11.1	28.0	33.3	43.4	40.7	35.3
	Bugs 1	3.3	11.5	16.0	22.2	40.6	35.8	29.4
	Natural	3.5	11.2	20.8	35.7	49.6	45.8	37.3
	Sprayed	3.9	10.7	13.8	31.1	44.4	40.6	31.3
	P > F	*0.79*	*0.88*	*0.24*	*0.15*	*0.41*	*0.42*	*0.16*
23 Aug	Bugs 3	2.5	10.5	76.3	48.9	37.5	40.8	44.9
	Bugs 2	2.5	12.5	71.0	40.0	33.6	35.1	38.7
	Bugs 1	2.3	11.9	60.0	60.0	35.8	41.9	41.9
	Natural	2.2	12.5	60.6	44.4	43.4	43.6	43.2
	Sprayed	2.5	11.9	16.2	31.1	44.0	40.8	34.2
	P > F	*0.97*	*0.16*	*0.07*	*0.15*	*0.47*	*0.18*	*0.21*
30 Aug	Bugs 3	2.0	13.4	100.0	71.1	49.4	54.2	56.5
	Bugs 2	1.7	13.6	100.0	71.1	41.5	48.0	50.6
	Bugs 1	1.9	13.8	100.0	62.2	39.5	44.4	48.0
	Natural	2.1	13.7	96.9	77.8	43.8	51.2	54.0
	Sprayed	2.3	12.6	91.2	44.4	36.8	38.6	43.7
	P > F	*0.84*	*0.32*	*0.46*	*0.40*	*0.74*	*0.37*	*0.34*

Table 3. Mean percent injured first position small squares, total first position squares, first position small, large, and total bolls, and total first position fruiting forms with symptoms of tarnished plant bug feeding injury observed during 3 sample dates for each infestation treatment.

Sample date	Infestation treatment	Total squares	Small bolls[z]	Large bolls	Total bolls	Total fruit. forms[z]
		(%)				
16 Aug	Bugs 3	23.5	24.4 a	8.5	12.9	14.4
	Bugs 2	8.0	13.3 ab	3.3	6.0	6.0
	Bugs 1	8.0	13.3 ab	2.3	5.2	5.5
	Natural	11.3	8.9 ab	4.1	5.4	6.4
	Sprayed	6.9	0.0 b	3.5	2.5	3.4
	P > F	*0.36*	*0.05*	*0.38*	*0.34*	*0.15*
23 Aug	Bugs 3	52.6	35.6 a	16.1	21.7	25.7 a
	Bugs 2	52.6	44.4 a	12.6	20.2	24.1 a
	Bugs 1	31.4	11.1 b	7.6	8.4	11.4 bc
	Natural	42.4	33.3 a	7.0	13.3	16.5 ab
	Sprayed	18.9	0.0 c	5.2	3.9	6.2 c
	P > F	*0.17*	*0.002*	*0.10*	*0.08*	*0.009*
30 Aug	Bugs 3	100.0	26.7	23.1	23.9	34.2
	Bugs 2	100.0	20.0	17.6	18.1	26.5
	Bugs 1	71.4	28.9	12.4	15.9	21.2
	Natural	75.0	15.6	14.4	14.6	21.4
	Sprayed	26.5	8.9	6.3	6.9	9.4
	P > F	*0.15*	*0.45*	*0.18*	*0.2*	*0.1*

[z] Means within a column for a sample date followed by different letters are significantly different (LSD 0.05).

Table 4. White flowers with feeding injury symptoms and number of tarnished plant bugs observed in 10 flowers on 2 sample dates following infestation treatments.

Sample date	Infestation treatment	Flowers with anther injury[z]	No. bugs in 10 flowers
16 Aug	Bugs 3	70.0	3.0
	Bugs 2	43.3	2.0
	Bugs 1	40.0	0.7
	Natural	40.0	1.7
	Sprayed	3.3	0.0
	P > F	*0.01*	*0.09*
23 Aug	Bugs 3	100.0	10.0
	Bugs 2	83.3	5.9
	Bugs 1	83.3	3.7
	Natural	70.0	7.0
	Sprayed	16.7	0.3
	P > F	*0.005*	*<0.001*

[z] Symptoms likely were associated with bug feeding although spotted cucumber beetles (*Diabrotica* spp.) were present in some flowers and could have contributed to injury.

Table 5. Mean cumulative lint yield for each infestation treatment for each date of harvest.

	Cumulative lint[z] yield per harvest date		
Infestation treatment	27 Sept	2 Oct	9 Oct
Bugs 3	601	970	1186
Bugs 2	516	872	1243
Bugs 1	496	841	1211
Natural	516	837	1253
Protected	391	819	1219
P>F	*0.84*	*0.94*	*0.89*

[z] Lint yields based on 0.33% gin turnout.

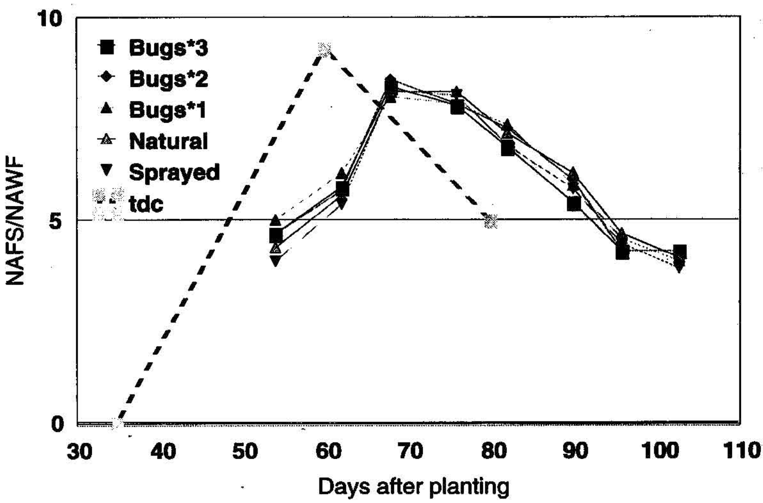


Fig. 1. Growth curves for plants in each treatment; data represent changes in nodes above first square/nodes above white flower through cutout. The latest possible cutout date, 9 Aug, was 99 days after planting.

EFFECTS OF APHID FEEDING ON FOLIAR ANTIOXIDANT ENZYMES IN COTTON

S. Karen Gomez, Derrick M. Oosterhuis, Satyendra N. Rajguru, and Donald R. Johnson[1]

RESEARCH PROBLEM

Conflicting results exist regarding the effects of aphid feeding on cotton (*Gossypium hirsutum* L.). It is still not clear if aphids themselves or their association with biotic stresses are responsible for physiological changes that could lead to decreased cotton yields. In previous studies, we found no significant change in photosynthesis or increased photosynthesis after exposing cotton plants to 9 days of aphid feeding. Very little information is available regarding the interactions between the aphid and cotton system. Moreover scarce information exists about the antioxidant responses in plants to phloem-feeding insects. In order to understand the biochemical changes induced by a phloem-feeding insect such as *Aphis gossypii* on cotton, we determined the activity of antioxidant enzymes after aphid feeding on cotton leaves.

BACKGROUND INFORMATION

Living organisms face a variety of internal and external stresses to which they must respond in order to maintain equilibrium. Numerous studies have reported that organisms may be stressed by biotic factors (e.g., nematodes, insects, and fungal, bacterial or viral pathogens) or abiotic factors (e.g., temperature extremes, drought, UV irradiation, high salt concentrations, herbicide exposure, nutrient deficiency) (in a review by Yu and Rengel, 1999). Life in an atmosphere containing oxygen has led to the evolution of biochemical adaptations that exploit the reactivity of active oxygen species (AOS) (Noctor and Foyer, 1998). Plants continuously produce AOS even under optimal conditions. AOS are involved in all major areas of aerobic biochemistry (e.g., respiratory and photosynthetic electron transport; oxidation of glycolate and glucose)

[1] Graduate assistant, distinguished professor, and research associate, Department of Crop, Soil, and Environmental Sciences, Fayetteville; and pest management section leader and IPM coordinator, Cooperative Extension Service, Little Rock.

and are produced in large quantities by several enzyme systems. These AOS attack lipids, proteins and nucleic acids, causing lipid peroxidation, protein denaturation and DNA mutation (Yu and Rengel, 1999; Noctor and Foyer, 1998). On the other hand, a defense system exists in plants that serves to detoxify these potentially dangerous reactive molecules. Most of these detoxification reactions are mediated by antioxidant enzymes. There is little doubt that arthropod herbivory induces biochemical and physiological changes in the host plants. In barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.), glutathione reductase activity increased after herbivory by aphids (*Sitobium avenae* F.) (Argandoña, 1994). Phloem-feeding insects seem to induce responses similar to pathogen infection and activate the salicylic acid (SA)-dependent and jasmonic acid (JA)/ethylene-dependent signaling pathways (Walling, 2000). Determination of antioxidant enzyme levels in host plants would serve as a quantitative indicator of stress following aphid herbivory.

MATERIALS AND METHODS

Three identical experiments were conducted in a growth chamber at the Altheimer Laboratory, University of Arkansas at Fayetteville. The growth chamber was programmed for 14:10 hours (day/night), with day/night temperatures ranging from 28°C to 16°C, and 75% relative humidity. 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. Plants were maintained in a well-watered status to avoid drought stress. 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, 50 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. Averages of 137 aphids per tagged leaf after 6 days of exposure and 255 aphids per tagged leaf after 9 days of exposure were recorded. After the plants had been exposed to 6 days of aphid feeding (26 DAP), three plants per treatment were sprayed with 1% (v/v) sodium dodecyl sulfate (SDS) and rinsed with deionized water one hour prior to collecting the leaves to remove the aphids. The tagged leaves were frozen in liquid nitrogen and kept at -70°C for subsequent protein extraction. The same procedure was repeated on the second leaf sampling in which leaves were exposed to 9 days of aphid feeding (29 DAP). For the protein extraction we followed the protocol used by Anderson et al. (1992), with slight modifications. Approximately 1 g of frozen tissue was used for the protein extraction, followed by centrifugation and desalting. The first antioxidant enzyme was catalase which had to be measured immediately due to its instability. The remaining eluate was frozen at -70°C for subsequent assays. All enzyme analyses were performed with a BioSpec

1601 UV/VIS spectrophotometer (Shimadzu, Columbia, Maryland). For the Catalase (CAT) assay, we followed Beers and Sizer (1952) protocol. We measured the disappearance of H_2O_2 by a decrease in absorbance at 240 nm for 1 min. at 25°C. A total of thirty-six tissue samples were processed, and each data point represents the mean of 27 values per treatment per sampling time. For the Peroxidase (POX) assay, the protocol used by Nickel and Cunningham (1969) was followed. We measured the hydrogen peroxide-dependent oxidation of 2, 3', 6 trichloroindophenol at 675 nm for 1 min. at 25°C. For the Ascorbate Peroxidase (APX) assay, we followed Anderson et al. (1992) protocol. We measured the ascorbic acid dependent reduction of H_2O_2 at 265 nm for 1 min. at 25°C. for the Glutathione Reductase (GR) assay, the assay used by Shaedle and Bassham (1977) was followed. We measured the glutathione dependent oxidation of NADPH+H at 340 nm for 1 min. at 25°C.

RESULTS AND DISCUSSION

An initial aphid infestation of 50 aphids per leaf increased to 137 aphids per leaf after 6 days and 255 aphids per leaf after 9 days. However, these populations of aphids had no significant effect on catalast, peroxidase, or ascorbate peroxidase activity. The activity of glutathione reductase was significantly higher in aphid-infested leaves than in non-infested leaves on day 6. This indicates that cotton plants were experiencing some stress caused by aphid herbivory. It has been shown that in this cascade of reactions, the levels of some antioxidant enzymes decrease as compared to others. It has been reported that antioxidant enzymes act almost immediately after the stress, and when the AOS are under control, the levels of antioxidant enzymes decrease. This could explain the unaltered levels of CAT, POX and APX.

PRACTICAL APPLICATION

Overall, an initial population of 50 aphids and 137 aphids per leaf on the sixth day did not alter the activity of foliar antioxidant enzymes, except for glutathione reductase. Probably cotton plants were experiencing some stress as indicated by higher levels of GR. An aphid infestation of 255 per leaf on the ninth day did not change the activity of foliar antioxidant enzymes in cotton. In general, this research demonstrated that cotton plants were only slightly altered physiologically or biochemically by the levels of aphid infestation and feeding duration used in this study.

ACKNOWLEDGMENTS

We are thankful to Dr. Nilda Burgos for the use of the spectrophotometer in her laboratory.

LITERATURE CITED

Anderson, J.V., Chevone, B.I., and Hess, J.L. 1992. Seasonal variation in the antioxidant system of Eastern white pine needles. Plant Physiology 98:501-508.

Argandoña, V.H. 1994. Effect of aphid infestation on enzyme activities in barley and wheat. Phytochemistry 35:313-315.

Beers, R.F., and Sizer, I. 1952. A spectrophotometric method for measuring the breakdown of hydrogen peroxide by catalase. J. Biological Chemistry 195:133-.

Nickel, R.S., and Cunningham, B.A. 1969. Improved peroxidase assay method using leuco 2, 3', 6 trichloroendophenol and application to comparative measurements of peroxidase catalysis. Annals of Biochemistry 27:292-299.

Noctor, G., and Foyer, C.H. 1998. Ascorbate and glutathione: Keeping active oxygen under control. Annual Review of Plant Physiology 49:249-279.

Schaedle, M., and Abassham, J. 1977. Chloroplast glutathione reductase. Plant Physiology 59:1011-1012.

Walling, L.L. 2000. The myriad plant responses to herbivores. Journal of Plant Growth Regulator 19:195-216.

Yu, Q., and Rengel, Z. 1999. Micronutrient deficiency influences plant growth and activities of superoxide dismutase in narrow-leafed lupins. Annals of Botany 83:175-182.

INCLUSION OF BENEFICIAL INSECTS INTO THE COTTON APHID TREATMENT THRESHOLD

Hugh E. Conway, Donald C. Steinkraus, and Timothy J. Kring[1]

RESEARCH PROBLEM

Aphids are a serious insect pest in Arkansas and more information is needed on control and threshold treatment levels. The objective of this study was to design management methods which incorporate the action of biological control agents in establishing a threshold for the cotton aphid, *Aphis gossypii.*

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 beneficial insects and the entomopathogenic aphid fungus, *Neozygites fresenii,* into the decision-making process. The use of natural enemies in making treatment decisions is a new and novel concept in row-crop agriculture.

METHODS

The 12-acre Clarkedale, Arkansas, study field was subdivided into 16 plots, each ~ 0.75 acre in size (56 rows x 63 m). The experiment consisted of four treatments with four replicates in a Latin Square design: (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., 2000). Conventional plots were treated when >50% of the plants were infested and aphid populations were increasing (Johnson, 2001). Experimental plots were treated when the conventional threshold was reached *and* aphid densities exceeded 15 aphids/leaf IF "no"

[1] Graduate assistant, professor, and professor, Department of Entomology, Fayetteville.

fungus, parasitoids or coccinellids; 30 aphids/leaf IF "no" fungus, 10% mummies, 1 coccinellid adult/row-m, 0.6 coccinellid larvae/row-m; 50 aphids/leaf IF 10% visible fungus, no parasitoids, or coccinellids; or 70 aphids/leaf IF 10% visible fungus, 10% mummies, 1 coccinellid adult/row-m, 0.6 coccinellid larvae/row-m.

Twice-weekly samples of aphid number and types (small, large, winged, and parasitized) were taken from one fully-expanded 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* (Steinkraus et al., 1991).

Twice weekly samples of natural enemies were taken using a dislodgement method where the plants were struck onto a wire covering a wash basin (Elkassabany et al., 1996). Density levels of beneficial insects were obtained by sampling 8 row-m per plot (8 samples per plot each sample 1 row-m in length). Beneficial insects collected using this method included: the coccinellids (lady beetles) *Coccinella septempunctata, Harmonia axyridis, Hippodamia convergens, Coleomegilla maculata, Scymnus* spp., predaceous Heteroptera *(Geocoris* spp., *Orius insidious, Nabis* spp.), lacewings *(Chrysopa* spp., *Hemerobius* spp.), and others (spiders and *Collops quadrimaculatus*).

RESULTS

Cotton aphid populations began increasing in mid-June to mid-July until reaching the conventional treatment level on 18 and 28 June 1999 (Fig. 1), 28 June and 3 July 2000 (Fig. 2), and 7 and 12 July 2001 (Fig. 3). The experimental treatment threshold was reached on 28 June 1999, 3 July 2000, and 19 July 2001. An application of 0.22 L/ha of imidacloprid was made to appropriate plots when aphids reached the threshold levels. When aphid populations neared a peak after the final insecticide applications, an epizootic of the fungus *Neozygites fresenii* caused a rapid decrease in aphid numbers. The aphid peak occurred on 29 Jun 1999 (Fig. 1), 6 July 2000 (Fig. 2), and 27 July 2001 (Fig. 3).

Aphid densities declined over the three years of the study; in the untreated plots, aphids/leaf peaked at ~140 in 1999 (Fig. 1), ~40 in 2000 (Fig. 2), and ~13 in 2001 (Fig. 3). Similarly in treated plots, aphids/leaf increased to ~50 in 1999 (Fig. 1), ~40 in 2000 (Fig. 2), and ~15 in 2001(Fig. 3).

The coccinellids (adult and larvae) were the dominant aphid predators present in the cotton field each year (Fig. 4). The larval density curve followed the aphid density increase with a lag of 5 to 10 days. Larval coccinellids/row-m in the untreated plots peaked at ~9 in 1999 (Fig. 5), ~4 in 2000 (Fig. 6), and ~0.6 in 2001 (Fig. 7). Larvae/row-m in the treated plots peaked at ~3 in 1999, ~1.5 in 2000, and ~ 0.5 in 2001. The adult coccinellid growth curve followed the increase in the larval curve with a lag of 5 to 10 days. Adult coccinellids/row-m in the untreated plots peaked at ~3 in 1999 (Fig. 5), ~2.5

in 2000 (Fig. 6), and ~0.5 in 2001 (Fig. 7). Adult coccinellids/row-m in treated plots peaked at ~1 in 1999, ~2 in 2000, and ~0.5 in 2001. In 2001, malathion sprays for the boll weevil eradication program that occurred on 5 and15 June and on 3, 11, 18, and 24 July clearly affected natural enemy populations (Fig. 7).

In 1999, cotton lint yield was significantly higher in plots using the experimental threshold ($P<0.05$, LSD) in comparison to untreated plots (Fig 8). Yields using conventional threshold were intermediate and not significantly different from untreated or the experimental plots. In 2001, cotton lint yield was higher than in 1999 or 2000.

PRACTICAL APPLICATION

The experimental threshold resulted in a 1 to 2 week delay in treatment application in each of the three years. The treatment delay eliminated the need for a second application in the experimental plots. We feel that the presence of the coccinellids permitted the treatment delay. The cotton lint yields were not negatively affected by reduced insecticide application during any of the three years. In fact during 1999 when aphid populations were greatest, there was a significant increase in yields in the experimental plots.

Research results indicate that inclusion of beneficial insects into the economic threshold have the potential of delaying the initial insecticide application and reducing the number of insecticide applications. Such delays in application oppose conventional wisdom, but show a potential for maintaining yields and decreasing the likelihood of pesticide resistance in the cotton aphid. This new and novel approach promises a benefit to cotton production, and on-farm demonstrations are planned for the 2002 growing season.

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.

Johnson, D.R. 2001. Insect Recommendations for Arkansas. University of Arkansas, United States Department of Agriculture, and County Government Cooperative Extension Service. MP 144:1-143.

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

Wells, M.L., R.M. McPherson, J.R. Ruberson, and G.A. Herzog. 2000. Effect of fungicide application on activity of *Neozygites fresenii* (Entomophthorales:Neozygitacaea) and cotton aphid (Homoptera: Aphididae) suppression. J. Econ. Entomol. 93:1118-1126.

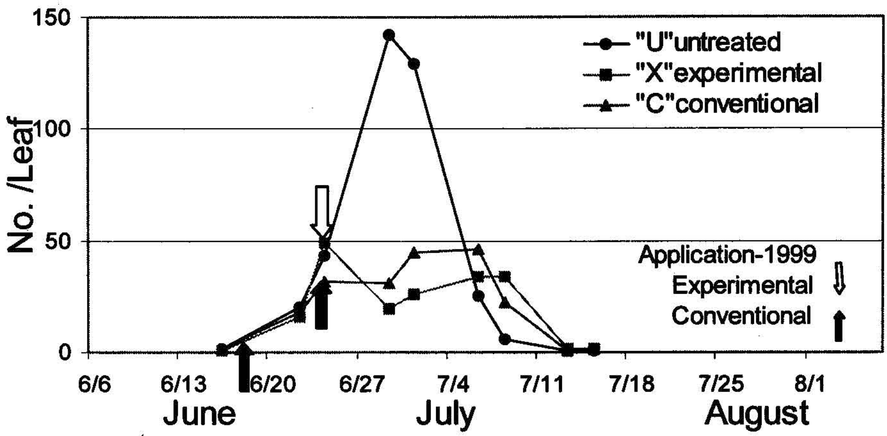


Fig. 1. Aphids per leaf from test plots at Delta Branch Station, Clarkedale, AR, 1999.

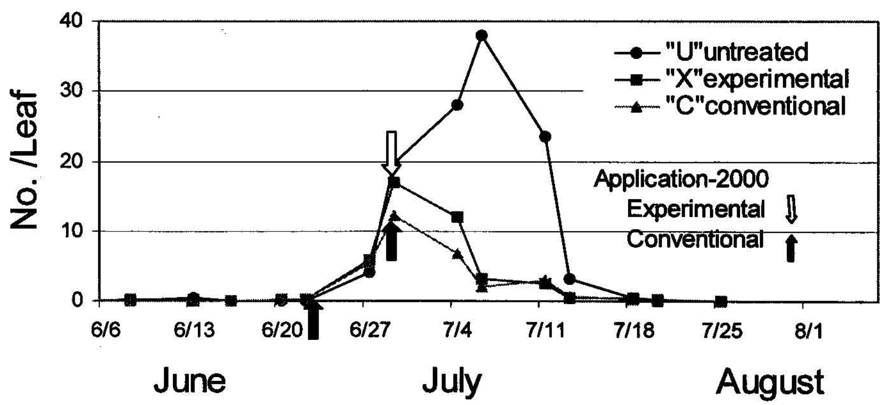


Fig. 2. Aphids per leaf from test plots at Delta Branch Station, Clarkedale, AR, 2000.

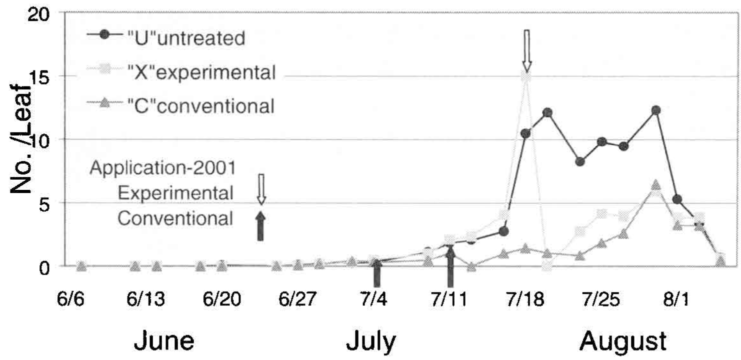


Fig. 3. Aphids per leaf from test plots at Delta Branch Station, Clarkedale, AR, 2001.

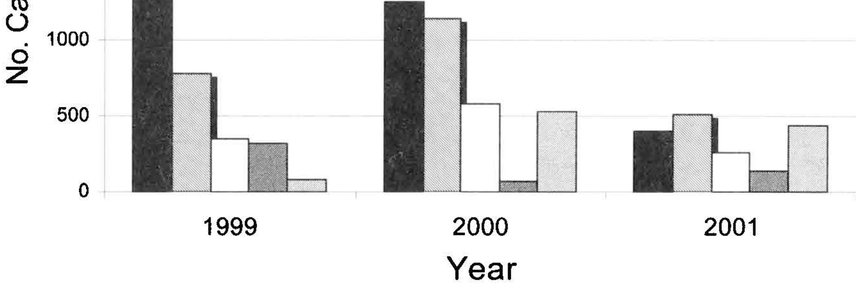


Fig. 4. Comparison of beneficial insects per year from test plots in Delta Research Station, Clarkedale, AR, 1999-2001.

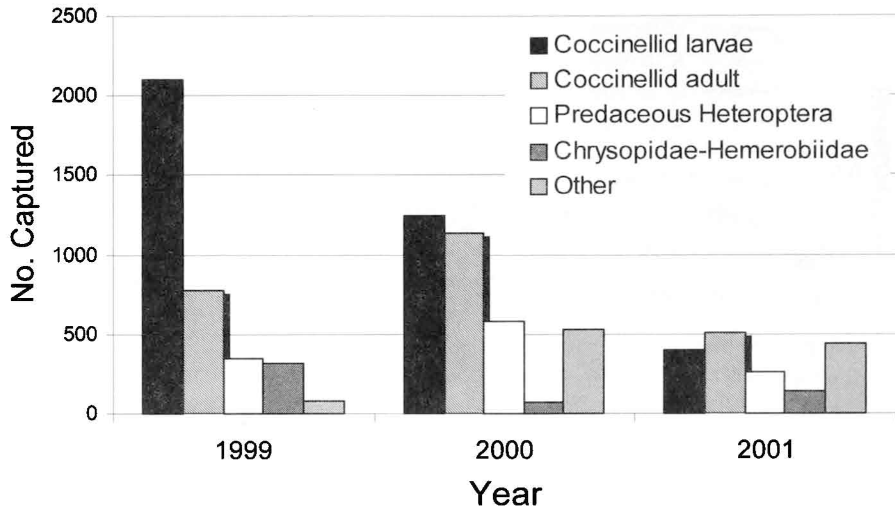


Fig. 5. Coccinellid (adult and larvae) per row meter taken from test plots in Delta Research Station, Clarkedale, AR, 1999.

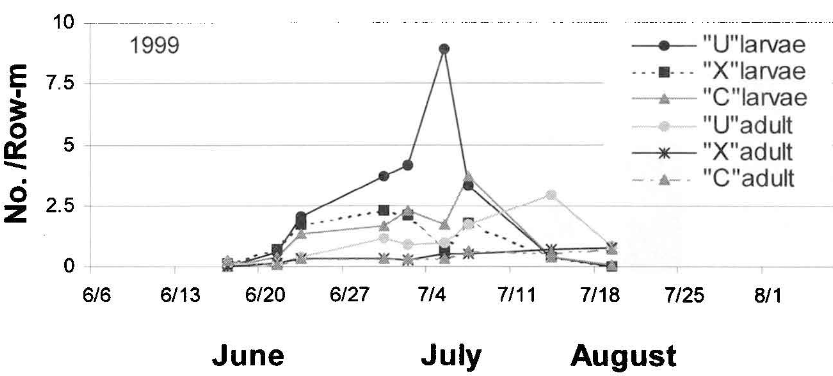


Fig. 6. Coccinellid (adult and larvae) per row meter taken from test plots in Delta Research Station, Clarkedale, AR, 2000.

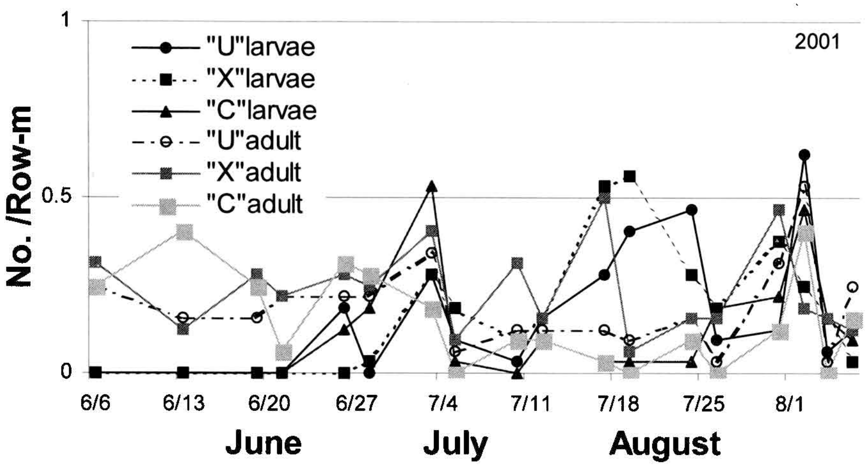


Fig. 7. Coccinellid (adult and larvae) per row meter taken from test plots in Delta Research Station, Clarkedale, AR, 2001.

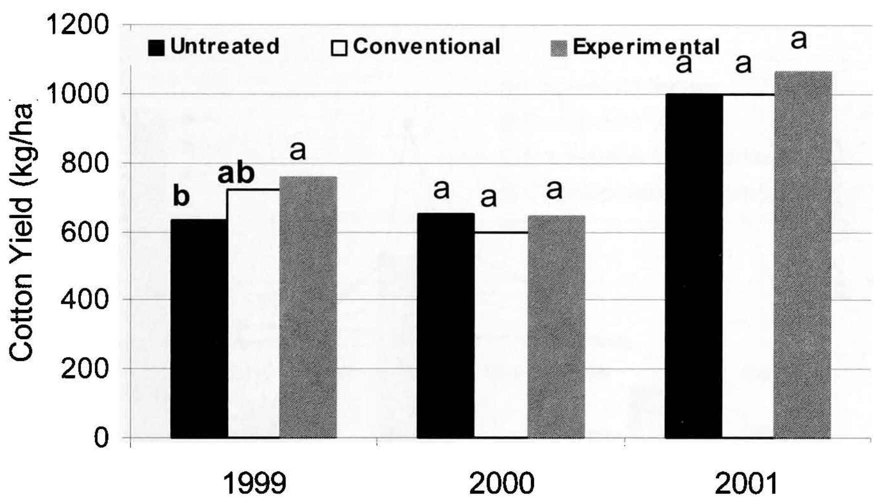


Fig. 8. Cotton lint yield results from test plots at Delta Research Station, Clarkedale, AR, 1999-2001.

EFFICACY OF EMERGING AND EXISTING INSECTICIDES FOR CONTROL OF APHIDS AND WHITEFLIES IN SOUTHEAST ARKANSAS COTTON

Jeremy K. Greene and Chuck Capps[1]

RESEARCH PROBLEM

The cotton aphid, *Aphis gossypii*, and the banded-winged whitefly, *Trialeurodes abutilonea*, were noteworthy "secondary" pests during 2001, and populations of both pests dramatically increased in transgenic *Bt* cotton (NuCOTN33B). Our trials addressed the effectiveness of several new insecticides when compared with existing materials.

BACKGROUND INFORMATION

Since the introduction of cotton containing genetic information from *Bacillus thuringiensis* (*Bt*), producers growing the transgenic crop have been dealing with insect pests that infrequently required attention in the past. Some of these pests were traditionally considered "secondary pests", i.e., secondary to the boll weevil *(Anthonomus grandis)*, to the tobacco budworm complex (*Heliothis virescens)*, and to the cotton bollworm (*Helicoverpa zea)*. Pests such as aphids and whiteflies have always been "secondary" to major pests, but over the years, there has been much research and debate over population levels needed to justify their control. In *Bt* cotton, aphids and whiteflies continue to receive additional attention because of their destructive potential in the low-spray environment of this crop. When chemical control of these pests is warranted, information about the effectiveness of new and existing products is needed. During 2001, we conducted insecticide efficacy trials for the cotton aphid, *Aphis gossypii*, and the banded-winged whitefly, *Trialeurodes abutilonea*, in southeast Arkansas.

---

[1] Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello.

MATERIALS AND METHODS

Plots of cotton (NuCOTN33B) planted on 4 June 2001 in loam soil at the Southeast Branch Experiment Station near Rohwer, Arkansas, consisting of four 38-inch rows by forty feet. Treatments were randomly assigned to plots and were replicated four times. Standard field preparation, fertilization, and irrigation procedures were followed using Arkansas Recommendations (Chapman et al., 2000).

Insecticides were applied on 6, 10, 12, 17, and 20 July for the aphid trials (I and II) and on 14 and 21 August and on 11 September 2001 for the whitefly trial. Insecticides and field-use rates for the aphid trials were dicrotophos (Bidrin 8, Amvac, Los Angeles, CA, 0.33 and 0.50 lb ai/acre); bifenthrin (Capture 2, FMC, Philadelphia, PA, 0.05 lb [ai]/acre); thiacloprid (Calypso 4, Bayer, Kansas City, MO, 0.036 and 0.047 lb ai/acre); imidacloprid/cyfluthrin (Leverage 2.7, Bayer, 0.0634 lb ai/acre); oxamyl (Vydate 3.77, DuPont, Wilmington, DE, 0.33 lb ai/acre); imidacloprid (Provado 1.6F, Bayer, 0.0125 and 0.047 lb ai/acre); thiamethoxam (Centric 25WG, Syngenta, Greensboro, NC, 0.0237 and 0.0473 lb ai/acre); dimethoate (Dimethoate 4EC, Helena, 0.25 lb ai/acre); and acetamiprid (Assail 70WP, Aventis Crop Science, Research Triangle Park, NC, 0.0374 and 0.05 lb ai/acre). Insecticides and field-use rates for the whitefly trial were bifenthrin (Capture 2, FMC, 0.05 lb ai/acre); thiacloprid (Calypso 4, Bayer, 0.036 and 0.047 lb ai/acre); imidacloprid/cyfluthrin (Leverage 2.7, Bayer, 0.0634 lb ai/acre); imidacloprid (Provado 1.6F, Bayer, 0.047 lb ai/acre); thiamethoxam (Centric 25WG, 0.0473 lb ai/acre); acephate (Orthene 97, Valent, Walnut Creek, CA, 0.75 lb ai/acre); and acetamiprid (Assail 70WP, 0.05 and 0.075 lb ai/acre). Insecticides were applied using a 4-row CO_2-powered plot boom attached to a hi-cycle sprayer calibrated to apply 10 GPA at 42 psi. Insect populations were estimated by counting/approximating all aphids or whitefly adults found on the underside of each of 10 leaves (uppermost large leaf) in each plot. Data were processed using Agriculture Research Manager (ARM) (Gylling Data Management, Inc., Brookings, SD), and means were separated using Least Significant Difference (LSD) procedures following significant F tests and Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Aphid Trials

On 2 July, pre-treatment (PT) counts of aphid populations resulted in an average of ca. 20 aphids per leaf (Table 1). By 3 days after the first treatment of insecticides (3DAT1), aphid numbers had reached 73 aphids per leaf in the untreated control (UTC). All products, except for Dimethoate and Capture, provided significant control of aphids 3DAT1, while both rates of Assail and Centric provided the best control. Kharboutli and Allen (2000) reported similar results with efficacy of Centric on aphids in trials in southeast Arkansas. During mid-July, the cotton aphid fungus, *Neozygites fresenii*, caused an epidemic, and aphid numbers "crashed." By 7DAT2, aphid numbers were

less than 8 aphids per leaf in the UTC plots. In the second aphid trial, PT counts resulted in an average of ca. 38 aphids per leaf (Table 2). Three days after the first treatment (3DAT1), Centric, Bidrin, and Vydate all significantly reduced aphid numbers, but only Centric provided extended control at 5DAT1. By 5DAT2 (mid-July), populations of aphids were greatly reduced throughout the test area.

Whitefly Trial

On 13 August, PT counts of banded-winged whitefly populations resulted in an average of 76 adult whiteflies per leaf (Table 3). By 2 days after the first application of insecticides (2DAT1), whitefly numbers decreased to 46 whitefly adults per leaf in the UTC. All materials provided significant control of whitefly adults 2DAT1, while the highest rate of Assail provided the best control. A recent comparable trial (unpublished) reported similar positive results with efficacy of Assail on silverleaf whiteflies, *Bemisia argentifolii* (Natwick and Deeter 2001). By 7DAT1, populations of adult whiteflies had rebounded, and no product provided significant extended suppression. Two days after the second treatment (2DAT2), Leverage, Assail, Centric, and Capture all provided significant control of whitefly adults. By 8DAT2, Assail and Centric were the only materials that provided significant suppression of whiteflies.

PRACTICAL APPLICATION

Overall, the newer insecticides, acetamiprid (Assail) and thiamethoxam (Centric), provided excellent control of both aphids and whiteflies, while the performance of some existing compounds was inadequate.

ACKNOWLEDGMENTS

We thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance. We also thank Syngenta, Bayer, FMC, Valent, AMVAC, and Aventis for their support of this research.

DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

LITERATURE CITED

Chapman, S.L. 2000. Soil Test Recommendations Guide. University of Arkansas Division of Agriculture publication 39.

Kharboutli, M.S., and C.T. Allen. 2000. Comparison of insecticides for cotton aphid control. *In:* D.M. Oosterhuis (ed.). University of Arkansas Agricultural Experiment Station Special Report 198:128-130.

Natwick, E.T., and B.D. Deeter. 2001. Comparison of neonicotinoid with pyrethroid insecticides for control of whitefly in cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN, 2:906-908.

Table 1. Average number of aphids per 10 leaves.

Treatment	PT	3DAT1	7DAT2
UTC	23.1 ab[z]	72.85 a	7.88 ab
Centric 0.0237 lb ai/acre	13.8 b	11.88 cd	3.92 c
Centric 0.0473 lb ai/acre	18.4 ab	11.63 cd	5.35 bc
Dimethoate 0.25 lb ai/acre	21.7 ab	66.13 a	10.38 a
Bidrin 0.5 lb ai/acre	17.9 ab	36.35 b	3.65 c
Provado 0.047 lb ai/acre	16.3 ab	23.15 bcd	5.25 bc
Calypso 0.036 lb ai/acre	21.6 ab	28.88 bc	4.57 bc
Calypso 0.047 lb ai/acre	13.9 b	34.40 b	5.00 bc
Bidrin 0.33 lb ai/acre + Provado 0.0125 lb ai/acre	19.6 ab	33.08 b	4.60 bc
Leverage 0.0634 lb ai/acre	25.9 a	31.48 b	3.45 c
Capture 0.05 lb ai/acre	21.2 ab	72.97 a	4.92 bc
Assail 0.0374 lb ai/acre	23.9 ab	12.23 cd	2.50 c
Assail 0.05 lb ai/acre	17.2 ab	6.53 d	2.20 c

[z] Treatment means within a column followed by same letter do not differ significantly (P >0.05, LSD).

Table 2. Average number of aphids per 10 leaves.

Treatment	PT	3DAT1	5DAT1	5DAT2
UTC	44.3 a[z]	76.25 a	41.13 a	0.55 ab
Centric 0.0473 lb ai/acre	38.2 a	8.35 c	4.57 b	0.58 ab
Bidrin 0.33 lb ai/acre	40.8 a	39.88 b	36.75 a	0.57 ab
Vydate 0.33 lb ai/acre	40.3 a	51.88 b	47.75 a	0.30 b

[z] Treatment means within a column followed by same letter do not differ significantly (P >0.05, LSD).

Table 3. Average number of whitefly adults per 10 leaves.

Treatment	PT	2DAT1	7DAT1	2DAT2	8DAT2
UTC	76.97 a[z]	46.05 a	44.63 a	47.75 a	68.75 b
Calypso 0.036 lb ai/acre	65.13 a	15.45 c	48.88 a	31.88 ab	51.50 b
Calypso 0.047 lb ai/acre	70.25 a	12.40 cd	68.38 a	32.13 ab	55.50 b
Leverage 0.0634 lb ai/acre	68.18 a	11.10 cde	58.50 a	15.25 b	59.50 b
Provado 0.047 lb ai/acre	94.90 a	11.30 cde	64.00 a	28.88 ab	66.88 b
Assail 0.05 lb ai/acre	76.38 a	5.75 de	66.75 a	18.00 b	13.82 c
Assail 0.075 lb ai/acre	81.55 a	3.28 e	41.50 a	13.63 b	11.57 c
Centric 0.0473 lb ai/acre	82.20 a	6.95 de	62.50 a	18.13 b	15.25 c
Capture 0.05 lb ai/acre	70.05 a	30.75 b	64.38 a	22.13 b	119.88 a
Orthene 0.75 lb ai/acre	70.25 a	6.97 de	68.13 a	32.13 ab	49.50 b

[z] Treatment means within a column followed by same letter do not differ significantly (P >0.05, LSD).

EFFICACY OF NEW AND STANDARD INSECTICIDES FOR CONTROL OF THE HELIOTHINE COMPLEX IN SOUTHEAST ARKANSAS COTTON

Jeremy K. Greene and Chuck Capps[1]

RESEARCH PROBLEM

The Heliothine complex, comprised of the cotton bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (F.), was the major pest complex of conventional cotton varieties in southeast Arkansas during 2001. The development of resistance to organophosphates, carbamates, and pyrethroids has facilitated the development of new chemistries of insecticides that may aid in controlling this pest complex, and our trials addressed the effectiveness of these new insecticides when compared with existing materials.

BACKGROUND INFORMATION

The development of new pest control measures is necessary for successful cotton production in southeast Arkansas. The Heliothine (cotton bollworm, *Helicoverpa zea,* and the tobacco budworm, *Heliothis virescens*) pest complex continues to develop resistance to over-used classes of insecticides, but the development of new insecticides such as Denim, Steward, Tracer, Intrepid, and advanced pyrethroids should help ease the resistance problem. Previous research has addressed some of these new products (Kharboutli, 2001; Reaper et al., 2001; Leonard et al., 2001), but their effectiveness needs evaluation over time. In trials conducted at the Southeast Branch Experiment Station, the effectiveness of these new insecticides was compared with that of existing standards.

---

[1] Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

Plots of cotton (Stoneville 474) planted on 4 June 2001 in loam soil at the Southeast Branch Experiment Station near Rohwer, Arkansas, consisted of four rows (38 in) by forty feet. Treatments were randomly assigned to plots and were replicated four times. Standard field preparation and fertilization procedures were followed using Arkansas recommendations (Chapman, 2000). Standard irrigation practices included four irrigations applied as needed according to the irrigation scheduler model.

An ovicide trial was conducted on the Mar Miles farm near Monticello, Arkansas. Cotton (Stoneville 4691B) was planted on 4 May 2001 on 38-in row spacing. Treatments were randomly assigned to plots that were four rows by thirty feet.

Insecticides applied on 21, 27, and 29 August and 6 September for the Heliothine Trial (Test 1), 17, 24, and 29 August 2001 for the Tank-mix Trial (Test 2), and 19 July for the Assail Ovicide Trial (Test 3) included the following: emamectin benzoate (Denim 0.16, Syngenta, Greensboro, NC, 0.0075 and 0.01 lb [ai]/acre); indoxacarb (Steward 1.25, DuPont, Wilimington, DE, 0.104 lb ai/acre); spinosad (Tracer 4, Dow AgroSciences, Indianapolis, IN, 0.067 lb ai/acre); lambda-cyhalothrin (Karate 2.08, Syngenta, 0.025 lb ai/acre); F0570 (FMC, Philadelphia, PA, 0.016 lb ai/acre); bifenthrin (Capture 2, FMC, 0.05 lb ai/acre); cyfluthrin (Baythroid 2, Bayer, Kansas City, MO, 0.025 lb ai/acre); imidacloprid/cyfluthrin (Leverage 2.7, Bayer, 0.0634 lb ai/acre); methoxyfenozide (Intrepid 2F, Rohm and Haas, Philadelphia, PA, 0.2 lb ai/acre); XR-225 (Dow AgroSciences, 0.00974 lb ai/acre); acetamiprid (Assail 70WP, Aventis Crop Science, Research Triangle Park, NC, 0.05 lb ai/acre); esfenvalerate (Asana XL, DuPont, 0.036 lb ai/acre); profenofos (Curacron 8E, Syngenta, 0.5 lb ai/acre); thiodicarb (Larvin 3.2, Aventis, 0.25 lb ai/acre); and methomyl (Lannate LV, DuPont, 0.25 lb ai/acre). Insecticides were applied using a 4-row CO_2-powered plot boom attached to a hi-cycle sprayer calibrated to apply 10 GPA at 42 psi. Insect and damage data were collected by examining 25 terminals, 25 squares (below the terminal), and 25 bolls in each plot. Treatments were applied to the ovicide trial by CO_2 backpack sprayer calibrated to apply 12.7 GPA. Eggs were collected (attempted to collect 100 eggs per treatment) the day after treatment and transported to the laboratory for observation for four days. Data were processed using Agriculture Research Manager (ARM, Gylling Data Management, Inc., Brookings, SD), and means were separated using Least Significant Difference (LSD) procedures following significant F tests using Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Test 1 (Heliothine)

A large moth flight near the end of August resulted in trap counts that were approximately 55% tobacco budworm and 45% bollworm. All insecticide treatments provided significant suppression of budworm/bollworm larval populations at three

days after the first application (3DAT1), while the compound F0570 and both rates of Denim provided the best control (Table 1). On the same date, all treatments resulted in significantly lower damage levels when compared with the UTC. Two days after the second application (2DAT2), both rates of Denim along with XR-225 provided the best control of Heliothines. On the same date, applications of Steward and XR-225 resulted in the lowest damage levels. Overall, some of the newest insecticides (XR-225, F0570, Denim, and Steward) demonstrated potential for use as budworm/bollworm materials while most of the other materials did not provide satisfactory control of mixed budworm/bollworm populations. Similar results were seen for most of these new chemistries in other tests conducted (Kharboutli, 2001; Reaper et al., 2001; Leonard et al., 2001).

Test 2 (Tank-Mix)

At four days after the first application (4DAT1), Denim + Baythroid (0.01 + 0.025) provided good control of mixed populations of budworm (55%) and bollworm (45%), while Steward + Asana, Lannate + Baythroid, and Tracer + Baythroid provided significant control as well (Table 2). All tank-mixed insecticides provided adequate control of Heliothines following the second application (3DAT2), with Tracer, Denim, and Steward (all with Baythroid) all providing the best control. In a test conducted in 2000 at the same location, Tracer, Denim, and Steward were effective treatments in reducing worm count and damage (Kharboutli, 2001).

Test 3 (Ovicide)

All treatments significantly reduced the percentage of eggs that hatched while increasing the mortality of the eggs when compared to the untreated check (Table 3).

PRACTICAL APPLICATION

Overall, Denim, Steward, XR-225, and F0570 provided good control of the Heliothine pest complex, especially when tank-mixed with a pyrethroid such as Baythroid or Asana. Larvin provided numerically the best ovicidal control of the Heliothine pest complex while Calypso and Assail also provided control.

DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

ACKNOWLEDGMENTS

We thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance. We also thank Syngenta, DuPont, Dow AgroSciences, FMC, Bayer, and Aventis for their support.

LITERATURE CITED

Chapman, S.L. 2000. Soil Test Recommendations Guide. University of Arkansas Division of Agriculture publication 39.

Kharboutli, M.S. 2001. Efficacy of new and traditional insecticides against the heliothine complex in southeast Arkansas cotton fields. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1105-1107.

Leonard, B.R., K. Emfinger, R. Gamble, J. Gore, and H. Jones. 2001. Insecticide efficacy against Louisiana populations of bollworm and tobacco budworm during 2000. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:927-930.

Reaper, J., J.D. Hopkins, D.R. Johnson, and G.M. Lorenz. 2001. Heliothine control in cotton with new chemistry. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1122-1125.

Table 1. Average number of larvae and damage counts (damaged terminals, squares, and bolls) per 25 plants from Heliothine Trial 2001.

		15 Aug 01 (PT)[z]		24 Aug 01 (3DAT1)[y]		29 Aug 01 (2DAT2)	
Treatment	Insecticide costs[x]	Avg. larvae	Total damage	Avg. larvae	Total damage	Avg. larvae	Total damage
(lb ai/acre)	($/acre)						
UTC	N/A	2.0 a	8.3 a	19.0 a	27.0 a	15.0 a	16.8 ab
Denim (0.0075)	$8.64	2.8 a	7.0 a	6.8 cd	12.0 b	7.8 cd	11.3 bc
Denim (0.01)	$11.53	4.5 a	6.3 a	6.5 cd	11.3 b	6.8 d	11.3 bc
Steward (0.104)	$13.77	2.3 a	5.0 a	7.0 cd	16.0 b	10.5 bcd	9.8 c
Tracer (0.0670)	$12.26	3.3 a	6.5 a	10.3 bc	12.0 b	9.8 bcd	11.8 bc
Karate Z (0.025)	$4.96	2.8 a	5.5 a	7.3 cd	11.8 b	10.0 bcd	12.5 abc
FO570 (0.016)	N/A	4.3 a	5.3 a	5.5 d	10.3 b	11.0 a-d	18.5 a
Capture (0.05)	$9.20	3.3 a	6.0 a	8.3 bcd	17.3 b	13.0 ab	13.8 abc
Baythroid (0.025)	$4.52	3.0 a	6.3 a	10.0 bc	13.3 b	8.3 cd	11.3 bc
Leverage (0.0634)	$9.04	3.0 a	6.0 a	7.0 cd	15.5 b	8.5 cd	10.0 c
Intrepid (0.2)	$18.60	2.3 a	4.8 a	9.8 bcd	14.0 b	11.8 abc	12.3 bc
XR-225 (0.00974)	N/A	2.3 a	5.0 a	8.8 bcd	13.3 b	7.5 cd	9.3 c
Assail (0.05)	N/A	3.5 a	6.3 a	12.3 b	14.8 b	9.5 bcd	14.8 abc

[z] PT = pretreatment
[y] DAT = days after treatment
[x] not including application costs

Table 2. Average number of larvae and damage counts (damaged terminals, squares, and bolls) per 25 plants from Tank-Mix Trial 2001.

		16 Aug 01 (PT)[z]		21 Aug 01 (4DAT1)[y]		27 Aug 01 (3DAT2)	
Treatment	Insecticide costs[x]	Avg. larvae	Total damage	Avg. larvae	Total damage	Avg. larvae	Total damage
(lb ai/acre)	($/acre)						
UTC	N/A	3.3 a	5.5 ab	7.5 a	12.3 a	13.5 a	20.3 a
Intrepid (0.06) + Baythroid (0.025)	$10.10	2.5 a	5.3 b	4.3 abc	4.8 c	3.5 c	8.0 bc
Steward (0.09) + Asana (0.036)	$16.83	4.3 a	7.5 ab	2.3 bc	6.0 bc	4.0 c	6.3 c
Tracer (0.0626) + Baythroid (0.025)	$15.98	3.8 a	5.0 b	2.5 bc	5.3 bc	3.3 c	5.3 c
Denim (0.01) + Baythroid (0.025)	$16.05	3.5 a	4.5 b	1.5 c	5.3 bc	3.8 c	6.0 c
Assail (0.05) + Baythroid (0.025)	N/A	4.3 a	6.3 ab	3.5 bc	5.3 bc	5.0 bc	8.8 bc
Curacron (0.5) + Karate (0.025)	$10.98	4.0 a	6.0 ab	4.8 abc	6.3 bc	4.3 c	9.8bc
Larvin (0.25) + Baythroid (0.025)	$8.90	5.5 a	6.5 ab	5.5 ab	9.0 ab	5.3 bc	10.5 bc
Lannate (0.25) + Baythroid (0.025)	$9.68	3.8 a	6.3 ab	2.3 bc	3.3 c	4.0 c	10.0 bc
Baythroid (0.025)	$4.52	3.8 a	8.5 a	3.3 bc	6.3 bc	7.5 b	12.5 b

[z] PT = pretreatment
[y] DAT = days after treatment
[x] not including application costs

Table 3. Average number of eggs, percentage of eggs hatched, percentage of eggs dead, and percentage of eggs parasitized from Ovicide Trial 2001.

Treatment	Avg. # of eggs	% hatched	% dead	% parasitized
UTC	19.50 a[z]	86.95 a	4.97 c	8.08 ab
Assail 0.05 lb ai/acre	20.80 a	45.30 b	52.52 ab	2.17 b
Assail 0.05 lb ai/acre + surfactant 0.25%	16.30 a	33.80 bc	51.15 ab	15.02 a
Assail 0.075 lb ai/acre + surfactant 0.25%	15.30 a	49.00 b	48.60 b	2.40 b
Larvin 0.25 lb ai/acre	19.30 a	20.85 c	71.78 a	6.28 b
Calypso 0.047 lb ai/acre	21.80 a	31.55 bc	66.27 ab	2.17 b

[z] Means followed by same letter do not significantly differ (P=0.05, LSD)

EVALUATION OF INSECTICIDE TERMINATION DECISIONS IN SOUTHEAST ARKANSAS

Jeremy K. Greene, Chuck Capps, William C. Robertson, and Steve Kelly[1]

RESEARCH PROBLEM

Insecticides are needed every year in southeast Arkansas to maintain viable cotton production, but they are very expensive inputs that add to the cost of production. Growers face the difficult decision every year of determining when to stop spraying for insect pests. If producers treat too long into the growing season, they spend money to protect fruit that will not contribute significantly to higher yields, resulting in higher costs of production and reduced profits. If growers terminate insecticide treatments too early, they sacrifice yield potential due to insect damage.

BACKGROUND INFORMATION

The correct time to stop spraying for insect pests is a critical decision that has been made by farmers for the past several years without a reliable model on which to base this decision. Recently, research has been conducted to help farmers make a decision on when to terminate sprays (Kharboutli and Allen, 2001). Much of this research has been based on COTMAN, COTton MANagement Model, which provides a system to help growers make management decisions. This system provides a way to monitor cotton growth and fruit development during the growing season, and research has supported the practical use of this model (Oosterhuis et al., 1996; Kharboutli and Allen, 2001).

COTMAN uses Nodes Above White Flower (NAWF) as the basis to determine crop maturity. Research has shown that fruiting forms produced on main-stem nodes above NAWF=5 did not contribute significantly to total yield (Bourland et al., 1992; Lammers, 1996). The date that the crop reaches NAWF=5 is the flowering date of the

---

[1] Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello; extension agronomist - cotton, Cooperative Extension Service, Little Rock; and Desha County extension agent, Cooperative Extension Service, McGehee.

last effective date boll (Oosterhuis et al., 1996). This study was conducted to investigate insecticide termination rules for southeast Arkansas by comparing standard practices with those associated with the COTMAN model.

RESEARCH DESCRIPTION

Two irrigated fields on a producer's farm in Desha County, Arkansas, were identified for these tests. The first field (Test 1) was planted to DPL 5415 on 2 May 2001, and the second field (Test 2) was planted to BXN 47 on 1 May 2001. Both tests were replicated four times, and each plot was 20 rows wide (the width of one plane pass) and approximately 1000 feet in length. On Test 1, treatments were terminated near NAWF=5 + 250 HU, near NAWF=5 + 450 HU, and near NAWF=5 + 650 HU. On Test 2, treatments were terminated at NAWF=5, near NAWF=5 + 250 HU, and near NAWF=5 + 550 HU. After NAWF=5, Test 1 was treated on 7 August with Baythroid (1 gal per 65 acres or 1.97 oz per acre) and Tracer (1 gal per 85 acres or 1.51 oz per acre); on 17 August with Tracer (1 gal per 70 acres or 1.83 oz per acre); and on 27 August with Tracer (1gal per 70 acres or 1.83 oz. per acre) and Centric (2 oz. per acre). After NAWF=5, Test 2 was treated on 7 August with Baythroid (1 gal per 65 acres or 1.97 oz per acre) and Tracer (1 gal per 85 acres or 1.51 oz per acre); on 17 August with Tracer (1 gal per 70 acres or 1.83 oz per acre); and on 4 September with Baythroid (1 gal per 65 acres or 1.97 oz per acre) and Tracer (1 gal per 85 acres or 1.51 oz per acre). Net returns were calculated using the cost of insecticides applied all season, cost of aerial application ($4.00), and $0.52 per pound for lint yield. Yields were statistically analyzed using ANOVA and LSD.

RESULTS AND DISCUSSION

All insecticide termination systems produced similar yields (Tables 1 and 2), but there was a numerical increase in yield with continued insecticide use. This was likely due to additional insecticide treatments protecting fruit high on the main-stem node that did not contribute significantly to yield. The economic returns for each insecticide termination system were similar, but there were numerical increases in net returns for the NAWF=5 + 250 HU termination system (Tables 1 and 2). No economic benefits were found by prolonging crop protection after NAWF=5 + 250 HU. Similar results were found in an insecticide termination study conducted in 2000 (Kharboutli and Allen, 2001).

PRACTICAL APPLICATION

Because of low yield potential due to inclement environmental conditions, a slight numerical difference in net return favored insecticide termination at NAWF=5 + 250 HU. No economic benefits were seen by making extra insecticide applications after NAWF=5 + 250 HU.

DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

ACKNOWLEDGMENTS

We thank Cotton Incorporated for their financial support of this project. We especially thank Mr. Steve Stevens for his support and cooperation during this project.

LITERATURE CITED

Bourland, F.M., D.M. Oosterhuis, and N.P. Tugwell. 1992. Conceptual model for modeling plant growth and development using main-stem node count. J. Prod. Agri. 5:532-538.

Lammers, J.D. 1996. Refining the target curve for the COTMAN system of cotton monitoring. M.S. Thesis, University of Arkansas.

Oosterhuis, D.M., F.M. Bourland, N.P. Tugwell, and M.J. Cochran. 1996. Terminology and Concepts Related to the COTMAN Crop Monitoring System. University of Arkansas Agricultural Experiment Station Special Reports 174.

Kharboutli, M.S., and C.T. Allen. 2001. Insecticide termination regimes in southeast Arkansas. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1103-1105.

Table 1. Insecticide termination data from Well Field, DPL 5415 planted on 2 May (Test 1).

Last treatment date	DAP[z]	HUAP[y]	Days after NAWF=5[x]	DD60[w] after NAWF=5	Lint yield	Insecticide costs	Net return
					(lb/acre)	($/acre)	($/acre)
7 August	98	1881	12	250	710	30.23	338.87
17 August	108	2090	22	459	728	44.70	333.96
27 August	118	2311	32	679	741	65.41	319.75

[z] DAP = days after planting.
[y] HUAP = Heat units after planting.
[x] NAWF = Nodes above white flower.
[w] DD60, Degree days (60EF).

Table 2. Insecticide termination data from Center Field, BXN 47 planted on 1 May (Test 2).

Late treatment date	DAP[z]	HUAP[y]	Days after NAWF=5[x]	DD60[w] after NAWF=5	Lint yield	Insecticide costs	Net return
					(lb/acre)	($/acre)	($/acre)
7 August	99	1869	0	0	827	26.54	403.66
17 August	109	2078	10	209	856	41.01	404.27
4 September	127	2411	28	542	868	59.22	391.98

[z] DAP = days after planting.
[y] HUAP = Heat units after planting.
[x] NAWF = Nodes above white flower.
[w] DD60, Degree days (60EF).

LABORATORY EVALUATIONS OF COTTON INSECTICIDES FOR CONTROL OF STINK BUGS

Jeremy K. Greene and Chuck Capps[1]

RESEARCH PROBLEM

The eradication of the boll weevil, expanding use of first- and second-generation transgenic *Bt* cotton varieties, and increasing focus on development and registration of target-specific insecticides have and will continue to create a "low-spray" environment, virtually free of broad-spectrum insecticide use for major pest groups, that will allow other insects, such as stink bugs, to thrive with the benefits of coincidental suppression eliminated. Predominant phytophagous (plant-feeding) stink bugs in the southeast and much of the mid-South are similar and include the green stink bug, *Acrosternum hilare* (Say), the southern green stink bug, *Nezara viridula* (L.), and the brown stink bug, *Euschistus servus* (Say). In 2001, we continued investigations, in laboratory bioassays, into the effects of several new chemistries with those of established materials on mortality of two important species: the green stink bug (GSB), and the brown stink bug (BSB).

BACKGROUND INFORMATION

The importance of stink bugs in cotton-producing regions of the mid-South will increase in the coming years because of various factors. The first will be the eradication of the boll weevil, *Anthonomus grandis* Boheman. In southeast Arkansas, the Boll Weevil Eradication Program (BWEP) completed its second growing season in 2001 with improvements in technology, personnel, and efficiency. Overall, previous cold winter temperatures combined with productive BWEP operations produced favorable results. Once eradicated, insecticide sprays (e.g. malathion) used during or before BWEP for weevil control will no longer be the standard, and coincidental suppression of stink bugs will be removed.

---

1 Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello.

Secondly, use of transgenic cotton varieties continues to increase, and producers of transgenic *Bt* cotton are aware that the modified cotton has no activity on stink bugs. But more important in *Bt* cotton is the further reduction of broad-spectrum insecticide use for worm (Lepidoptera) control. With conventional varieties, insecticide applications (many pyrethroids) for bollworm/budworm control during mid-to-late season suppress numbers of stink bugs as a side benefit. In the absence of these control measures, stink bugs are more of a problem in terms of reduced yield and quality. Since the commercial introduction of *Bt* cotton in 1996, acreage planted to the transgenic crop has and likely will continue to increase, and as it does, so will the impact of stink bugs on the crop. Furthermore, in university and company trials, second-generation *Bt* varieties are enhanced in controlling worm pests, offering potential for additional reductions in insecticide usage.

Thirdly, insecticide chemistries that target worm pests in conventional non-*Bt* varieties have been and continue to be developed. These foliar, lep-selective materials offer little or no control of stink bugs, basically functioning similar to *Bt* cotton with regard to stink bug populations. When increasing use of these target-specific materials, growing *Bt* cotton acreage, and a successful BWEP are added up, the sum equals problems with once secondary pests such as stink bugs. Entomologists have been addressing this problem for several years now and have generated some useful information concerning management of stink bugs in cotton (Greene et al., 1999; Greene et al., 2001a,b).

MATERIALS AND METHODS

Adults and nymphs of the green stink bug and the brown stink bug were collected from soybeans with a sweepnet and held overnight in an environmental chamber at 27°C, 60% RH, and a photoperiod of 14:10 (L:D) h. They were provided with water and green beans (Harris and Todd, 1981), and the following day, adults and fifth instars of each species were placed singly in 30-ml plastic diet cups with a 3- to 4-cm section of green bean before topical assays.

Doses of each insecticide simulated the concentrations of field-use rates applied at a total volume of 10 gal per acre. Mixtures using 1 ml or 1 g of material were made for the following insecticides and field-use rates: dicrotophos (Bidrin 8, Amvac, Los Angeles, CA, 0.33 and 0.50 lb ai/acre); cyfluthrin (Baythroid 2, Bayer, Kansas City, MO, 0.04 lb ai/acre); spinosad (Tracer 4, Dow AgroSciences, Indianapolis, IN, 0.067 lb ai/acre); indoxacarb (Steward 1.25, DuPont, Wilmington, DE, 0.11 lb ai/acre); emamectin benzoate (Denim 0.16, Syngenta, Greensboro, NC, 0.0125 lb ai/acre); zetacypermethrin (Fury 1.5, FMC, Philadelphia, PA, 0.0445 lb ai/acre); methoxyfenozide (Intrepid 2F, Rohm and Haas, Philadelphia, PA, 0.06 lb ai/acre); bifenthrin (Capture 2, FMC, 0.06 lb ai/acre); thiacloprid (Calypso 4, Bayer, 0.094 lb ai/acre); imidacloprid/cyfluthrin (Leverage 2.7, Bayer, 0.0634 lb ai/acre); acephate (Orthene 97, Valent, Walnut Creek, CA, 0.5

and 0.75 lb ai/acre); lambda-cyhalothrin (Karate 2.08, Syngenta, 0.03 lb ai/acre); thiamethoxam (Centric 25WG, Syngenta, 0.05); acetamiprid (Assail 70WP, Aventis Crop Science, Research Triangle Park, NC, 0.025 and 0.05 lb ai/acre); malathion (Malathion 5, Terra International, Sioux City, IO, 0.773 lb ai/acre); and profenofos (Curacron 8E, Syngenta, 0.75 lb ai/acre). To simulate practical efficacy in the field, 1 µl of each insecticide mixture was applied to the ventral abdominal segments of each insect. Each bug was returned to its respective diet cup following treatment. A bug was considered dead if in a supine position and no coordinated movement was observed after agitating its cup. Mortality was recorded 24, 48, 72, and 96 hr after treatment.

RESULTS

The predominant species of stink bugs in cotton in southeast Arkansas during 2001 were the green stink bug (GSB) and the brown stink bug (BSB). The southern green stink bug (SGSB) was uncommon in the state during 2001, most likely due to cold temperatures (Elsey 1993) experienced during the previous winter. Bidrin provided excellent control (96 to 100% mortality) of GSB and BSB (Tables 1 to 4) at both rates (0.33 and 0.50 lb ai/acre). The pyrethroid insecticides provided good control (74 to 97%) of GSB nymphs and adults 24 hr after treatment (Tables 1 and 2), but poor control (43 to 75%) of BSB (Tables 3 and 4), except for Capture which provided 85% and 96% mortality of BSB nymphs and adults, respectively. Lep-specific materials (Intrepid, Tracer, Denim, and Steward) offered little or no control of both species, but increased mortality (78%) of BSB immatures (Table 3) after 72 hr. Insecticides designed for sucking pests (Centric, Assail, and Calypso) provided variable results. Centric provided excellent control of immatures of both species, but poor/fair control of adults. Assail and Calypso offered little control in topical assays. Malathion, at a rate commonly used in boll weevil eradication programs, provided poor control (27 to 38% mortality) of both species at 24 hr. Cumulative mortalities for several treatments fluctuated slightly and, in some cases, decreased over time because some bugs recorded as dead apparently recovered from initial "knockdown". These results were consistent with those found previously concerning SGSB and BSB (Greene and Herzog, 2000; Greene et al., 2001a).

PRACTICAL APPLICATION

In laboratory bioassays, dicrotophos (Bidrin), a standard organophosphate used for control of bug pests, provided excellent control (96 to 100% mortality) of field-collected fifth instars and adults of the green stink bug (GSB) and the brown stink bug (BSB); remained efficacious at a reduced rate (0.33 lb ai/acre); and is relatively inexpensive. Zetacypermethrin (Fury), bifenthrin (Capture), lambda-cyhalothrin (Karate), and cyfluthrin (Baythroid), standard pyrethroids used for control of worm pests, provided good/excellent control of GSB but poor/fair control of BSB, except for Capture, which

provided excellent control of BSB. Comparatively, acephate (Orthene) and Capture were more effective on BSB than on GSB and could be alternatives to Bidrin in controlling this species if necessary.

ACKNOWLEDGMENTS

We thank Cotton Incorporated, AMVAC, Aventis, Bayer, Dow AgroSciences, DuPont, FMC, Syngenta, and Valent for support of this work.

DISCLAIMER

The mention of trade names in this report is for informational purposes only and does not imply an endorsement by the University of Arkansas Cooperative Extension Service.

LITERATURE CITED

Elsey, K.D. 1993. Cold tolerance of the southern green stink bug (Heteroptera: Pentatomidae). Environ. Entomol. 22:567-570.

Greene, J.K., S.G. Turnipseed, M.J. Sullivan, and G.A. Herzog. 1999. Boll damage by southern green stink bug (Hemiptera: Pentatomidae) and tarnished plant bug (Hemiptera: Miridae) caged on transgenic *Bacillus thuringiensis* cotton. J. Econ. Entomol. 92:941-944.

Greene, J.K., and G.A. Herzog. 2000. Mortality of southern green stink bug exposed to new cotton insecticides in laboratory bioassays and field comparisons of insecticides and stink bug damage to cotton. 1999 Georgia Cotton Research and Extension Reports. UGA/CPES Research-Extension Publication No.4:251-255.

Greene, J.K., G.A. Herzog, and P.M. Roberts. 2001a. Management decisions for stink bugs. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:913-917.

Greene, J.K., S.G. Turnipseed, M.J. Sullivan, and O.L. May. 2001b. Treatment thresholds for stink bugs (Hemiptera: Pentatomidae) in cotton. J. Econ. Entomol. 94:403-409.

Harris, V.E., and J.W. Todd. 1981. Rearing the southern green stink bug, *Nezara viridula,* with relevant aspects of its biology. J. Ga. Entomol. Soc. 16:203-210.

Table 1. Cumulative mortality of field-collected fifth instars of the green stink bug, *Acrosternum hilare* (Say), over a 4-d interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays.

Treatment	Reps	$/acre/application	% cumulative mortality			
			24 hr	48 hr	72 hr	96 hr
UTC	127	$0.00	12	27	43	46
Denim (0.0125)	127	14.41	10	27	51	63
Steward (0.11)	127	14.56	9	26	49	65
Tracer (0.067)	127	12.26	9	27	40	47
Intrepid (0.06)	127	5.58	8	17	35	39
Karate (0.03)	127	6.02	80	83	91	94
Capture (0.06)	127	11.05	74	82	93	95
Fury (0.0445)	127	5.84	90	94	97	98
Baythroid (0.04)	127	7.23	87	88	96	98
Leverage (0.0634)	127	9.04	95	98	98	99
Bidrin (0.33)	127	3.74	98	99	100	100
Bidrin (0.5)	127	5.67	100	100	100	100
Orthene (0.5)	127	5.28	68	78	87	91
Orthene (0.75)	127	8.16	78	95	98	99
Centric (0.05)	127	9.45	96	98	98	98
Assail (0.025)	127	N/A	50	51	67	73
Assail (0.05)	127	N/A	63	70	83	88
Calypso (0.094)	127	N/A	23	39	51	51
Malathion (0.773)	48	3.61	38	58	73	73
Curacron (0.75)	106	9.02	20	42	58	67

Table 2. Cumulative mortality of field-collected adults of the green stink bug, *Acrosternum hilare* (Say), over a 4-d interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays.

			% cumulative mortality			
Treatment	Reps	$/acre/application	24 hr	48 hr	72 hr	96 hr
UTC	34	0.00	21	29	38	41
Denim (0.0125)	34	14.41	35	41	50	50
Steward (0.11)	34	14.56	24	38	47	53
Tracer (0.067)	34	12.26	15	29	35	38
Intrepid (0.06)	34	5.58	24	35	41	44
Karate (0.03)	34	6.02	82	88	91	94
Capture (0.06)	34	11.05	97	97	97	97
Fury (0.0445)	34	5.84	91	94	97	97
Baythroid (0.04)	34	7.23	85	91	97	97
Leverage (0.0634)	34	9.04	97	91	97	97
Bidrin (0.33)	34	3.74	100	100	100	100
Bidrin (0.5)	34	5.67	100	100	100	100
Orthene (0.5)	34	5.28	29	68	76	76
Orthene (0.75)	34	8.16	47	76	85	88
Centric (0.05)	34	9.45	50	68	74	74
Assail (0.025)	34	N/A	29	38	41	50
Assail (0.05)	34	N/A	50	56	59	62
Calypso (0.094)	34	N/A	15	26	32	32
Malathion (0.773)	197	3.61	27	38	50	53
Curacron (0.75)	29	9.02	34	55	69	69

Table 3. Cumulative mortality of field-collected fifth instars of the brown stink bug, *Euschistus servus* (Say), over a 4-d interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays.

			% cumulative mortality			
Treatment	Reps	$/acre/application	24 hr	48 hr	72 hr	96 hr
UTC	40	0.00	8	15	15	23
Denim (0.0125)	40	14.41	23	45	78	78
Steward (0.11)	40	14.56	10	20	28	35
Tracer (0.067)	40	12.26	10	20	43	48
Intrepid (0.06)	40	5.58	5	15	23	33
Karate (0.03)	40	6.02	43	60	80	83
Capture (0.06)	40	11.05	85	98	100	100
Fury (0.0445)	40	5.84	75	83	85	85
Baythroid (0.04)	40	7.23	43	55	63	73
Leverage (0.0634)	40	9.04	88	88	88	88
Bidrin (0.33)	40	3.74	100	100	100	100
Bidrin (0.5)	40	5.67	100	100	100	100
Orthene (0.5)	40	5.28	80	90	95	95
Orthene (0.75)	40	8.16	80	98	98	98
Centric (0.05)	40	9.45	93	90	90	90
Assail (0.025)	40	N/A	38	43	43	45
Assail (0.05)	40	N/A	53	58	58	58
Calypso (0.094)	40	N/A	15	23	28	30
Malathion (0.773)	25	3.61	32	40	48	52
Curacron (0.75)	40	9.02	20	30	50	63

Table 4. Cumulative mortality of field-collected adults of the brown stink bug, *Euschistus servus* (Say), over a 4-d interval following exposure to insecticides (1-ml to ventral abdominal segments) in laboratory bioassays.

			% cumulative mortality			
Treatment	Reps	$/acre/application	24 hr	48 hr	72 hr	96 hr
UTC	73	0.00	14	25	32	33
Denim (0.0125)	73	14.41	22	33	37	40
Steward (0.11)	73	14.56	10	16	22	23
Tracer (0.067)	73	12.26	8	29	36	41
Intrepid (0.06)	73	5.58	10	18	23	34
Karate (0.03)	73	6.02	47	47	51	59
Capture (0.06)	73	11.05	96	95	95	96
Fury (0.0445)	73	5.84	53	51	52	55
Baythroid (0.04)	73	7.23	49	40	40	38
Leverage (0.0634)	73	9.04	75	68	67	67
Bidrin (0.33)	73	3.74	96	97	97	97
Bidrin (0.5)	73	5.67	99	99	99	99
Orthene (0.5)	73	5.28	60	77	82	82
Orthene (0.75)	73	8.16	73	90	95	96
Centric (0.05)	73	9.45	73	75	77	74
Assail (0.025)	73	N/A	10	14	16	16
Assail (0.05)	73	N/A	16	19	23	23
Calypso (0.094)	73	N/A	10	12	14	14
Malathion (0.773)	182	3.61	38	53	63	66
Curacron (0.75)	70	9.02	20	34	39	40

DURATION OF FEEDING BY TARNISHED PLANT BUG ON SMALL BOLLS AND IMPACT ON YIELD AND FIBER QUALITY

Jeremy K. Greene and Chuck Capps[1]

RESEARCH PROBLEM

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), can be a very damaging pest to cotton during squaring, with their feeding causing square shed. Plant bugs also feed on small bolls causing a loss of fiber quality, boll shed, and yield loss. While it is known that the plant bug damages bolls, less is known about the length of time that a plant bug must feed upon a boll before damage is done (Kharboutli, 2001).

BACKGROUND INFORMATION

The tarnished plant bug (TPB) continues to cause damage to cotton in Arkansas, and two recent developments may cause the plant bug to become more damaging to cotton grown in Arkansas. First of all, the Boll Weevil Eradication Program (BWEP) is eliminating the boll weevil and the number of insecticide applications for its control that incidentally help suppress numbers of plant bugs. Multiple aerial applications of Ultra-Low-Volume (ULV) malathion provide significant population reductions of tarnished plant bugs (Allen and Kharboutli, 2000). Secondly, the widespread usage of transgenic *Bt* cotton has also reduced the number of chemicals applied that have some level of control of TPB. Early season damage to cotton caused by the plant bug has been thoroughly discussed in the literature (Hanny et al., 1977; Smith, 1986; Johnson et al., 1996). This research demonstrated that plant bug-associated square loss was reported to delay fruiting and crop maturity. Little is known about the relationship between boll damage caused by the plant bug and length of time required during feeding to cause significant boll damage and yield loss.

---

[1] Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

The study was conducted on the Southeast Research and Extension Center on the University of Arkansas at Monticello (UAM) campus to avoid ULV malathion sprays applied for boll weevils by BWEP. Twenty rows of NuCotn 33B planted on 14 May 2001 were 40 feet in length with a row spacing of five feet. Plants were irrigated using drip irrigation. Tarnished plant bugs were obtained from USDA near Greenville, MS, placed inside paper containers containing green beans and held overnight in an environmental chamber at 27°C, 60%RH and a 14 h photoperiod. Adult plant bugs were placed into 2-ml vials (2 plant bugs per vial), and each vial was placed into a 20 x 18 cm net drawstring cage. The cages were taken to the field and placed on small first-position bolls that had been prepared by removing the petals. The vials were opened to release the plant bugs, which were left to feed on bolls for 12, 24, 36, and 48 hours. Controls (0 hours) were included in the experiments and consisted of caged bolls without plant bugs. Following each treatment duration, plant bugs were destroyed, and cages were removed. Trials were conducted on 11, 16, 24, and 26 July and on 1 August 2001, with an equal number of cages for all five feeding regimes. Cotton was protected with insecticides (Capture 2 at 0.1 lb ai/acre and Fury 1.5 at 0.045 lb ai/acre on 9, 10, and 22 August 2001) after the last experiment terminated on the last test date and harvested on 25 September 2001.

RESULTS AND DISCUSSION

There were no significant differences in seedcotton weights as indicated by boll weight (Table 1) or High Volume Instrument fiber quality variables (Table 2) analyzed. Except for the 48-hr regime, there was a trend toward reduced yield with increasing exposure to tarnished plant bug. Overall, feeding exposure from 12 hours to 48 hours had little impact on yield and lint quality. These results were consistent with those obtained in 2000 (Kharboutli, 2001).

FUTURE RESEARCH

A number of modifications will be implemented for this study in 2002. The number of replications will be increased by increasing acreage, the cage design will be modified, and bolls caged will be older than those used in 2000 and 2001.

ACKNOWLEDGMENTS

We thank Cotton Incorporated for funding and Dr. Gordon Snodgrass (USDA, Stoneville, MS) for the tarnished plant bugs used in this study.

LITERATURE CITIED

Allen, C.T., and M.S. Kharboutli. 2000. Effects of ULV malathion on tarnished plant bug in Arkansas Boll Weevil Eradication Program. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. 2:1207-1208.

Hanny, B.W., T.C. Cleveland, and W.R. Meridith. 1977. Effect of tarnished plant bug, (*Lygus lineolaris*), infestation on presquaring cotton. Environ. Entomology. 6:460-462.

Johnson, D.R., C.D. Klein, H.B. Myers, and L.D. Page. 1996. Pre-bloom square loss, causes and diagnosis. *In*: P. Dugger and D. A. Richter (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 103-105.

Kharboutli, M.S. 2001. Proceedings of the 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. Arkansas Agriculture Experiment Station.

Smith, R.H. 1986. Early season production management practices: Insects. *In:* J.M. Brown and T.C. Nelson (eds.). Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Table 1. Effect of duration of plant bug feeding on boll weight.

Feeding regime	Boll weight[z]
(hours)	(g/boll)
0	4.6
12	4.2
24	4.1
36	3.8
48	4.5

[z] No significant differences (P >0.05).

Table 2. Effect of duration of plant bug feeding on fiber quality[z].

Feeding regime	Micronaire	Length	Uniformity	Strength	Reflectance	Yellowness
(hours)		(in.)	(%)	(g/tex)		
0	4.6	1.1	82.2	27.7	69.4	7.7
12	4.3	1.1	82.3	28.1	70.0	8.9
24	4.9	1.1	82.2	26.5	68.5	8.4
36	4.9	1.1	82.2	27.3	71.6	8.3
48	4.3	1.1	82.5	28.6	69.5	9.7

[z] No significant differences (P >0.05).

EVALUATION OF THRIPS CONTROL OPTIONS IN SOUTHEAST ARKANSAS COTTON

Jeremy Greene and Chuck Capps[1]

RESEARCH PROBLEM

New insecticides continue to be developed to help control thrips (*Frankliniella* spp.) infestations in cotton. Some of the new products are foliar insecticides, but the newest materials are seed treatments. Many farmers in southeast Arkansas continue to use Temik because it controls thrips and also helps suppress nematode populations. We continued to evaluate these control options for thrips in 2001.

BACKGROUND INFORMATION

Thrips continue to be an economic pest in cotton by causing delayed maturity and stunted growth resulting in lower yields. Heavy infestations of thrips can severely injure the terminals of cotton plants causing the plant to die or abort the terminal and grow as "crazy cotton." Temik typically has been the standard thrips treatment in southeast Arkansas because of its effectiveness against thrips, but also in its effectiveness at suppressing nematodes in cotton. Continued yield losses due to thrips injury and nematode activity sustains the need for further research in both thrips and nematode control.

RESEARCH DESCRIPTION

NuCotn 33B was planted on 11 June 2001 on the Southeast Branch Experiment Station near Rohwer, Arkansas. The row spacing was 38 in., and plots were 8 rows by 40 feet and replicated four times. Standard fertilization and herbicide practices were followed according to current University of Arkansas Extension recommendations. Foliar treatments of Novaluron and Orthene were applied 3 times on 19 and 26 June and

---

[1] Extension entomologist and pest management technical support specialist, Southeast Research and Extension Center, Monticello.

on 3 July with a John Deere 6500 High-cycle at 2.8 mph with a 13 treatment plot boom at 10 GPA with a spray pressure of 42 psi. Spray nozzles were TX-6 hollow cones with 2 nozzles per row. The other treatments, such as Temik (in-furrow) and Gaucho and Adage (seed treatments), were applied at time of planting. Thrips were collected on 18 June (pre-treatment for foliar applications), 22, 25, and 29 June and 3 and 6 July by randomly pulling plants from rows 3 and 6 of each plot (total of ten plants per plot) and washing them off in 1-quart jars of alcohol. Nymphs and adults were counted and separated by species using filtration procedures in the laboratory.

RESULTS

On the first sample date, all in-furrow or seed treatments except Adage provided significant control of thrips compared with the untreated check (UTC). There were no significant differences in any of the treatments on the second sample date. On the third and fifth sample date, only the Novaluron treatments did not provide significant control of thrips. Novaluron at 0.092 lb ai/acre, all rates of Temik, Orthene, and Adage provided significant control of thrips on the fourth sample date. All treatments provided significant thrips control when compared with the UTC on the last sample date. It should be noted that 100% of the thrips sampled were tobacco thrips.

PRACTICAL APPLICATION

Across all dates, Temik (all 3 rates), Orthene, Gaucho (except 29 June), and Adage provided adequate control of thrips when compared with the UTC. Novaluron (all 3 rates) provided significant suppression on the last sample date.

ACKNOWLEDGMENTS

The authors thank Cori Treat, Jeffery Treat, Brian Lawhon, Brian Weatherford, Joe Belvedrisi, Tony Jordan, and Aventis, Gustafson, Syngenta, and Uniroyal for their cooperation and work in helping conduct this trial.

Table 1. Effect of foliar and seed treatments on thrips (nymphs and adults) control.

Treatment rate	18 June	22 June	25 June	29 June	3 July	6 July
(lb ai/acre)	(# thrips/10 plants)					
UTC	1.75 a[z]	0.00 a	12.25 a	19.50 a	40.00 a	63.75 a
Novaluron 0.023	1.00 ab	0.00 a	11.75 ab	13.50 ab	45.25 a	20.50 b
Novaluron 0.046	1.00 ab	0.50 a	14.75 a	20.00 a	41.75 a	16.50 b
Novaluron 0.092	0.25 b	0.25 a	9.50 abc	9.50 bc	50.50 a	21.25 b
Temik 0.525	0.00 b	0.25 a	3.00 cd	3.25 c	13.00 b	4.50 b
Temik 0.6	0.25 b	0.00 a	0.75 d	7.75 bc	14.75 b	9.75 b
Temik 0.75	0.00 b	0.00 a	1.25 d	3.75 c	11.75 b	7.00 b
Orthene 0.2	0.50 ab	0.00 a	0.50 d	5.75 bc	3.25 b	0.50 b
Gaucho (seed trt)	0.25 b	0.75 a	3.75 bcd	11.00 abc	16.00 b	9.75 b
Adage (seed trt)	1.25 ab	0.00a	0.25 d	2.50 c	19.00 b	7.50 b

[z] Treatment means within a column followed by same letter do not differ significantly (P>0.05, LSD).

THRIPS MANAGEMENT IN ARKANSAS COTTON

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

RESEARCH PROBLEM

Thrips is an early-season cotton pest that has the potential to cause delayed maturity and yield loss in Arkansas cotton, with the level of damage varying from year to year based on the severity of the thrips infestation. As the severity of thrips infestation cannot be predicted, cotton producers rely on in-furrow insecticides and insecticidal seed treatments as a prophylactic measure to reduce the risk of thrips damage. This project was designed to evaluate in-furrow (IFAP), seed treatment (ST), and combination ST + foliar insecticides (FS) for thrips management in cotton.

BACKGROUND INFORMATION

Early-season damage caused by thrips is an annual problem that occurs with varying degrees of severity in Arkansas cotton depending on the size of the thrips population in any given year. In 2000, approximately 36,563 bales were lost due to early season thrips damage (Williams, 2001). Prior to cotton emergence, thrips populations build up on wild or other alternate hosts. When these hosts begin to dry down, thrips move to emerging cotton seedlings and can cause terminal damage resulting in delayed maturity and yield loss (Micinski et al., 1990). When thrips population numbers are low, cotton plants can outgrow and compensate for some thrips injury, however, when thrips numbers reach high levels, yield reductions can occur if thrips are left unchecked (Herbert, 1995; Roberts and Rechel, 1996). In the mid-South production area, the tobacco thrips, *Frankliniella fusca* (Hinds), is the predominant species that occurs on cotton. However, the western flower thrips, *Frankliniella occidentalis* (Pergrande), was quite common in 1999 and caused a great deal of concern among Arkansas producers. Other species that have been reported in mid-South cotton include the flower thrips, *Frankliniella tritici* (Fitch), and the soybean thrips, *Neohydatothrips vari-*

[1] Entomology associate specialist and entomology extension specialist, Cooperative Extension Service, Lonoke; extension entomologist-pest management section leader and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock.

ables (Beach) (Burris et al., 2000), and the onion thrips, *Thrips tabaci* (Lindeman) (Eddy and Livingstone, 1931). The objective of this study was to evaluate the effectiveness of various in-furrow seed treatment, and seed treatment + foliar spray combinations for thrips control in cotton.

RESEARCH DESCRIPTION

These trials were conducted in locations that have been historically free of root-knot and reniform nematodes to eliminate confounding as Temik is nematicidal as well as insecticidal. Cotton was planted at the Northeast Research and Extension Center in Mississippi County on 10 May and at the Cotton Branch Station in Lee County, Arkansas, on 14 May. Plots were four 38-inch rows X 35 ft. in length, arranged in a randomized complete block design with four replications. Granular insecticide treatments were applied at planting using granular applicator boxes mounted on a John Deere 7100 planter. Cottonseed used in the test had previously been shipped to the appropriate chemical company (Syngenta or Gustafson) for seed treatment. The foliar application was made 29 days after planting (DAP) with a CO_2 backpack sprayer. The 2-row boom was equipped with conejet TXVS 6 nozzles on a 19-inch spacing. Operating pressure was 35 psi with a final spray volume of 12 gallons per acre.

In Mississippi County, thrips counts were made on 29 May (19 DAP), 5 June (26 DAP), 12 June (33 DAP), and 19 June (40 DAP). In Lee County, thrips counts were made on 29 May (15 DAP), 5 June (22 DAP), 12 June (29 DAP), and 19 June (36 DAP). Five plants were randomly selected from the middle two rows in each plot. Each plant was cut and immediately placed into a mason jar containing 70% ethyl alcohol. In the laboratory, thrips were rinsed from the plants with alcohol. To separate thrips from the alcohol, rinsate was poured onto a coffee filter lining the inside of a Buchner funnel. A vacuum pump was used to quickly evacuate the alcohol leaving the thrips on the coffee filter. The thrips on the coffee filter were rinsed with alcohol into a petri dish. Immature and adult thrips were then counted using a dissecting microscope. Thrips collected from the untreated control plots were identified to determine species distribution (Fig. 1 and 2).

Thrips damage was visually rated in the Mississippi County plots on 12 June (33 DAP) and 19 June (40 DAP). Damage was rated in the Lee County plots on 26 May (15 DAP), 12 June (29 DAP), and 19 June (36 DAP). Damage was evaluated using a 1 to 10 damage-rating system with 1 equal to no damage, 5 equal to moderate damage, and 10 equal to plant death. 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 most severe damage rating of 10 was given to plots with dead plants and plants having severe

damage and leaves without form.

A stand count was made on 19 June (40 DAP/ Mississippi County and 36 DAP/ Lee County). Plots were harvested in Mississippi County on 10 October (153 DAP) and in Lee County on 2 November (172 DAP). All four rows of each plot were harvested with a commercial cotton picker. The cotton was weighed and lint yield was determined based upon a 35% 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 2001, thrips pressure was light and tobacco thrips was the predominant species infesting cotton at both trial locations (Figs. 1 and 2). At the Mississippi County location, all treatments provided a numerical reduction in total thrips count compared to the untreated control at 19 DAP. At 26 and 33 DAP all treatments significantly (P=0.05) reduced total thrips counts below that of the untreated control but failed to differ significantly among themselves. At 40 DAP, again, all treatments significantly (P=0.05) reduced total thrips counts below that of the untreated control, however, L0263-A1 (250 fl oz/cwt seed) was the least effective chemical treatment. When rated at 33 and 40 DAP all chemical treatments significantly (P=0.05) reduced the level of thrips damage compared to the untreated control (Table 1).

Thrips damage ratings among chemical treatments failed to differ at 40 DAP, however, at 33 DAP (IFAP) and 11 DAT (FS), all Temik treatments and the Gaucho 480FS + Orthene 97 treatment had significantly less thrips damage than the seed treatments. No treatment differed significantly (P=0.05) from the untreated control with respect to stand count at 40DAP. No significant treatment differences were observed with respect to cotton lint yield. On a numerical basis only, Temik applied at a rate of 5 lb/acre was the lowest yielding treatment at 968 lb lint/acre compared to 986 lb lint/acre for the untreated check. Numerically, the highest yielding treatments in this trial were L0263-A1 followed by (fb) Adage 5FS fb Gaucho 480FS fb Gaucho 480FS + Orthene 97. Numerically, the Temik treatments had the lowest yields among the chemical treatments (Table 2).

At the Lee County location, no treatment differed significantly (P=0.05) from the untreated control with respect to total thrips counts when rated at 15, 22, 29, and 36 DAP. On a numerical basis, all treatments reduced thrips numbers below the level found in the untreated control through 22 DAP. At 29 DAP, Temik (3.5, 4.0, and 5.0 lb/acre) and L0263-A1 had numerically higher thrips numbers than the untreated control. At 36 DAP, only Temik (5.0) and L0263-A1 had numerically higher thrips numbers than the untreated control (Table 3).

When rated at 15 and 29 DAP all chemical treatments numerically reduced the level of thrips damage compared to the untreated control. At 36 DAP, all chemical

treatments significantly (P=0.05) reduced the level of thrips damage compared to the untreated control. The treatments providing the lowest damage ratings 36 DAP were Gaucho 480FS + Orthene 97, Gaucho 480FS, Adage 5FS, and Temik 15G (5.0 and 7.0). When rated at 36 DAP, the only treatment to have a stand count significantly (P=0.05) higher than the untreated control was Gaucho 480FS + Orthene 97. On a numerical basis, the highest stand counts were obtained with Gaucho 480FS + Orthene 97, L0263-A1, Adage 5FS, and Gaucho 480FS. The plant stands in the Temik (5.0 and 7.0) treatments were numerically less than the plant stand in the untreated control by 23% and 20%, respectively. No significant treatment differences were observed with respect to cotton lint yield. On a numerical basis only, all Temik treatments failed to out-yield the untreated control. Numerically, the highest yielding treatments in this trial were Adage 5FS followed by (fb) Gaucho 480FS fb L0263-A1 fb Gaucho 480FS + Orthene 97. These seed treatments out-yielded the untreated control (987 lb lint/acre) by 5 to 8% (Table 4).

Results from these trials indicate that the Adage, Gaucho, and L0263-A1 seed treatments offer a level of thrips protection equal to that provided by Temik under light to moderate thrips pressure.

PRACTICAL APPLICATION

The data presented from these trials indicate that the Adage and Gaucho seed treatments offer a level of thrips protection similar to that provided by the standard in-furrow granular insecticide under light to moderate pressure from tobacco thrips. These seed treatments offer a more convenient and time efficient method of thrips control compared to in-furrow granular insecticide applications, which involve a separate set of activities at the planter (calibration and handling).

LITERATURE CITED

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.

Herbert, D.A. 1995. Insect pest management in Virginia peanuts, soybeans, and cotton. Virginia Tech, Tidewater Agricultural Research and Extension Center Info Ser. No. 372, pp. 97-110.

Micinski, S., P.D. Colyer, K.T. Nguyen, and K.L Koonce. 1990. Effects of planting date and early-season pest control on yield in cotton. J. Prod. Agric. 3:597-602.
Roberts, B.A., and E.A. Rechel. 1996. Effects of early season thrips feeding on root development, leaf area and yield. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 939-941.
Williams, M.R. 2001. Cotton Insect Losses 2000. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Table 1. Total thrips counts: Insecticide screening for thrips control. Mississippi County, AR. 2001.

Treatment /form	Rate	Applic. method[z]	Total thrips (adults+larvae) 19DAP	26DAP	33DAP	40DAP
	(lb/acre)		(thrips/5 plants)			
UTC			3.3 a[y]	4.0 a	12.5 a	23.8 a
Temik 15G	3.5	IFAP	2.4 a	0.3 b	5.0 b	8.0 c
Temik 15G	4.0	IFAP	0.3 a	0.5 b	3.5 b	7.8 c
Temik 15G	5.0	IFAP	1.0 a	0.5 b	3.0 b	16.5 abc
Temik 15G	7.0	IFAP	1.0 a	0.0 b	3.0 b	8.5 c
Gaucho 480FS	8.0[x]	ST	1.3 a	0.0 b	5.8 b	10.5 bc
L0263-A1	250.0[w]	ST	2.3 a	1.0 b	2.8 b	19.5 ab
Adage 5FS	300.0[v]	ST	1.3 a	0.5 b	2.0 b	12.5 bc
Gaucho 480FS +	8.0[x] +	ST +	1.8 a	0.5 b	2.0 b	7.0 c
Orthene 97	0.206	FS 29DAP				

[z] IFAP = In-Furrow At Planting; ST = Seed Treatment, FS = Foliar Spray.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Trt. P(F) is sign. at mean comparison OSL.
[x] oz/cwt seed.
[w] fl oz/cwt seed.
[v] gm/100Kg seed.

Table 2. Thrips damage, stand count, and yield: Insecticide screening for thrips control. Mississippi County, AR. 2001.

Treatment/ form	Rate	Applic. method[z]	Thrips damage rating[y] 33DAP	Thrips damage rating[y] 40DAP	Stand count 40DAP	Cotton lint yield 153DAP
	(lb/acre)				(#/3 row ft)	(lb/acre)
UTC			6.8 a[x]	5.3 a	74.3 abc	986 a
Temik 15G	3.5	IFAP	2.8 c	2.0 b	62.0 c	1016 a
Temik 15G	4.0	IFAP	2.3 cd	1.3 b	68.0 bc	1005 a
Temik 15G	5.0	IFAP	2.3 cd	2.0 b	68.5 bc	968 a
Temik 15G	7.0	IFAP	1.3 d	2.5 b	70.8 abc	1022 a
Gaucho 480FS	8.0[w]	ST	4.5 b	2.5 b	66.8 bc	1051 a
L0263-A1	250.0[v]	ST	4.3 b	2.3 b	81.3 ab	1072 a
Adage 5FS	300.0[u]	ST	4.5 b	2.8 b	85.0 a	1053 a
Gaucho 480FS +	8.0[w] +	ST +	3.3 c	1.5 b	76.8 abc	1045 a
Orthene 97	0.206	FS 29DAP				

[z] IFAP = in-furrow at planting; ST = seed treatment.
[y] 1 = none, 10 = severe.
[x] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Trt. P(F) is significant at mean comparison OSL.
[w] oz/cwt seed.
[v] fl oz/cwt seed.
[u] gm/100Kg seed.

Table 3. Total thrips counts: Insecticide screening for thrips control. Lee County, AR. 2001.

Treatment /form	Rate	Applic. method[z]	Total thrips (adults+larvae)/5 plants 15DAP	22DAP	29DAP	36DAP
(lb/acre)						
UTC			2.5 a[y]	4.3 a	11.5 a	55.8 a
Temik 15G	3.5	IFAP	1.3 a	3.3 a	18.3 a	51.0 a
Temik 15G	4.0	IFAP	1.3 a	3.0 a	24.8 a	30.3 a
Temik 15G	5.0	IFAP	1.5 a	3.0 a	17.8 a	59.8 a
Temik 15G	7.0	IFAP	0.8 a	1.5 a	9.8 a	31.5 a
Gaucho 480FS	8.0[x]	ST	1.8 a	1.5 a	4.5 a	35.3 a
L0263-A1	250.0[w]	ST	0.5 a	5.0 a	15.8 a	60.5 a
Adage 5FS	300.0[v]	ST	1.0 a	0.8 a	10.0 a	20.8 a
Gaucho 480FS +	8.0[x] +	ST +	0.0 a	1.3 a	4.0 a	16.3 a
Orthene 97	0.206	FS 25DAP				

[z] IFAP = In-Furrow At Planting; ST = Seed Treatment, FS = Foliar Spray.
[y] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Trt. P(F) is significant at mean comparison OSL.
[x] oz/cwt seed.
[w] fl oz/cwt seed.
[v] gm/100Kg seed.

Table 4. Thrips damage, stand count, and yield: Insecticide screening for thrips control. Lee County, AR. 2001.

Treatment/ form	Rate	Applic. method[z]	Thrips damage rating[y] 15DAP	29DAP	36DAP	Stand count 36DAP	Cotton lint yield 172DAP
	(lb/acre)					(#/3rwft)	(lb/acre)
UTC			2.8 a[x]	5.3 a	5.8 a	64.3 bc	987 abc
Temik 15G	3.5	IFAP	1.5 a	4 a	2.3 bc	66 bc	956 bc
Temik 15G	4.0	IFAP	1.5 a	3.5 a	2.5 b	66.3 bc	907 c
Temik 15G	5.0	IFAP	1.5 a	3 a	1.8 bcd	49.3 c	926 c
Temik 15G	7.0	IFAP	2.8 a	3.3 a	1.8 bcd	51.5 c	900 c
Gaucho 480FS	8.0[w]	ST	2.3 a	4.5 a	1.5 cd	79.8 ab	1056 a
L0263-A1	250.0[v]	ST	2 a	3.8 a	2 bcd	82.5 ab	1045 ab
Adage 5FS	300.0[u]	ST	1.5 a	3.8 a	1.8 bcd	82.3 ab	1062 a
Gaucho 480FS + Orthene 97	8.0[w] + 0.206	ST + FS 25DAP	2.3 a	4.5 a	1.3 d	89 a	1035 ab

[z] IFAP = In-Furrow At Planting; ST = Seed Treatment.
[y] 1 = none, 10 = severe.
[x] Means followed by same letter do not significantly differ (P=0.05, Duncan's New MRT). Mean comparisons performed only when AOV Trt. P(F) is significant at mean comparison OSL.
[w] oz/cwt seed.
[v] fl oz/cwt seed.
[u] gm/100Kg seed.

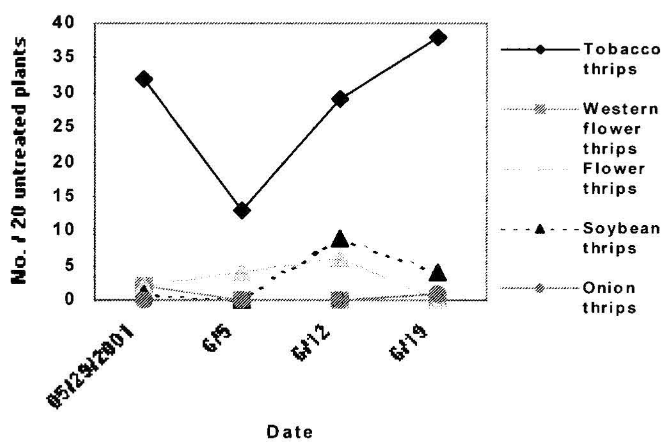


Fig. 1. Thrips species distribution from thrips control trial in cotton. Mississippi County, AR. 2001.

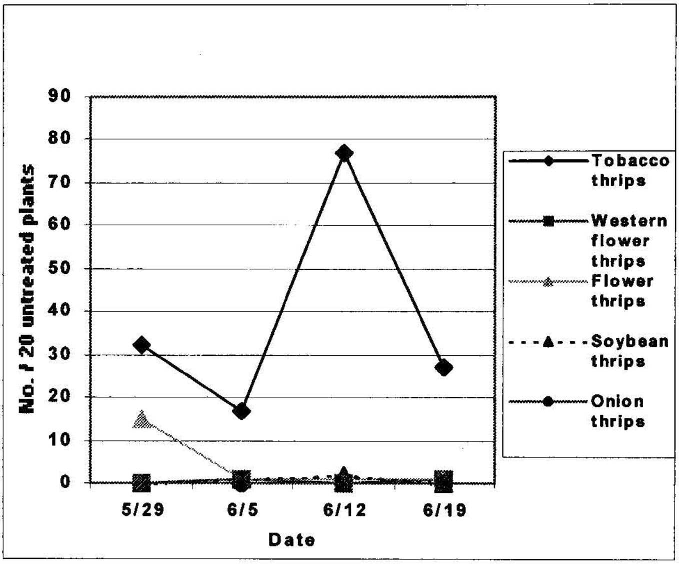


Fig. 2. Thrips species distribution from thrips control trial in cotton. Lee County, AR. 2001.

EVALUATION OF COTTON VARIETIES FOR THRIPS RESISTANCE

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

RESEARCH PROBLEM

Host plant resistance to thrips in cotton has the potential to reduce input costs for producers. Two trials were conducted in Keiser and Marianna, Arkansas, to evaluate several cotton varieties for thrips resistance.

BACKGROUND INFORMATION

Thrips infest approximately 85% of U.S. cotton annually (Williams, 2001); however, crop damage sustained from this pest differs from year to year with respect to economic severity. As a result, most cotton producers utilize in-furrow insecticides or seed treatments at a cost of $10 to 15 per acre as an insurance policy against thrips infestation.

While the presence of thrips has been observed throughout the cotton growing season (Leigh, 1995), the cotton plant is most vulnerable during the seedling stage. Thrips feed on the terminal area, disrupting normal plant growth. Early-season thrips injury will certainly affect the plant throughout its life cycle. Cotton plant responses to thrips feeding include pre-bloom square loss, reduced leaf area, poor root development, delayed crop maturity, and decreased lint yield (Johnson et al., 1996; Roberts and Rechel, 1996; Hawkins et al., 1966; Cater et al., 1989; Fairbanks et al., 2000).

Morphological and physiological traits have allowed some cotton cultivars to establish a level of tolerance to thrips damage; however, these traits are not present in common varieties (Jenkins, 1994). Older cotton varieties such as Empire have genetic backgrounds indicating thrips resistance (Tugwell and Waddell, 1964; Hawkins et al., 1966). Other research has indicated no differences in growth or yield for certain variet-

---

[1] Extension entomologist-pest management section leader, Cooperative Extension Service, Little Rock; entomology extension specialist and entomology associate specialist, Cooperative Extension Service, Lonoke; and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock.

ies with respect to thrips treatment (Sadras and Wilson, 1988; Fairbanks et al., 2000). The mechanism for thrips resistance in the older cultivars must be fully understood before the implementation into common cotton varieties is achieved.

The objective of this research was to evaluate the potential resistance to thrips damage for several cotton cultivars by observing growth and yield responses to a thrips seed treatment.

RESEARCH DESCRIPTION

Eighteen cotton varieties (Tables 1 and 2) were planted at the University of Arkansas Northeast Research and Extension Center in Keiser, AR, on 10 May and at the Cotton Branch Station in Marianna on 14 May. Plots consisted of two 38-inch rows 35 ft. in length arranged in a randomized complete block design with four replications. Each variety was subjected to two treatments prior to planting: Gaucho seed treatment and untreated. Visual damage ratings were recorded on a scale of one (low damage) to ten (high damage) on 29 May, 12 June, and 19 June. Thrips evaluations were made at both locations on 29 May, 5 June, 12 June, and 19 June by randomly selecting five plants from each plot. Each plant was cut and immediately placed into a mason jar containing 70% ethyl alcohol. In the laboratory, thrips were rinsed from the plants with alcohol. To separate thrips from the alcohol, rinsate was poured onto a coffee filter lining the inside of a Buchner funnel. A vacuum pump was used to quickly evacuate the alcohol leaving the thrips on the coffee filter. The thrips on the coffee filter were rinsed with alcohol into a petri dish. Immature and adult thrips were then visually counted using a dissecting microscope. All plots at both locations were harvested with a commercial cotton picker. The cotton was weighed and lint yield was determined based upon a 36% gin turnout. All data were processed using Agriculture Research Manager Ver. 6.0.1 and analyzed via ANOVA and LSD (P = 0.05).

RESULTS AND DISCUSSION

In 2001, thrips pressure was substantially lower at Keiser than at Marianna (Tables 1 and 2). The Gaucho seed treatment was effective in decreasing the number of thrips present on all varieties at both locations. The difference in treatments was more evident at the Marianna location due to increased thrips pressure.

At Marianna, Gaucho was effective in reducing the number of thrips observed throughout the season for all varieties (Table1). Two varieties, St 474 and DP 428 B, actually had higher thrips numbers with the Gaucho treatment, while all others were lower (Table 2). Although thrips pressure was higher at Marianna, average thrips damage ratings were higher at Keiser, possibly due to environmental differences between locations. As with total number of thrips observed, the Gaucho treated varieties had lower visual damage ratings for most varieties. Little difference in damage rating

between the untreated and Gaucho treatments was observed with DP 428 B at Keiser and Asiatic A1 49 at both locations. These varieties were the only ones to exhibit possible thrips resistance characteristics from a visual damage-rating standpoint.

The yield data for the untreated and Gaucho treatments was subjected to regression analysis to further evaluate the yield response of the varieties. Figures 1 and 2 display the results for Marianna and Keiser, respectively. Data points that fall on the regression trendline had equal yields between untreated and Gaucho treatments. Data points above the regression line represent varieties that had greater yields with the untreated treatment, while those points below had greater yields with Gaucho.

As expected, the older cotton varieties seemed to display more consistent thrips resistance characteristics across both locations. Coker 100A, Auburn 56, and Asiatic A1 49 had similar yields at both locations. Although Empire WR61 has historically exhibited thrips resistance potential, difference in yield at Keiser was 106 lb/acre while no yield difference was observed at Marianna. The modern variety DP 428 B exhibited thrips resistance potential at both locations with respect to yield and thrips damage rating. At Keiser, no yield difference was observed between treatments for three experimental varieties: 9101-97-09, 9108-23-05, and 9111-57-20. Variety 9108-04-17 had similar yields between treatments at Marianna; however, no experimental line was consistent with respect to thrips resistance potential in this study.

PRACTICAL APPLICATION

Thrips host plant resistance is a distinct possibility, particularly in older cotton varieties. The modern variety DP 428 B indicated resistance potential in this study along with older, less common varieties. Older varieties Coker 100A, Auburn 56, and Asiatic A1 49 exhibited resistance characteristics at both locations. DP 428 B was the only current variety to indicate resistance potential from both damage rating and yield parameters. Further evaluation of these varieties is necessary to pinpoint genetic characteristics that provide the resistance mechanism. Utilizing host plant resistance can reduce dependence on thrips insecticides, resulting in fewer inputs and reducing environmental impact.

LITERATURE CITED

Fairbanks, M.W., D.R. Johnson, and T.J. Kring. 2000. Thrips resistance in current obsolete and foreign cotton varieties. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1111-1112.

Fairbanks, M.W., D.R. Johnson, and T.J. Kring. 2001. Species composition and population increase of early season thrips on cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1069-1070.

Fairbanks, M.W., D.R. Johnson, and T.J. Kring. 1999. Thrips tolerance on selected cotton cultivars. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 980-981.

Jenkins, J.N. 1994. Host plant resistance to insects in cotton. *In:* Proc. World Cotton Res. Conf. pp. 359-372.
Johnson, D.R., C.D. Klein, H.B. Myers, and L.D. Page. 1996. Pre-bloom square loss, causes, and diagnosis. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 103-105.
Hawkins, B.S., H.A. Peacock, and T.E. Steele. 1966. Thrips injury to upland cotton (*Gossypium hirsutum* L.) varieties. Crop Sci. 6:256-258.
Sadras, V.O., and L.J. Wilson. 1988. Recovery of cotton crops after early season damage by thrips. Crop Sci. 38:399-409.
Tugwell, N.P., and B.A. Waddle. 1964. Yield and lint quality of cotton as affected by varying production practices. University of Arkansas Agricultural Experiment Station Bulletin 682.
Williams, M.R. 2001. Cotton insect loss estimates – 2000. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 774-776.

Table 1. Evaluation of cotton cultivars for thrips resistance, Marianna, AR, 2001.

Variety	Total seasonal thrips[z]		Thrips damage rating[y]		Lint yield	
	Untreated	Gaucho	Untreated	Gaucho	Untreated	Gaucho
					----- (lb/acre) -----	
9101-97-09	139.3	65.3	3.8	1.7	884	954
9101-97-10	177.5	81.0	4.1	1.8	848	1008
9108-04-17u	204.0	69.8	4.4	1.8	1183	1111
9108-23-03	173.0	70.8	4.5	2.1	879	934
9108-23-05	158.5	70.3	4.6	2.3	1023	1154
9111-57-12	121.5	71.3	4.6	2.3	769	905
9111-57-20	178.8	65.0	4.3	2.0	836	949
Ark 8712	165.5	58.8	4.3	2.3	1053	1051
St 474	176.3	40.0	4.8	2.5	782	870
PM 1560 BG	165.3	76.0	3.9	2.5	652	753
SG 105	164.0	51.3	3.9	2.1	793	929
DP NuCotn 33B	103.0	33.8	4.7	2.2	674	788
DP 428 B	136.0	86.8	4.2	2.0	938	939
Coker 100A	193.8	37.3	3.8	1.9	616	666
Rex	193.8	59.3	3.6	1.8	708	776
Auburn 56	163.8	62.0	4.3	1.8	575	583
Empire WR61	152.3	84.8	3.4	1.8	628	635
Asiatic A1 49	94.5	54.8	1.2	1.1	146	174
LSD (P=0.05)	70.1		0.6		133.4	

[z] Total number from five plants per plot at four sampling dates.
[y] Visual damage rating average: 1 (low damage) to 10 (high damage).

Table 2. Evaluation of cotton cultivars for thrips resistance, Keiser, AR, 2001.

	Total seasonal thrips[z]		Thrips damage rating[y]		Lint yield	
Variety	Untreated	Gaucho	Untreated	Gaucho	Untreated	Gaucho
					----- (lb/acre) -----	
9101-97-09	59.5	35.0	5.4	1.9	1015	938
9101-97-10	47.0	33.5	5.5	1.4	948	1064
9108-04-17	56.5	19.3	6.0	1.8	1015	1207
9108-23-03	55.8	9.0	5.8	1.4	879	918
9108-23-05	59.8	31.8	5.4	3.3	1009	968
9111-57-12	47.8	35.0	5.5	2.4	892	925
9111-57-20	60.0	38.8	5.9	3.6	937	913
Ark 8712	66.3	28.8	5.5	2.6	918	1052
St 474	58.0	62.0	6.0	3.5	764	785
PM 1560 BG	46.5	24.0	6.1	3.5	840	830
SG 105	63.8	24.8	5.1	3.0	929	1070
DP NuCotn 33B	64.5	29.8	5.6	2.4	896	925
DP 428 B	43.0	56.3	4.1	3.5	937	936
Coker 100A	57.3	36.3	4.6	2.8	891	871
Rex	54.3	39.0	3.9	2.6	847	872
Auburn 56	88.8	52.3	6.3	2.8	730	725
Empire WR61	63.3	29.8	4.0	1.5	686	792
Asiatic A1 49	45.3	19.5	2.6	1.8	347	347
LSD (P=0.05)	34.5	1.5	172.8			

[z] Total number from five plants per plot at four sampling dates.
[y] Visual damage rating average: 1 (low damage) to 10 (high damage).

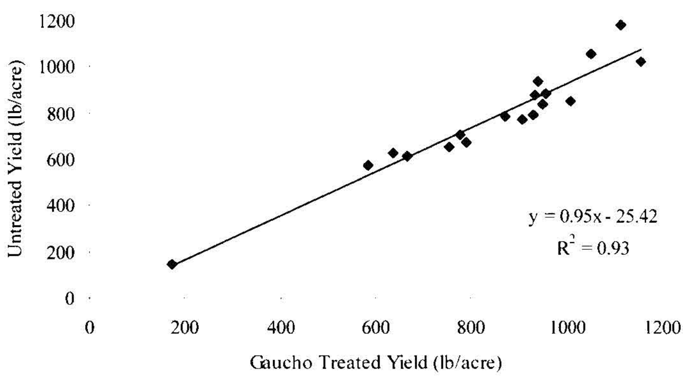


Fig. 1. Lint yield comparison of untreated and Gaucho-treated cotton varieties, Marianna, AR. 2001.

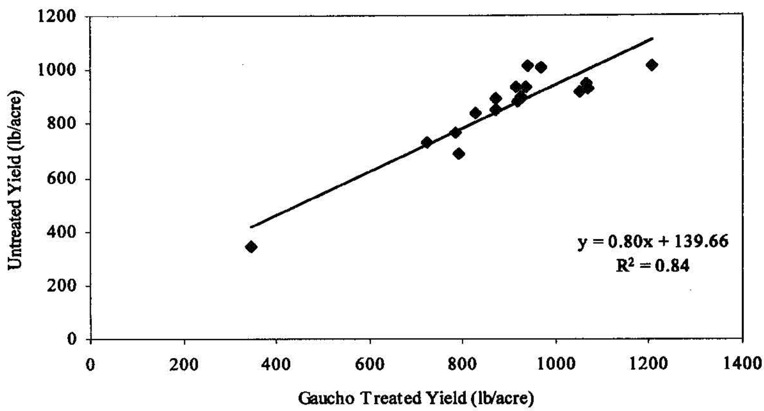


Fig. 2. Lint yield comparison of untreated and Gaucho-treated cotton varieties, Keiser, AR. 2001.

HELIOTHINE CONTROL IN *Bt* AND NON-*Bt* COTTON WITH THE ADVENT OF BOLL WEEVIL ERADICATION

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

RESEARCH PROBLEM

A successful boll weevil eradication program in Arkansas will not only eliminate the boll weevil as a threat to cotton producers but will also influence the control strategies of other traditional pests. Several new insecticides and a pyrethroid standard were evaluated for heliothine performance in transgenic *Bt* and conventional cotton during the late stages of boll weevil eradication.

BACKGROUND INFORMATION

Cotton bollworm (*Heliocoverpa zea*) and tobacco budworm (*Heliothis virescens*) pest management represents a significant but necessary investment for Arkansas cotton growers. These pests reduced Arkansas cotton yields approximately 3.3%, with more than 60,000 bales lost (Williams, 2001). Many studies have confirmed the positive yield benefit from effective insect pest management. The boll weevil eradication program allows producers to take full advantage of the beneficial insect population in management of cotton pests. Innovation in cost reduction coupled with improved conservation of beneficial insects is needed to help lower cotton production costs for the Arkansas cotton producer. This study will identify improved and more economical means for management of bollworm and tobacco budworm populations and identify improved management strategies, which allow conservation of beneficial insects. Identification and use of improved bollworm and tobacco budworm management practices will in turn improve the competitive position of the Arkansas cotton producer in the world cotton market.

---

[1] Extension entomologist-pest management section leader, Cooperative Extension Service, Little Rock; entomology extension specialist and entomology associate specialist, Cooperative Extension Service, Lonoke; and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock.

Arkansas has traditionally adhered to using environmentally sound IPM practices in the management of cotton. The cotton industry is currently on the brink of a new wave of innovation that will utilize several classes of new crop-protection chemicals and revolutionary new approaches in biotechnology. Considering the past performance of the boll weevil eradication program, approximately 5 million acres of cotton in 10 states are weevil-free (El-Lissy and Grefenstette, 2001). The amount of pesticide applied in these areas has been reduced significantly. Yields have also increased due to greater lint production in the upper portion of plants, areas vulnerable to late-season boll weevil infestation (Cunningham and Grefenstette, 1998). Transgenic *Bt* varieties planted in boll weevil-free areas have created low insecticide-use environments compared to historical standards. This shift in insecticide-use patterns has caused significant changes in the cotton pest spectrum (Smith, 1998). Studies in the southeastern U.S. have shown a significant shift in the pest complex associated with cotton production. Early season disruption of beneficial insects using older, broad-spectrum insecticides can lead to increased populations of aphids, cotton bollworm, and fall armyworm in *Bt* cotton. Previous research has indicated early to mid-season applications of broad-spectrum insecticides can compromise the effectiveness of *Bt* cotton by disrupting populations of beneficial insects in the absence of the boll weevil (Turnipseed and Sullivan, 1997). The development of effective bollworm and budworm management strategies is necessary to maximize the benefits from boll weevil eradication and best utilize beneficial insects to help control the pests of *Bt* and conventional cotton.

RESEARCH DESCRIPTION

This trial was conducted on the Gary Burton Farm in Lafayette County, Arkansas, in 2001. The treatments observed in the experiment are listed in Table 1. Stoneville varieties ST 4793 R and ST 4892 BR were planted on 4 May in plots containing 24 38-inch rows 80 ft. in length. The experimental design was a split-plot arranged in a randomized complete block design with four replications. 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 sprayer equipped with a compressed air delivery system. The boom was equipped with conejet TXVS 6 nozzles on 19-inch spacings. Operating pressure was 45 psi with a final spray volume of 8.6 GPA. Treatments were applied as foliar sprays on 11 July, 19 July, and 6 August. The ST 4892 BR variety was not treated on 19 July due to insect pressure below the recommended treatment threshold. Insect counts and damage ratings were made on 17 July (6DAT#1), 24 July (5DAT#2), and 10 August (4DAT#3). Beneficial insect populations were sampled from each plot using a gas-powered blower equipped with a mechanism for trapping insects in a cloth bag. The beneficial insect samples were transferred to plastic bags, stored in a cool environment, and transported to the lab for identification. Heliothine data were collected by randomly examining 50

squares and 50 terminals from the center of each plot for the presence of live larvae and damage. 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 with a commercial cotton harvester on 30 October (179DAP) and lint yields were determined based on a 35% 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 2001, Heliothine pressure was predominately from cotton bollworm in Lafayette County. Other areas of Arkansas reported similar population trends.

Average beneficial insect populations for selected species are displayed in Table 1. Lady beetle adults were the predominant species throughout the study, and varietal differences in population are evident. Surprisingly, the Bollgard variety had greater numbers overall when compared to conventional cotton. The Karate treatment resulted in fewer beneficial insects in the conventional variety; however, the lady beetle population in the Bollgard variety was comparable to the other insecticide treatments. Of all the non-pyrethroid compounds, Intrepid had the least effect on populations of big-eyed bugs and parasitic wasps in the Bollgard variety. Applications of malathion were made by the Boll Weevil Eradication Program during the growing season and this likely caused the low beneficial populations observed at the rating dates.

For the conventional variety, all insecticides significantly reduced square damage below the untreated check with the exception of Intrepid (0.25 lb ai/acre; Table 2). As expected, the untreated check had the greatest presence of live larvae throughout the season. Tracer (0.067 lb ai/acre) and Karate had live larvae levels significantly lower than Intrepid (0.25 lb ai/acre). The performance of Karate in the conventional variety reflects back on the species composition throughout the 2001 growing season, with cotton bollworm remaining dominant. Insecticide treatment had no effect on Heliothine control for the Bollgard variety, with no significant differences among treatments with respect to square damage and live larvae. The mean values in Table 2 display the reduced square damage obtained with Bollgard. Only Tracer (0.067) and Steward (0.065) achieved significantly equal levels of suppression regardless of variety. No differences in live larvae were observed between treatments of the Bollgard variety. In this study, Bollgard was successful in suppressing the Heliothine complex without the need for any insecticide applications. Overall, lint yield was very low, and no significant yield differences were observed in this study even between the untreated treatments for both varieties. The level of Heliothine control observed more than likely would have been reflected in the yield. This lack of difference suggests an additional environmental factor was responsible for these results.

PRACTICAL APPLICATION

The results from this study indicate Bollgard to be an effective method of controlling the Heliothine complex without any insecticide applications. All insecticides used in this study successfully controlled insect pressure in conventional cotton. Low populations of tobacco budworm resulted in acceptable performance of Karate in controlling cotton bollworm. Although beneficial populations were affected by malathion, more lady beetles were present in the Bollgard rather than conventional cotton. Further investigation is necessary to determine economical Heliothine management options in boll weevil eradication areas.

LITERATURE CITED

Cunningham, G., and B. Grefenstette. 1998. Boll weevil eradication – a beltwide prospectus. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 999-1000.

El-Lissy, O., and B. Grefenstette. 2001. Boll weevil eradication - national status, 2000. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 776-781.

Smith, R.H. 1998. Year two of Bollgard behind boll weevil eradication – Alabama observations. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 965-966.

Turnipseed, S.G., and M.J. Sullivan. 1997. Reduced effectiveness of BT cotton following disruption of beneficial with early-season insecticides. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Williams, M.R. 2001. Cotton insect loss estimates – 2000. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 774-776.

Table 1. Effect of variety and chemical treatment on seasonal average Heliothine control in cotton.

Variety	Treatment	Damaged squares[z]	Total live larvae[z]	Lint yield
	(lb ai/acre)	(%)		(lb/acre)
ST 4793 R	Untreated	4.16 a[y]	2.75 a	666 a
	Tracer 4SC (0.045)	2.91 bc	0.92 bc	715 a
	Tracer 4SC (0.067)	1.42 def	0.17 c	682 a
	Steward 1.25SC (0.065)	1.25 d-g	1.00 bc	720 a
	Steward 1.25SC (0.09)	2.08 cd	0.92 bc	773 a
	Intrepid 2F (0.125) + Latron CS-7 (0.125%)	2.33 cd	0.75 bc	735 a
	Intrepid 2F (0.25) + Latron CS-7 (0.125%)	3.75 ab	1.58 b	654 a
	Karate Z 2.08CS (0.033)	1.59 de	0.50 c	717 a
ST 4892 BR	Untreated	0.33 efg	0.00 c	778 a
	Tracer 4SC (0.045)	0.34 efg	0.25 c	747 a
	Tracer 4SC (0.067)	0.58 efg	0.08 c	762 a
	Steward 1.25SC (0.065)	0.33 efg	0.17 c	736 a
	Steward 1.25SC (0.09)	0.42 efg	0.00 c	695 a
	Intrepid 2F (0.125) + Latron CS-7 (0.125%)	0.25 efg	0.25 c	644 a
	Intrepid 2F (0.25) + Latron CS-7 (0.125%)	0.00 g	0.08 c	594 a
	Karate Z 2.08CS (0.033)	0.17 fg	0.25 c	765 a

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

Table 2. Beneficial insect population response to reduced cost-management strategies for control of the Heliothine complex in cotton.

Variety	Treatment	Lady beetle adults	Minute pirate bugs	Big-eyed bug adults	Parasitic wasps
	(lb/acre)	(#/80-row ft)[z]			
ST 4793 R	Untreated	1.50 e[y]	0.00 b	0.30 b	0.30 bc
	Tracer 4SC (0.045)	4.00 b-e	0.30 b	0.00 b	0.30 bc
	Tracer 4SC (0.067)	4.30 b-e	0.00 b	0.30 b	0.30 bc
	Steward 1.25SC (0.065)	1.80 de	0.00 b	0.30 b	0.00 c
	Steward 1.25SC (0.09)	2.50 cde	0.00 b	0.00 b	0.00 c
	Intrepid 2F (0.125) + Latron CS-7 (0.125%)	1.30 e	0.80 ab	0.00 b	0.00 c
	Intrepid 2F (0.25) + Latron CS-7 (0.125%)	2.30 cde	0.30 b	0.50 b	0.00 c
	Karate Z 2.08CS (0.033)	1.00 e	0.00 b	0.00 b	0.00 c
ST 4892 BR	Untreated	7.50 a-d	1.30 a	0.80 ab	0.80 abc
	Tracer 4SC (0.045)	7.50 a-d	0.30 b	0.80 ab	0.50 bc
	Tracer 4SC (0.067)	4.80 b-e	0.50 ab	0.00 b	1.00 ab
	Steward 1.25SC (0.065)	7.30 a-d	0.50 ab	0.00 b	0.00 c
	Steward 1.25SC (0.09)	10.50 a	0.00 b	0.30 b	0.00 c
	Intrepid 2F (0.125) + Latron CS-7 (0.125%)	8.00 abc	0.00 b	1.50 a	1.30 a
	Intrepid 2F (0.25) + Latron CS-7 (0.125%)	8.50 ab	0.00 b	0.50 b	0.30 bc
	Karate Z 2.08CS (0.033)	7.30 a-d	0.30 b	0.00 b	0.00 c

[z] All insects obtained from an 80-row ft. sample following the final insecticide application in August.

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

EFFICACY OF NEW AND STANDARD CHEMISTRY FOR HELIOTHINE CONTROL IN COTTON

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

RESEARCH PROBLEM

Monitoring and comparing the performance of new and traditional insecticides is an essential part of managing Heliothine resistance and developing effective cotton pest management programs. Two experiments were conducted to compare the efficacy of new and standard insecticides for Heliothine control in cotton.

BACKGROUND INFORMATION

Development and testing of new compounds are essential components of managing Heliothine resistance to traditional cotton insecticides. In recent years, non-pyrethroid compounds such as Tracer (spinosad) have become an integral part of most cotton pest management programs in Arkansas. Many other non-pyrethroid compounds have been developed and continued evaluation of the efficacy of these new insecticides is necessary for their integration into cotton pest management programs.

Steward (indoxacarb) insecticide from Dupont Crop Protection received full registration for use on Arkansas cotton in 2001. This compound is a sodium-channel blocker, which causes paralysis and death by inhibiting the flow of sodium into nerve cells (Sherrod, 2001). Steward controls a broad spectrum of cotton worm pests including cotton bollworm, tobacco budworm, beet and fall armyworm, and loopers (Bierman, 1998). Previous research has indicated Steward (0.11 lb ai/acre) to be comparable to Tracer with respect to Heliothine control (Hopkins et al., 2001)

Denim contains emamectin benzoate, a second-generation avermectin insecticide that provides control of many Lepidopteran species including tobacco budworm, cotton bollworm, armyworms, and loopers (Dunbar et al., 1998). While emamectin benzoate is susceptible to photodegradation, reservoirs of the compound develop in cot-

[1] Entomology extension specialist and entomology associate specialist, Cooperative Extension Service, Lonoke; extension entomologist-pest management section leader and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock.

ton 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).

The molt-accelerating compound Intrepid belongs to the diacylhydrazine class of chemistry developed by Rohm and Haas Company (now a part of Dow AgroSciences). Intrepid mimics an insect-molting hormone when ingested, which causes feeding to cease within hours (Edgecomb and Schlesselman, 2001). 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).

XR-225 is a compound from Dow AgroSciences currently in the developmental stages. This compound is a gamma-cyhalothrin, a fully-resolved isomer of lambda-cyhalothrin (Karate). While its mode of action and pest spectrum are similar to other pyrethroids, XR-225 has shown equal activity to Karate at half the recommended Karate rate (Nead-Nylander, personal communication).

Two field experiments were conducted to compare the efficacies of these compounds to traditional insecticides and determine the effects of combinations of new and traditional insecticides for Heliothine control in cotton.

RESEARCH DESCRIPTION

The trials were conducted on the Chuck Hooker Farm in Jefferson County, Arkansas, in 2001. This farm was located within the boll weevil eradication zone and received programmed sprays of ULV malathion that virtually eliminated boll weevil and plant-bug pressure. The treatments observed in the two experiments are listed in Tables 1 and 2. The cultivar DeltaPine 425R was planted on 30 April in small plots (eight 38-inch rows x 50 ft) arranged in a randomized complete block design with four replications.

During the conduct of this trial, the cotton bollworm made up the majority of the Heliothine population (range 63 to 78%) based on pheromone trap catches (Fig. 1). Treatments were initiated based on estimated peak Heliothine egg lay.

Applications were made with a John Deere 6000 hi-cycle sprayer equipped with a compressed air delivery system. The boom was equipped with conejet TXVS 6 nozzles on 19-inch spacings. Operating pressure was 45 psi with a final spray volume of 8.6 GPA. Treatments were applied as foliar sprays on 11 July, 18 July, and 3 August. Insect counts and damage ratings were made on 16 July (5DAT#1), 23 July (5DAT#2), and 7 August (4DAT#3). Data were collected by randomly examining 50 squares and 50 terminals from the center of each plot for the presence of live larvae and damage. 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 with a commercial two-row John Deere cotton harvester on 25 October (178DAP) 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 (P=0.05).

RESULTS AND DISCUSSION

All treatments in experiment 1 resulted in significantly less square damage than was found in the untreated control (Table 1). The seasonal live-larval count was suppressed with all treatments except Intrepid (0.15 lb ai/acre) and Karate (0.025 lb ai/acre), which were not significantly different from the untreated control. Steward (0.104 lb ai/acre) and Denim (0.01 lb ai/acre) resulted in lower percentage square damage than Intrepid, while Denim also significantly reduced the presence of live larvae when compared to Intrepid. All treatments, including the pyrethroids, provided statistically similar Heliothine suppression when compared to the Tracer (0.063 lb ai/acre) treatment. This lack of means separation may be explained by the high bollworm:budworm ratio experienced throughout the growing season. Typically, more budworms than bollworm are present from late July through mid-August. In 2001, populations of these pests were reversed.

Treatment differences were more apparent when cotton lint yield was obtained at season's end, with all treatments yielding higher than the untreated control. Tracer provided significantly greater yield than all treatments except Steward and Denim, which provided the best Heliothine suppression throughout the season. New products Intrepid and XR-225 failed to provide greater control and yield than the standard pyrethroid insecticides. No rate response was observed with XR-225 when applied at 0.0042 and 0.014 lb ai/acre.

In experiment 2, no statistically significant (P=0.05) treatment differences, including the untreated control, were observed with respect to square damage and seasonal live larval count (Table 2). Lower seasonal Heliothine pressure occurred in 2001 when compared to most years, and this may have influenced the lack of response for this particular experiment. Numerical trends in the data did suggest that all chemical treatments had an adverse effect on the Heliothine population. Treatment differences were much more evident with respect to cotton lint yield. All treatments resulted in greater yield than the untreated control. Only Denim (0.01 lb ai/acre) provided a yield greater than Intrepid (0.15 lb ai/acre) and all standard pyrethroid insecticides with the exception of Karate (0.028 lb ai/acre). No yield differences were observed between Denim, Tracer (0.063 lb ai/acre), Steward (0.104 lb ai/acre), XR-225 (0.014 lb ai/acre), Decis (0.01 lb ai/acre), Karate (0.028 lb ai/acre), and the Calypso + Steward tank mix.

PRACTICAL APPLICATION

The selective use of both new and traditional insecticides can decrease the development of Heliothine resistance and result in more effective cotton pest manage-

ment programs. Continuous evaluation of new and traditional insecticides is necessary to monitor performance against possible Heliothine resistance. In 2001, lower than normal Heliothine populations resulted in little or no difference between new, non-pyrethroid insecticides and traditional insecticides. The results from these experiments indicated that newer insecticides Steward and Denim provided Heliothine control equal to that of Tracer and greater than the standard pyrethroids. Performance of Intrepid and XR-225 was significantly lower than the previously mentioned products. Further evaluation of these products is necessary to determine performance under different environmental conditions as well as observe how they may be integrated into cotton best management programs.

ACKNOWLEDGMENTS

The authors thank Mr. Chuck Hooker, Dow AgroSciences, DuPont Crop Protection, Bayer Corporation, and Syngenta for providing the resources needed to conduct this research.

LITERATURE CITED

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

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. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1116-1119.

Edgecomb, D.W., and J.T. Schlesselman. 2001. Confirm™ and Intrepid™: new MAC chemistry for western cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 996-997.

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

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, and J.D. Reaper. 2001. Steward (Indoxacarb) performance in cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Mempis, TN. pp. 1081-1084.

Sherrod, D. 2001. Steward™ insecticide – an overview of performance under section 18 in 2000. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 60-61.

Table 1. Seasonal average heliothine control in cotton using new and traditional insecticides (Experiment 1).

Treatment	Damaged squares[z]	Total live larvae[z]	Lint yield
(lb ai/acre)	(%)		(lb/acre)
Untreated control	25.64 a[y]	3.75 a	595 g
Tracer 4SC (0.063)	10.30 bc	1.23 bc	1054 a
Steward 1.25SC (0.104)	6.84 c	1.25 bc	984 abc
Intrepid 2F (0.15) + Latron CS-7 (0.125%v/v)	13.14 b	2.65 ab	813 ef
Denim 0.16EC (0.01)	5.96 c	0.90 c	1033 ab
Karate Z 2.09CS (0.025)	11.30 bc	2.42 abc	943 bcd
Decis 1.5EC (0.01)	9.50 bc	1.87 bc	864 def
XR-225 150CS (0.0042)	10.50 bc	1.92 bc	786 f
XR-225 150CS (0.014)	8.00 bc	1.32 bc	880 def
Karate Z 2.09CS (0.0084)	11.70 bc	1.67 bc	822 ef
Karate Z 2.09CS (0.028)	10.16 bc	2.27 bc	914 cde

[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. Seasonal average heliothine control in cotton using new and traditional insecticides (Experiment 2).

Treatment	Damaged squares[z]	Total live larvae[z]	Lint yield
(lb ai/acre)	(%)		(lb/acre)
Untreated control	14.64 a[y]	2.10 a	735 d
Tracer 4SC (0.063)	10.20 a	1.67 a	1052 ab
Steward 1.25SC (0.104)	7.96 a	1.17 a	965 abc
Intrepid 2F (0.15) + Latron CS-7 (0.125%v/v)	12.26 a	2.75 a	933 bc
Denim 0.16EC (0.01)	8.86 a	0.97 a	1094 a
Decis 1.5EC (0.01)	10.50 a	1.35 a	985 bc
XR-225 150CS (0.014)	7.86 a	2.02 a	992 bc
Karate Z 2.08CS (0.028)	9.96 a	1.83 a	1025 abc
Baythroid 2EC (0.03)	9.60 a	1.25 a	882 c
Karate Z 2.08 (0.028) + Intrepid 2F (0.06) + Latron CS-7 (0.125%v/v)	8.70 a	1.67 a	901 bc
Calypso 4SC (0.047) + Steward 1.25SC (0.104)	5.46 a	1.07 a	997 abc

[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).

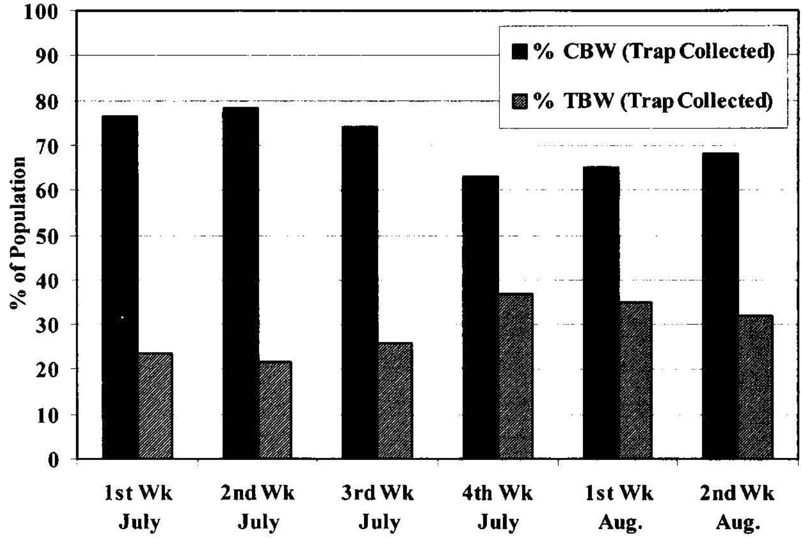


Fig. 1. Heliothine population distribution based on pheromone trap collection. Jefferson County, AR, 2001.

EFFICACY OF HELIOTHINE CONTROL MATERIALS IN *Bt* AND NON-*Bt* COTTON

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

RESEARCH PROBLEM

This study was conducted to evaluate potential benefits from low or reduced rates of supplemental insecticides applied to control the Heliothine complex in *Bt* cotton and to evaluate control strategies in *Bt* and non-*Bt* cotton.

BACKGROUND INFORMATION

The bollworm, *Helicoverpa zea* (Boddie), and the tobacco budworm, *Heliothis virescens* (Fab.), are perennial pests of cotton in Arkansas and growers utilize control measures to prevent economic damage each year in non-*Bt* cotton varieties. The commercialization of transgenic cotton cultivars containing the insecticidal endotoxin of *Bacillus thurengiensis* (*Bt*) 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 widely used in Arkansas with approximately 8% of the 1.08 million cotton acres in 2001 being planted to transgenic *Bt* varieties and 51% of the acreage being planted to stacked gene (*Bt* plus Roundup Ready) varieties. Continued research is needed to help understand how best to maximize the benefits of this new tactic for Heliothine control in cotton. Cotton containing a single gene for the production of CryIA(c) toxin 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; Hopkins et al., 2001). Resistance management is

[1] Entomology associate specialist, Cooperative Extension Service, Lonoke; extension entomologist-pest management section leader and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock; and entomology extension specialist, Cooperative Extension Service, Lonoke.

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 6 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 using *Bt* cotton along with low or reduced rates of supplemental insecticide for enhanced Heliothine control.

RESEARCH DESCRIPTION

This trial was conducted on the Chuck Hooker Farm in Jefferson County, Arkansas, in 2001. This farm is located within the boll weevil eradication zone and received programmed sprays of ULV malathion that virtually eliminated boll weevil pressure and reduced plant bug pressure. Treatments were evaluated in small plots (eight 38-inch rows x 50 ft) arranged in a randomized complete block design with four replications. The cotton varieties used were Deltapine 451BR and Deltapine 425R, planted on 30 April. The treatments tested with *Bt* cotton were: untreated control, Fury 1.5 EC (0.024 lb ai/acre); Steward 1.25 SC (0.078 lb ia/acre) + Dyne-Amic (0.38% v/v); Tracer 4 SC (0.067 lb ai/acre); Karate Z 2.08 CS (0.015 lb ai/acre); and Vydate C-LV 3.77 SL (0.25 lb ai/acre). The treatments test with non-*Bt* cotton were: untreated control, Fury 1.5 EC (0.0375 lb ai/acre); Steward 1.25 SC (0.104 lb ai/acre) + Dyne-Amic (0.38% v/v); Tracer 4 SC (0.067 lb ai/acre); Karate Z 2.08 CS (0.028 lb ai/acre); and Denim 0.16 EC (0.015 lb ai/acre).

The crop was furrow-irrigated on an as-needed basis. Treatments were initiated based on estimated peak Heliothine egg lay. 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 19-inch spacing. Operating pressure was 45 psi with a final spray volume of 8.6 gallons per acre. Treatments were applied as foliar sprays on 11 July (non *Bt* only), 18 July, and 3 August. Insect counts and damage ratings were made in the *Bt* cotton on 16 July (Pretreatment), 23 July ((t days after treatment; 5DAT#1), and 7 August (4DAT#2); and in the non-*Bt* cotton on 16 July (5DAT#1), 23 July (5DAT#2), 7 August (4DAT#3). 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 inch + >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 23 October (176DAP) and lint yields were determined based on a 35% 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=0.10) was used to separate means only when AOV Treatment P(F) was significant at P=0.05.

RESULTS AND DISCUSSION

This trial was conducted under predominantly cotton bollworm pressure. Based on pheromone trap catches, the percentage of the Heliothine population made up of bollworms ranged from 95 to 99% and 73 to 100%, respectively, during the conduct of the trial (Fig. 1). With the exception of Vydate C-LV 3.77SL (0.25 lb ai/acre), all supplemental insecticide treatments on both *Bt* and non-*Bt* varieties significantly (P=0.05) reduced Heliothine square damage. In the *Bt* cotton, no differences were observed among treatments with respect the seasonal average live Heliothine larvae count in squares. In the non-*Bt* cotton, all insecticide treatments significantly lowered (P=0.05) the live Heliothine larvae count in squares compared to the untreated control when looking at the seasonal average (Table 1). On a numerical basis, all chemical treatments in the *Bt* cotton resulted in less Heliothine damaged terminals than found in the untreated *Bt* cotton alone; however, no treatment differed significantly from the untreated *Bt* cotton with respect to the live Heliothine larvae count in terminals. In the non-*Bt* cotton, all chemical treatments resulted in significantly less (P=0.05) Heliothine damaged terminals and lower live-Heliothine larvae counts in terminals compared to the untreated non-*Bt* cotton control (Table 2). In the *Bt* cotton, no chemical treatment significantly out-yielded the untreated *Bt* cotton control. On a numerical basis only, Vydate C-LV 3.77SL (0.25 lb ai/acre), Karate Z 2.08CS (0.015 lb ai/acre), and Tracer 4SC (0.067 lb ai/acre) did out-yield the untreated *Bt* cotton control (1232 lb lint/acre) by 211, 106, and 100 lb lint/acre, respectively. In the non-B.t cotton, all chemical treatments significantly (P=0.05) out-yielded the untreated non-*Bt* control but did not differ among themselves. Numerically, the highest yielding treatments in the non-*Bt* cotton plots were Denim 0.16EC (0.015 lb ai/acre), Tracer 4SC (0.067 lb ai/acre), and Steward 1.25SC (0.104 lb ai/acre) + Dyne-Amic (0.38% v/v), which each out-yielded the untreated non-*Bt* control by 235, 227, and 226 lb lint/acre, respectively (Fig. 2).

PRACTICAL APPLICATION

The results obtained suggest that the potential for higher yields is greater with the tested *Bt* cotton variety than with the tested non-*Bt* cotton variety. Also, trends in the data suggest that increased yields may be obtained when appropriate supplemental insecticides, targeted at pests not adequately controlled by the CryIA(c) toxin, are utilized in *Bt* cotton. In addition, the results of this study show that increased yields can be obtained when appropriate supplemental insecticides are utilized to control the Heliothine complex in non-*Bt* cotton.

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. *In:* 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. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 923-926.

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

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Performance of new and conventional insecticides in *Bt* cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1079-1081.

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:* D.M. Oosterhuis (ed.). Proc. of the 2000 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station Special Report 198:245-248.

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. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 863-867.

Table 1. Seasonal average percent Heliothine-damaged squares and live larval count: Efficacy of Heliothine control materials in *Bt* and non-*Bt* Cotton. Jefferson County, AR. 2001.

	Deltapine 451BR (*Bt*)[z]		Deltapine 425R (non-*Bt*)	
Treatment	Heliothine-damaged sq./50 sq. seasonal avg.	Total live Heliothine larvae/ 50 sq. seasonal avg.	Heliothine-damaged sq./50 sq. seasonal avg.	Total live Heliothine larvae/ 50 sq. seasonal avg.
(lb ai/acre)				
Untreated control	2.3 a[y]	0.1 a	12.7 a	3.8 a
Fury 1.5EC (0.024)	0.4 b	0.0 a	5.5 b	1.3 b
Steward 1.25SC (0.078) + Dyne-Amic (0.38%v/v)	0.8 b	0.0 a	2.8 b	0.8 b
Tracer 4SC (0.067)	0.3 b	0.0 a	5.2 b	1.1 b
Karate Z 2.08CS (0.015)	0.3 b	0.0 a	3.0 b	0.9 b
Vydate C-LV 3.77SL (0.25)	2.0 a	0.5 a		
Denim 0.16EC (0.015)			4.4 b	0.5 b

[z] Deltapine 451BR (*Bt*) received 2 treatment applications and Deltapine 425R (non-*Bt*) received 3 applications.

[y] Means in same column followed by same letter do not significantly differ (P=.05, Duncan's New MRT). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 2. Seasonal average Heliothine-damaged terminals and live larval count: Efficacy of Heliothine control materials in *Bt* and Non-*Bt* Cotton. Jefferson Co., AR. 2001.

	Deltapine 451BR (*Bt*)[z]		Deltapine 425R (non-*Bt*)	
Treatment	Heliothine-damaged sq./50 sq. seasonal avg.	Total live Heliothine larvae/ 50 sq. seasonal avg.	Heliothine-damaged sq./50 sq. seasonal avg.	Total live Heliothine larvae/ 50 sq. seasonal avg.
(lb ai/acre)				
Untreated control	2.5 a[y]	0.1 a	8.4 a	1.3 a
Fury 1.5EC (0.024)	0.9 a	0.0 a	5.3 b	1.0 ab
Steward 1.25SC (0.078) + Dyne-Amic (0.38%v/v)	1.3 a	0.0 a	3.6 b	0.3 bc
Tracer 4SC (0.067)	1.0 a	0.0 a	3.3 b	0.2 c
Karate Z 2.08CS (0.015)	0.4 a	0.0 a	3.8 b	0.4 bc
Vydate C-LV 3.77SL (0.25)	1.9 a	0.0 a		
Denim 0.16EC (0.015)			2.5 b	0.0 c

[z] Deltapine 451BR (*Bt*) received 2 treatment applications and Deltapine 425R (non-*Bt*) received 3 applications.

[y] Means in same column 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.

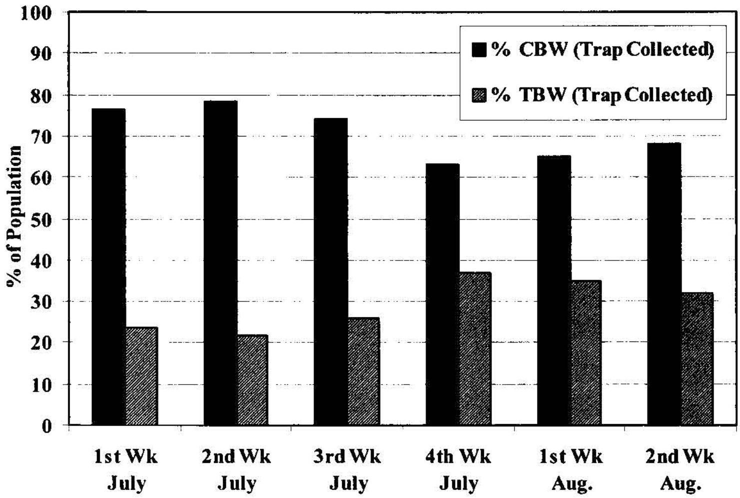


Fig. 1. Heliothine population distribution based on pheromone trap collections. Jefferson County, AR, 2001.

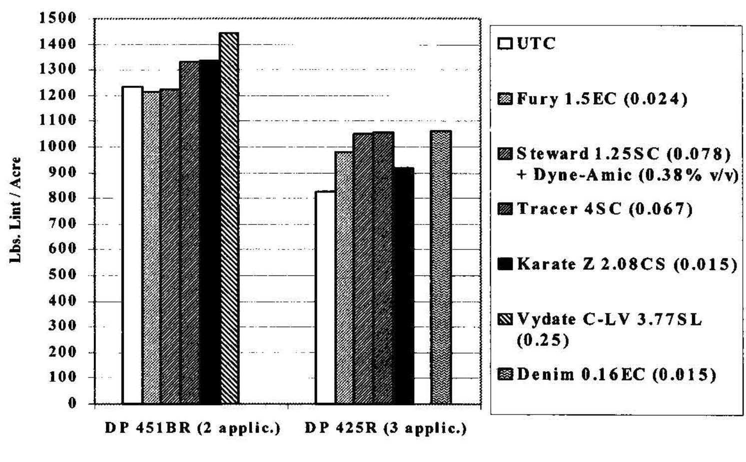


Fig. 2. Lint yield (35% turnout): Efficacy of Heliothine control materials in *Bt* and non-*Bt* cotton. Jefferson County, AR, 2001.

EFFICACY OF ASANA XL TANK MIXED WITH NEW CHEMISTRY FOR HELIOTHINE CONTROL IN COTTON

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

RESEARCH PROBLEM

As Heliothine resistance to pyrethroid insecticides becomes more common, cotton producers are constantly searching for economic pest-management options while utilizing the latest technology. This experiment was conducted to evaluate the efficacy of Asana XL, a pyrethroid, when tank mixed with newer, non-pyrethroid insecticides for Heliothine control in cotton.

BACKGROUND INFORMATION

Resistance of the Heliothis complex to several pyrethroid insecticides has been evident over the past several years. Many states throughout the mid-South have documented tobacco budworm (*Heliothis virescens*) and cotton bollworm (*Heliocoverpa zea*) resistance to this class of insecticides (Payne et al., 2001; Williams, 1999; Brown et al., 1998; Bagwell et al., 1996; Wall, 1994; Abd-Elghafar et al., 1993; Ernst and Dittrich, 1992). In Arkansas, critical levels of tobacco budworm resistance to certain pyrethroid and organophosphate compounds have been observed over the past few years while signs of cotton bollworm resistance are becoming apparent (Williams, 1999; Wall, 1994).

A direct result of pyrethroid resistance has been the development of several effective non-pyrethroid insecticides including Tracer, Steward, Denim, and Intrepid; however, these products may be more costly when compared to some traditional pyrethroids. In addition to these options, other pyrethroid insecticides, specifically Asana XL, have maintained acceptable control levels in areas with little or no resistance due to insecticide management recommendations. Previous research has indicated reduced

[1] Entomology extension specialist and entomology associate specialist, Cooperative Extension Service, Lonoke; extension entomologist-pest management section leader and extension entomologist-IPM coordinator, Cooperative Extension Service, Little Rock.

rates of S-1812 and Steward tank mixed with Asana XL has provided equal Heliothine control when compared to labeled rates of the products (Hopkins et al., 2001; Reaper et al., 2001).

The objective of this experiment was to observe the tank-mix efficacy of Asana XL with reduced rates of newer insecticides in addition to comparing the results with control of the recommended labeled rates.

RESEARCH DESCRIPTION

This trial was conducted on the Chuck Hooker Farm in Jefferson County Arkansas, in 2001. The treatments observed are listed in Table 1. Delta Pine 425R was sown on 30 April in small plots (eight 38-inch rows x 50 ft) arranged in a randomized complete block design with 4 replications. 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 sprayer equipped with a compressed air delivery system. The boom was equipped with conejet TXVS 6 nozzles on 19-inch spacings. Operating pressure was 45 psi with a final spray volume of 8.6 GPA. Treatments were applied as foliar sprays on 11 July, 18 July, and 3 August. Insect counts and damage ratings were made on 16 July (5DAT#1), 23 July (5DAT#2), and 7 August (4DAT#3). Data were collected by randomly examining 50 squares and 50 terminals from the center of each plot for the presence of live larvae and damage. 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 25 October (178DAP) 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 P=0.05.

RESULTS AND DISCUSSION

Populations of tobacco budworm and cotton bollworm were lower than those observed in 2000. Normally, tobacco budworm populations are greater in late July through early August. While this trend held true in 2001 (Table 1), overall pressure was lower than normal.

All treatments observed in this study resulted in fewer damaged squares, total live larvae, and greater lint yield when compared to the untreated control (Table 2). However, no differences in these parameters were observed between Steward, Tracer, Denim, and S-1812 when used alone or in combination with Asana XL. The addition of Asana XL (0.04 lb ai/acre) mixed with a reduced rate of Intrepid (0.10 lb ai/acre) did significantly reduce square damage below that observed for the labeled rate of Intrepid (0.15 lb ai/acre). Although square damage was suppressed with the tank mix, no difference in live larvae or lint yield was observed.

While no differences in total live larvae were observed, Intrepid did produce a lower yield than those observed with the Asana XL, Tracer, Denim, S-1812,and Asana + Tracer tank mix. The higher percentage square damage recorded for the Intrepid treatment more than likely caused this yield decrease.

Lack of significance among treatments indicates satisfactory performance of Asana XL used in combination with reduced rates of newer insecticides. It is important to note that equal levels of Heliothine control were achieved using labeled rates of all insecticides, including Asana XL, with the exception of Intrepid. Heliothine insect populations, particularly for tobacco budworm, were lower in 2001 than those observed in recent years. This fact may have contributed to the performance of the Asana XL treatment.

Many Heliothine control options currently exist for cotton producers in Arkansas. However, strict insecticide management is vital for preventing resistance in all production areas. Combining new compounds with traditional chemistry has, in this study and others, been an effective method of controlling the Heliothine complex. More importantly, a greater number of options are introduced to the producer while helping to manage insect resistance.

PRACTICAL APPLICATION

The increased expense involved with using the newer insecticides is a drawback for growers. Heliothine efficacy with lower rates of the new insecticides tank mixed with a standard pyrethroid may be a more economical approach to Heliothine control in cotton. Low populations of tobacco budworm caused few significant differences among treatments. No differences in square damage, live larvae, or lint yield were observed between Steward, Tracer, Denim, or S-1812 when used alone or at lower rates in combination with Asana XL. Equal levels of Heliothine control where achieved using labeled rates of all insecticides, including Asana XL, with the exception of Intrepid. Lack of significance among treatments indicates satisfactory performance of Asana XL tank mixed with reduced rates of newer insecticides. However, results may vary in years with greater tobacco budworm pressure, a species known to be resistant to pyrethroid insecticides.

ACKNOWLEDGMENTS

The authors thank Mr. Chuck Hooker, DuPont Crop Protection, Dow AgroSciences, Syngenta, and Valent for providing the resources necessary for this research.

LITERATURE CITED

Abd-Elghafar, S.F., C.O. Knowles, and M.L. Wall. 1993. Pyrethroid resistance in two field strains of *Heliocoverpa zea* (Lepidoptera: Noctuidae). J. Econ. Entomol. 89:509-593.

Bagwell, R.D., J.B. Graves, B.R. Leonard, E. Burris, S. Mucinski, J.H. Fife, and V. Mascarenhas. 1996. Status of insecticide resistance in tobacco budworm and bollworm in Louisiana during 1995. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1059-1067.

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 *Heliocoverpa zea* and transgenic cotton in South Carolina. Crop Protection 17:441-445.

Ernst, G. and V. Dittrich. 1992. Comparative measurements of resistance to insecticides in three closely related old and new world bollworm species. Pestic. Sci. 34:147-152.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, and J.D. Reaper. 2001. Steward (Indoxacarb) performance in cotton. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1081-1084.

Payne, G.T., J.S. Bacheler, J.W. Van Duyn, R.D. Bagwell, B.R. Leonard, M.L. Boyd, B.L. Freeman, N. Liu, J.R. Weeks, A. Herbert, G.A. Herzog, D.R. Johnson, M.B. Layton, G. Lentz, R. Seward, S.H. Martin, P.V. Pietrantonio, M.E. Roof, M.J. Sullivan, and R.K. Sprenkel. 2001. U.S. cottonbelt survey: testing the susceptibility of the bollworm, *Heliocoverpa zea* (Boddie) to pyrethroid insecticides. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 782-785.

Reaper, J.D., J.D. Hopkins, D.R. Johnson, G.M. Lorenz, and A.M. Fisher. 2001. Heliothine control in cotton with new chemistry. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 1122-1125.

Wall, M.L. 1994. Status of insecticide resistance in tobacco budworm and bollworm in Arkansas. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp.775-777.

Williams, K.R. 1999. Five years of vial testing on a county-wide basis for bollworm and budworm resistance to Tracer, pyrethroids, and Curacron in Ashley County, Arkansas. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp. 878-880.

Table 1. Heliothine composition of Jefferson and Lincoln Counties, AR, 2001.

Observation date	Cotton bollworm[z]	Tobacco budworm[z]
6 July	88.90	11.10
13 July	96.87	3.13
20 July	91.74	8.26
27 July	44.33	55.67
3 August	55.88	44.12
10 August	78.66	21.34
17 August	58.42	41.58

[z] Numbers based upon 7-day averages of pheromone traps throughout the counties.

Table 2. Seasonal Heliothine control in cotton with reduced rates of new insecticides tankmixed with a Pyrethroid insecticide.

Treatment	Damaged squares[z]	Total live larvae[z]	Lint yield
(lb ai/acre)	(%)		(lb/acre)
Untreated check	19.14 a[y]	1.70 a	656 c
Asana XL 0.66EC (0.04)	6.00 c	0.43 b	1067 a
Asana XL 0.66EC (0.04) + Steward 1.25SC (0.09)	5.30 c	0.52 b	989 ab
Asana XL 0.66EC (0.04) + Tracer 4SC (0.047)	5.30 c	0.17 b	1069 a
Asana XL 0.66EC (0.04) + Denim 0.16EC (0.0075)	6.16 c	0.25 b	976 ab
Asana XL 0.66EC (0.04) + Intrepid 2F (0.1)	4.20 c	0.60 b	991ab
Asana XL 0.66EC (0.04) + S-1812 35WP (0.1)	4.60 c	0.17 b	1036 ab
Steward 1.25SC (0.104)	4.30 c	0.32 b	921 ab
Tracer 4SC (0.067)	5.40 c	0.43 b	1052 a
Denim 0.16EC (0.015)	6.24 c	0.23 b	1106 a
Intrepid 2F (0.15)	12.26 b	0.40 b	857 b
S-1812 35WP (0.15)	6.84 c	0.17 b	1078 a

[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).

COTTON RESPONSE TO PRE-SQUARE TERMINAL INJURY FROM VARIOUS SIZES OF TARNISHED PLANT BUG NYMPHS

Steven Coy, Tina G. Teague, N. Philip Tugwell. and Eric J. Villavaso[1]

RESEARCH PROBLEM

Tarnished plant bugs [*Lygus lineolaris* (Palisot de Beauvois)] can move onto cotton from proximate wild host plants when those plants senesce or are sprayed with herbicides. For example, in a reduced tillage production system where herbicide application for weeds is delayed until after crop emergence, adult plant bugs present on weed hosts may move on to pre-squaring cotton and feed and/or fly to other areas. Movement of immature plant bugs is more restricted, and plant injury from their feeding activity could be severe. The objective of this study was to determine how feeding by plant bugs of different ages in pre-squaring cotton affect plant development, maturity, and yield.

BACKGROUND INFORMATION

The tarnished plant bug is a key pest in mid-South cotton (Tugwell et al., 1976). In pre-squaring cotton, the terminal portions of plants are preferred feeding sites (Layton, 1995). Injury from tarnished plant bug feeding at this crop stage can cause a loss of apical dominance, which can result in multiple terminals per plant, a condition sometimes referred to as "crazy cotton" (Scales and Furr, 1968). Reduced growth following terminal injury of pre-squaring cotton can delay development of squares and crop maturity and reduce yield if optimal growing conditions do not allow for compensatory growth (Wene and Sheets, 1964; Strong, 1970; Hanny et al., 1977). In studies with *Lygus hesperus* Knight, Wene and Sheets (1964) found that pre-square injury by adults resulted in a 4-week delay in squaring; lint yield reduction of 224 kg/ha (200 lb/acre); suppression of the growing point; prevention of development of true leaves;

[1] Research specialist-cotton entomology and professor, Arkansas State University, Jonesboro; professor, Department of Entomology, Fayetteville; and research scientist, ARS-USDA, Mississippi State, MS.

and produced plants with multiple main stems. When this feeding occurred during cool weather, the percent of plants producing multiple stems was almost double that from injury during warm weather. Strong (1970) reported that as little as 20 min. of feeding by *L. hesperus* destroyed the terminal of seedling cotton resulting in cessation of growth. With no further injury to the plant, re-growth of a new terminal occurred in about 10 days. Given adequate time and resources, the crop can recover from terminal injury with no reduction of yield (Brook et al., 1992) or costly yield penalties.

RESEARCH DESCRIPTION

The variety Stoneville 4892 was planted on Wildy Farms near Manila (Mississippi County) on 8 May. No insecticides were applied at planting. The soil is a sandy, excessively drained part of the Routon-Dundee-Crevasse complex. Furrow irrigation began on 15 June and continued weekly until 3 September. One post-emergence herbicide application of 0.66pt/acre of Caparol (prometryn) post direct and 1.5pt/acre of Direx (diuron) under a hood was made on 15 June. Plots were 4 rows wide and 30 feet long. After plant emergence, 10 ft of row that contained 15 healthy plants were marked off within the 2 center rows of each plot and all treatments and data collection were subsequently made on these plants.

The following treatments were initiated when cotton had grown 2 true leaves: (1) an uninfested check, (Control; (2) one first-second instar (Sm Bug) per plant; (3) one third instar (Med Bug) per plant; and (4) one fifth instar (Lg Bug) per plant. Bugs were released 15 days after planting. Nymphs of the appropriate size were aspirated into glass vials and placed in a small cooler containing ice for transfer to the field. Nymphs were allowed to walk out of the vials or were gently poured from the vial directly on true leaves. Care was taken to ensure that the bugs were clinging to the plant after release. Tarnished plant bug nymphs were obtained from a colony maintained on artificial diet at the USDA-ARS Biological Control and Mass Rearing Unit at Mississippi State, MS (Cohen, 2000).

At 9 and 18 days after release of bugs, the number of plants with terminal damage (withered, flagged, or aborted), active terminal growth (new unfurled growth of a leaf), and number of true leaves per plant were recorded. Plants were monitored weekly through cutout using COTMAN™ (Danforth and O'Leary, 1998). Weekly insecticide applications of Provado 1.6F (imidacloprid) (0.047 lb ai/acre) were made to uninfested check plots on 11, 19, 26 June and 2 July. All plots were sprayed on 20 July [Orthene 90S (1/3 lb/acre)] and 1 and 11 Aug [Centric 40 WG (3 oz/acre)]. Defoliant was applied on 1 Oct. One row from each plot was hand harvested on 17 September, 28 September, 17 October, and 29 October. The cumulative weight per plot of each harvest was used to calculate the mean maturity date for each treatment (Richmond and Ray, 1966; Bourland et al., 2001). The mean maturity date is equal to the sum of each sequential harvest weight times the number of days after planting for each harvest date divided by the sum total weight of harvest.

RESULTS AND DISCUSSION

Results from plant injury assessments indicated that injury from Med Bug and Lg Bug treatments was significantly greater than Sm Bug and Control treatments (Table 1). At 18 DAT, plants in the Med Bug and Lg Bug treatments contained significantly fewer true leaves per plant than plants in the Check and Sm Bug treatments, indicating a developmental delay in plants injured by Med and Lg Bugs (Table 1).

The average plant height of the infested plots was 2 to 3 inches shorter than the Check plots, (6.75 inches) at the time of post-direct application of herbicide on 15 June. Selectivity of post-emergence herbicide applications was reduced because of the plant height differences. Some plants injured by tarnished plant bugs did not survive the combination of plant bug and herbicide injury. Initial squaring was delayed in all tarnished plant bug-treated plots; on 18 June (41DAP) the mean number of squares per plant was 2.5 in Check plots and 0 in treated plots. On 27 June (50 DAP) there was a significant difference in the number of plants per plot producing squares, 54% (Med bug), 58% (Lg Bug), 84% (Control), and 82% (Sm Bug). Differences were observed for plant height, number of sympodial nodes, and number of squaring nodes on all sampling dates (data not shown). Mean number of squaring nodes for each treatment was plotted as nodes above first square and nodes above white flower in COTMAN growth curves (Fig. 1). When compared to the COTMAN target development curve, it is apparent that square initiation in all plots was delayed. This common delay was probably related to the cool weather immediately after planting. Once squaring began, a significant delay was noted between treatments. No plots reached physiological cutout (NAWF=5) prior to 9 Aug (93 DAP), the latest possible cutout date for the study area. Based on historical weather data, a flower on this date has a 50% probability of accumulating the necessary heat units (850 DD60's) required for boll maturation. There were no differences between treatments in days to cutout (NAWF=5). The mean maturity date shows a significant delay of 6 days between the Control and Lg Bug treatments ($P = 0.02$). Yields were significantly lower in the Lg Bug treatments compared to other treatments in the first two harvests, on 17 and 28 Sept; however, by 17 and 26 Oct there were no differences between treatments (Table 2).

PRACTICAL APPLICATION

While no significant yield reduction resulted from plant bug-induced injury, there was a trend for lower yields apparent in the plots infested with large nymphs. A significant delay in crop maturity was observed where large nymphs were released. Favorable weather conditions allowed the injured plants ultimately to compensate for injury caused by plant bug nymphs. In some years, crop delay from plant bug injury would force the crop to mature at the end of the season when insect pest pressure is high and when weather conditions unfavorable for crop termination are more likely.

Accurate early season scouting will allow timely detection of plant bugs and enable the grower to avoid crop delay associated with severe plant bug infestations. Growers should time herbicide applications to burn down spring weed hosts before cotton is established to eliminate the risk of plant bugs moving from in-field weed hosts directly onto the crop.

ACKNOWLEDGMENTS

The authors thank David Wildy, Justin Wildy, the staff at Wildy Farms, Dale Wells, and USDA-ARS research specialists Joe Stewart and Gay McCain for their assistance in the study.

LITERATURE CITED

Bourland, F.M., N.R. Benson, E.D. Vories, N.P. Tugwell, and D.M. Danforth. 2001. Measuring maturity of cotton using nodes above white flower. J. Cotton Sci. 5:21-28.

Brook, K.D., A.B. Hearn, and C.F. Kelly. 1992. Response of cotton, *Gossypium hirsutum* L., to damage by insect pest in Australia: Manual simulation of damage. J. Econ. Entomology 85:1368-1377.

Cohen, A.C. 2000. New Oligidic Production Diet for *Lygus hesperus* Knight and *L. lineolaris* (Palisot de Beauvois). J. Entomol. Sci. 35:301-310.

Danforth, D.M. and P.F. O'Leary (eds.). 1998. COTMAN expert system 5.0. User's Manual. University of Arkansas Agricultural Experiment Station, Fayetteville.

Hanny, B.W., T.C. Cleveland, and W.R. Meredith, Jr. 1977. Effects of tarnished plant bug (*Lygus lineolaris*) infestation on presquaring cotton (*Gossypium hirsutum*). Environ. Entomol. 6:460-462.

Layton, M.B. 1995. Tarnished plant bug: Biology, thresholds, sampling, and status of resistance. *In:* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN.

Richmond, T.R. and L.L. Ray. 1966. Product-quantity measures of crop maturity in cotton. Crop Sci. 6:235-239.

Scales, A.L., and R.E. Furr. 1968. Relationship between the tarnished plant bug and deformed cotton plants. J. Econ. Entomol. 61:114-118.

Strong, F.E. 1970. Physiology of injury caused by *Lygus hesperus*. J. Econ. Entomol. 63:808-814.

Tugwell, N.P., S.C. Young, Jr., B.A. Dumas, and J.R. Phillips. 1976. Plant bugs in cotton: importance of infestation time, types of cotton injury, and significance of wild host near cotton. University of Arkansas Agricultural Experiment Station Report Series 227. 24 pp.

Wene, G.P., and L.W. Sheets. 1964. Lygus bug injury to pre-squaring cotton. Ariz. Agric. Exp. Stn. Tech. Bull. 166. 28 pp.

Table 1. Percent of plants with actively growing terminals and mean number of true leaves per plant determined at 9 and 18 days after release of 1 TPB nymph per plant onto cotton at 2-leaf stage[z].

Treatment	Plants with actively growing terminals		Mean number true leaves/plant	
	9 DAT[y]	18 DAT	9 DAT	18 DAT
	----------- (%) -----------			
Check	67.3	85.8	1.8	3.7
Sm Bug	56.3	76.5	1.7	3.1
Med Bug	34.2	39.8	1.5	1.5
Lg Bug	20.5	32.5	1.5	1.7
P > F	0.002	0.002	0.11	0.01
$MSD_{0.05}$	27.3	34.0		1.8

[z] Bugs were released 15 days after planting.
[y] Days after treatment.

Table 2. Yield response to terminal injury treatments following release of TPB nymphs on 2-leaf stage cotton[z].

Treatment	Mean lint yield for each date of harvest			
	17 Sep	28 Sep	17 Oct	29 Oct
	---------- (lb/acre) ----------			
Check	379	588	1130	1264
Sm Bug	297	472	1053	1287
Med Bug	286	486	992	1171
Lg Bug	188	313	763	951
P > F	0.02	0.02	0.13	0.12
$MSD_{0.05}$	152	210		

[z] Lint yield was calculated as 33% of seedcotton weight.

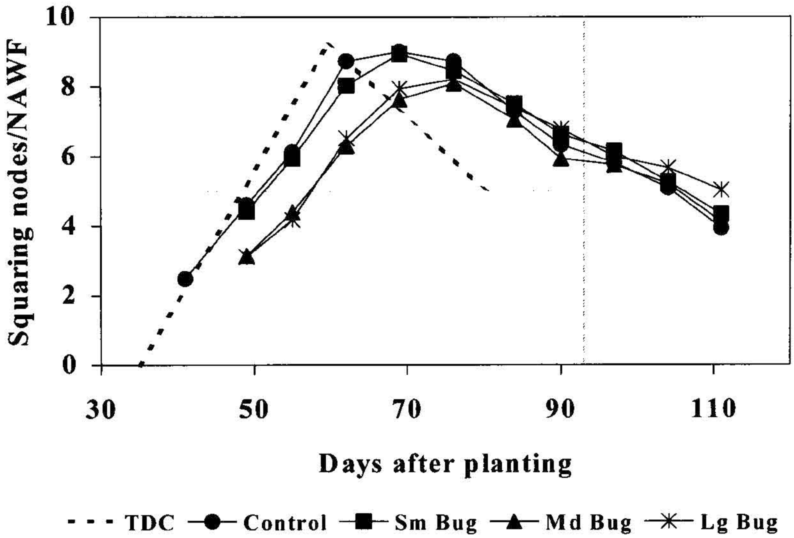


Fig. 1. COTMAN target development curve (TDC) and crop growth curve for untreated control plants and plants on which small, medium, and large TPB nymphs were released at the 2-leaf stage. The latest possible cutout date for the production region is 9 August which occurred 93 days after planting for this study.

SUBLETHAL EFFECTS OF NEW INSECTICIDES ON INSIDIOUS FLOWER BUG

Glenn E. Studebaker and Timothy J. Kring[1]

RESEARCH PROBLEM

Integration of chemical and biological controls is an important aspect of IPM. Insecticides may not always cause mortality in non-target species, but may affect other aspects such as fecundity, longevity, etc. Knowledge of these effects on beneficial insects is essential to a cotton IPM program in which conservation of natural populations of beneficial insects is a goal.

BACKGROUND INFORMATION

Many of the insecticides used in cotton have a broad range of activity, affecting both target as well as non-target arthropods. However, many of the newer chemistries are more specific and as a result may have less dramatic effects on non-target organisms. However, lack of simple mortality may not indicate the lack of negative effects. More subtle effects may occur affecting fecundity, longevity, searching behavior, predation, or general movement within the field or plant canopy. Such sublethal effects have been observed in several pest species after exposure to imidacloprid (Drinkwater, 1994; Chaisuekul and Riley, 2001; Elzen, 2001).

RESEARCH DESCRIPTION

A colony of *Orius insidiosus* was maintained at the Northeast Research and Extension Center, Keiser, Arkansas. Insects in the colony were fed bollworm eggs and green bean pods daily. Green bean pods also served as a substrate for oviposition. Plots of cotton cultivar SureGrow 125 were planted at the University of Arkansas Northeast Research and Extension Center, Keiser. No insecticides were applied to plots with the exception of the insecticide treatments outlined in this study. Also, no in-

[1] Entomologist, Northeast Research and Extension Center, Keiser; and professor, Department of Entomology, Fayetteville.

furrow insecticides were applied at planting to insure insecticide-free plants. Plots were 4 rows by 7.6 m long arranged in a randomized complete block design with 4 replications. Insecticides were applied using a CO_2-powered backpack sprayer. The sprayer was calibrated to deliver 10 gallons per acre at a pressure of 40 psi through 2-TX8 hollowcone nozzles per row. Water alone was applied to the untreated control plots. Only the center 2 rows of each plot were treated to give a buffer of 2 rows between each pair of treated rows. Treatments were applied early in the morning, just after sunrise, when wind conditions were negligible to avoid spray drift. The spray boom was cleaned between each treatment by rinsing with a water and bleach solution, followed by pure water.

O. insidiosus individuals were caged on plants as soon as sprays had dried. Cages were placed on the fourth leaf down from the plant's terminal. Cages were constructed from 6-cm diameter polystyrene petri dishes held together and on the plant by 11.5-cm hair clips that were bent to fit around the dish. Each cage was constructed of either 2 petri dish bases or 2 petri dish tops so that the edges would meet forming an enclosure. Strips of foam were glued to the edges of each dish so that a seal would form when the cage was closed. A hole 3.2-cm in diameter was cut in each side of the cage and a piece of organdy cloth was glued over the opening to allow for air flow through the cage. Insects were caged on the plants for 24 hours and then removed. Only adults that were 7 to 10 days old were used to insure females had mated and were beyond their preoviposition period (Ruberson et al., 1991). Survivors were evaluated for sublethal effects by placing them individually in 1-oz plastic cups with a single piece of green bean pod and 10 *Helicoverpa zea* eggs. Each day green bean pods and *H. zea* eggs were removed and replaced with fresh bean pods and eggs. The number of *H. zea* eggs consumed each day was recorded, as well as the number of eggs deposited in green bean pods by *O. insidiosus* females. Insects were caged individually on treated plants (20 per replicate). Males, females and third-instar nymphs were evaluated separately to determine the variation in effects on gender and insect stage. Means were subjected to analysis of variance and separated by least significant difference test (LSD, $P \leq 0.05$).

RESULTS AND DISCUSSION

Survival of third-instar nymphs and males was significantly reduced by imidacloprid and indoxacarb, while none of the compounds tested had any effect on females (Table 1). Both imidacloprid and indoxacarb significantly reduced feeding activity in third instars, females and males (Table 2). However, females were not as severely affected as the others. Imidacloprid also had a more dramatic effect on males than did indoxacarb. Fecundity was also significantly reduced by indoxacarb and imidacloprid (Table 3). Spinosad, methoxyfenozide and tebufenozide had no apparent adverse effects on survival, feeding activity, or fecundity (Tables 1-3).

Imidacloprid and indoxacarb had the most far-reaching sublethal effects in all three of the areas measured in this study. Exposure to spinosad, methoxyfenozide and tebufenozide resulted in no measurable sublethal effects, making them more appropriate for use in beneficial insect conservation.

PRACTICAL APPLICATION

Integrating chemical and biological controls is difficult with insecticides. Although imidacloprid and indoxacarb may not have a broad spectrum of activity, they do have far-reaching sublethal effects on *O. insidiosus,* making them less likely to be of use in conserving this important predator. However, spinosad, methoxyfenozide and tebufenozide all show no lethal or sublethal effects on this predator and should be the insecticides of choice when trying to conserve this and other related predators.

LITERATURE CITED

Chaisuekul, C. and D.G. Riley. 2001. Thrips (Thysanoptera: Thripidae) feeding response to concentration of imidacloprid in tomato leaf tissue. J. Entomol. Sci. 36:315-317.

Drinkwater, T.W. 1994. Comparison of imidacloprid with carbamate insecticides, and the role of planting depth in the control of false wireworms, *Somaticus* species, in maize. Crop Prot. 13:341-345.

Elzen, G.W. 2001. Lethal and sublethal effects of insecticide residues on *Orius insidiosus* (Hemiptera: Anthocoridae) and *Geocoris punctipes* (Hemiptera: Lygaeidae). J. Econ. Entomol. 94:55-59.

Ruberson, J.R., L. Bush, and T.J. Kring. 1991. Photoperiodic effect on diapause induction and development in the predator *Orius insidiosus* (Heteroptera: Anthocoridae). Environ. Entomol. 20:786-789.

Table 1. Survival of 7 to 10 day old *Orius insidiosus* after exposure to treated cotton leaves.

Treatment	Rate	Survival		
		Third instars	Females	Males
	(kg ai/hectare)	------------------- (days) -------------------		
Untreated control		18.2 a[z] (69)[y]	6.1 a (75)	6.9 a (70)
spinosad	0.09	17.9 a (67)	5.9 a (70)	7.9 a (69)
spinosad	0.199	17.5 a (68)	5.8 a (71)	5.5 ab (58)
indoxacarb	0.078	4.7 b (59)	5.7 a (45)	3.4 b (38)
indoxacarb	0.123	5.2 b (58)	4.2 a (65)	2.6 b (42)
imidacloprid	0.027	7.2 b (31)	4.2 a (42)	5.0 ab (41)
imidacloprid	0.053	4.4 b (18)	4.4 a (33)	3.2 b (39)
methoxyfenozide	0.28	16.0 a (62)	6.0 a (64)	7.6 a (74)
methoxyfenozide	0.84	15.7 a (65)	5.9 a (66)	7.8 a (66)
tebufenozide	0.14	15.9 a (66)	5.4 a (64)	5.6 ab (73)
tebufenozide	0.28	16.1 a (66)	6.3 a (62)	6.7 a (65)

[z] Means within a column followed by same letter do not significantly differ ($P \leq 0.05$, LSD).
[y] Number in parentheses is number of individuals evaluated.

Table 2. Percent of *Orius insidiosus* resuming feeding on *H. zea* eggs after exposure to treated cotton leaves.

Insecticide	Rate	Third instars	Females	Males
	(kg ai/hectare)	------------------- (%) -------------------		
untreated control		98.8 a[z] (69)[y]	98.8 a (75)	98.8 a (70)
spinosad	0.09	100.0 a (67)	97.5 a (70)	95.0 a (69)
spinosad	0.199	98.8 a (68)	92.5 ab (71)	87.5 a (58)
indoxacarb	0.078	10.0 b (59)	73.8 b (45)	27.5 b (38)
indoxacarb	0.123	2.5 b (58)	68.3 b (65)	45.0 b (42)
imidacloprid	0.027	7.5 b (31)	82.5 ab (42)	2.5 c (41)
imidacloprid	0.053	0.0 b (18)	65.0 c (33)	7.5 c (39)
methoxyfenozide	0.28	97.5 a (62)	92.5 ab (64)	97.5 a (74)
methoxyfenozide	0.84	97.5 a (65)	90.0 ab (66)	96.2 a (66)
tebufenozide	0.14	98.8 a (66)	88.8 ab (64)	93.8 a (73)
tebufenozide	0.28	100.0 a (66)	87.5 ab (62)	93.8 a (65)

[z] Means within a column followed by same letter do not significantly differ ($P \leq 0.05$, LSD).
[y] Number in parentheses is number of individuals evaluated.

Table 3. Fecundity of *Orius insidiosus* after exposure to treated cotton leaves in 2001.

Treatment	Rate	Eggs/female/day
	(kg ai/hectare)	
untreated control		3.9 a[z] (75)[y]
spinosad	0.09	4.2 a (70)
spinosad	0.199	4.5 a (71)
indoxacarb	0.078	1.3 b (45)
indoxacarb	0.123	0.6 b (65)
imidacloprid	0.027	1.3 b (42)
imidacloprid	0.053	1.9 b (33)
methoxyfenozide	0.28	4.1 a (64)
methoxyfenozide	0.84	4.2 a (66)
tebufenozide	0.14	4.8 a (64)
tebufenozide	0.28	4.1 a (62)

[z] Means within a column followed by same letter do not significantly differ ($P \leq 0.05$, LSD).
[y] Number in parentheses is number of individuals evaluated.

DISCOVERY AND ISOLATION OF A BACTERIAL CHITOSANASE GENE WITH POTENTIAL FOR GENETICALLY ENGINEERED FUNGAL RESISTANCE

Bill Hendrix, Jason Hammack, and James M. Stewart[1]

RESEARCH PROBLEM

Fungal pathogens like *Rhizoctonia*, *Thielaviopsis*, and *Fusarium* thrive in the soils of Arkansas and are a major threat to both emerging cotton seedlings and established crops. For the Arkansas cotton farmer, these and other fungal pathogens make fungicide application a necessary part of production. The toxicity, environmental harm, and expense that come with fungicides, though, leave many farmers looking for other options. In the future, genetically-engineered cotton plants that produce enzymes to degrade key structural polymers found in fungal cell walls may provide farmers with a more attractive option. One such enzyme, chitosanase, has the potential to slow or prevent fungal infection by degrading the structural chitosan found in cell walls of many fungi. This is a preliminary report of a study to evaluate the efficacy of chitosanase to increase fungal resistance.

BACKGROUND INFORMATION

Chitinase is well known as a plant defensive enzyme that degrades chitin, the major polymer of crustacean shells and insect exosketelons, but it is also a component in the cell walls of some fungi. Chitin is a hard polymer of glucosamine in which the amine has an acetyl group attached. When the acetyl group is absent, the result is a more flexible polymer known as chitosan that is not susceptible to degradation by chitinases. This form is probably more abundant in fungal cell walls. It is now recognized that chitosanases are also produced in many plants, bacteria, and fungi. While chitosanases also are considered as pathogenesis-related (PR) proteins, they exist in many forms in plants. This redundancy has prompted the suggestion that the varied isoforms may have functions other than pathogen defense. In addition to pathogen

---

[1] Undergraduate, former undergraduate, and professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

attack, chitosanases are induced in response to arbuscular mycorrhizal symbiosis (Pozo et al., 1998) and cold stress (de los Reyes, personal communication).

El Quakfaoui et al. (1995) were the first to report a successful plant transformation with a bacterial chitosanase (*Streptomyces* sp. strain N174). Their chitosanase gene construct was driven by the 35S cauliflower mosaic-virus promoter and retained activity without adversely affecting the growth of the explants.

RESEARCH DESCRIPTION

Many ecological niches were sampled to find organisms that produced chitosanase. Samples from each niche were collected and streaked onto agar plates with chitosan as the sole carbon source. The prospective organisms were isolated and streaked on opaque chitosan plates augmented with LB medium to verify chitosanase activity as determined by plate clarification. A bacterium with high activity was selected, and the 16s rRNA gene was sequenced to identify the organism. Its genome was cloned in a plasmid expression vector in *E. coli*. A colony with chitosanase activity was chosen. The Erase-a-base system (Promega) was used to generate over-lapping DNA fragments for sequencing of the chitosanase gene. The sequence was compared to the Genbank database to confirm function and sequence location of the gene. Primers flanking the mature protein region were synthesized (Sigma-Genosys), and a PCR-amplified sequence was fused into pGEM-T vector to verify that a functional protein had been isolated. The fragment was subsequently modified to contain a 3' signal sequence and cloning sites on each end. The modified fragment was cloned in a plant transformation vector already possessing a plant promoter and an essential selectable antibiotic resistance gene.

Following complete sequence confirmation of the gene, *Nicotiana tabacum* will be transformed via *Agrobacterium tumenfaciens* to test for chitosanase efficacy against fungi. Assuming positive results, cotton will then be transformed with the gene construct.

RESULTS

Strong extra-cellular expression of chitosanase by the bacteria was determined by clear halos around the test colonies growing on medium made opaque by insoluble chitosan. A bacterium capable of utilizing chitosan as an energy source was selected and most closely matched a *Paenibacillus* species by the 16S rRNA gene sequence. One colony in the *E. coli* genomic DNA library of this bacterium showed strong chitosanase activity and was used for the construction of the Erase-a-Base library. Most of the gene sequence could be obtained from this second library, but construction of specific PCR primers based on flanking sequences was necessary to span one gap. The resulting sequence showed high homology in GenBank with chitosanases produced by *Bacillus ehimenisis* and *B. circulans*.

New primers were designed to PCR amplify the mature protein region of the chitosanase. When cloned in an expression vector, this fragment retained chitosanase activity as confirmed by chitosan clarification by a total protein extraction obtained by boiling. The sequence corresponding to the mature protein gene has been modified to contain a signal peptide sequence and cloned into a plant transformation vector with a strong promoter and 3' termination sequence.

Following confirmation of the correct DNA sequence, the vector will be placed in *A. tumefaciens* and transformed into tobacco (*Nicotiana tabacum*). Tobacco is used because it can be regenerated from callus quickly in order to test the efficacy of the gene construct against fungi. If the transgenic tobacco plants show improved fungal resistance, then the gene construct will be used to transform cotton, which requires a much longer regeneration period.

PRACTICAL APPLICATION

In addition to potentially reducing fungicide use and increasing the efficiency with which Arkansas cotton farmers can combat fungi, this study may answer questions regarding chitosanase function in plant systems. It has been shown that chitinase, another "anti-fungal" PR protein, is involved in leaf abscission, response to cold and drought stress, response to ozone, and freezing tolerance (anti-freeze protein action) (de los Reyes et al., 2001). We suspect that chitosanase may also be involved in similar activities and plan to investigate such possibilities.

ACKNOWLEDGMENTS

This research was supported in part by a Dale Bumpers College of Agriculture, Food and Life Sciences Undergraduate Research Award and an Arkansas SURF/SILO Research Award to the senior author.

LITERATURE CITED

Pozo, M.J., C. Azcon-Aguilar, E. Dumas-Gaudot, and J.M. Barea. 1998. Chitosanase and chitinase activities in tomato roots during interactions with arbuscular mycorrhizal fungi or *Phytophthora parasitica*. Exp. Bot. 49:1729-1739.

de los Reyes, B.G., C. Taliaferro, M. Anderson, U. Melcher, and S. McMaugh. 2001. Induced expression of the class II chitinase gene during cold acclimation and dehydration of bermudagrass (Cydon sp.). Theor. Appl. Genet. 103:297-306.

STS MARKERS CO-SEGREGATE WITH COTTON CYTOPLASMIC MALE STERILITY RESTORER GENE RF1

Chunda Feng, Jinfa Zhang, and James M. Stewart[1]

RESEARCH PROBLEM

Marker-assisted selection (MAS) can be used with high efficiency for indirect selection of both qualitative and quantitative traits by the selection of molecular markers that are tightly linked with the genes controlling the aim traits (Mohan et al., 1997). However, such markers as RFLP, AFLP, and RAPD have disadvantages in MAS because of expense or accuracy. A reliable but inexpensive molecular marking system is needed to aid in the breeding of restorer parental lines for hybrid seed production in cotton.

BACKGROUND INFORMATION

In several crops, restorer-of-fertility genes have been tagged with different kinds of molecular markers such as RFLP, AFLP, and RAPD. RFLP and AFLP techniques are expensive and time- and labor-consuming, thus they not suitable for marker-assisted selection in plant breeding programs. The RAPD method is quick and simple but prone to errors. Sequence-tagged site (STS) markers avoid the disadvantages of other markers in that they allow the use of the Polymerase Chain Reaction (PCR) with a specific primer that yields a single marker associated with the trait in question. Because of this, RFLP, AFLP, and RAPD markers often have been converted into STS markers for MAS. We have found RAPD markers associated with a cotton cytoplasmic male sterility restorer gene, Rf_1, located 4.5cM and 2.7 cM away from Rf_1, and three markers that co-segregate with Rf_1. Conversion of the latter three RAPD markers to STS markers will increase their usefulness in development of male parental lines for hybrid production. Also, they should allow detection of other potential resources of restorer genes from different cotton species.

---

[1] Visiting scholar, former research assistant, and professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

PCR bands (RAPDs) that co-segregated with the cotton Rf_1 gene in a testcross population were retrieved from an agarose gel, cloned in a pGEM-T vector, and then transformed into *E. coli* strain JM109. Cloned DNA fragments were sequenced with a Perkin Elmer ABI Prism 377 DNA sequencer in the Core Molecular Biology Laboratory, Dale Bumpers College of Agricultural, Food and Life Sciences, University of Arkansas. STS primers 18 to 21 nucleotide bases in length were designed from the RAPD fragments using Stanford Web Primer software, and the oligonucleotides were synthesized commercially. The primers were tested in PCR using DNA from the original segregating testcross population (B416R X Ark8518) X Ark8518 to determine the genetic distance between the STS markers and the Rf_1 gene. PCR products were electrophoresed on 1% agarose gel to confirm the uniqueness and size of the STS markers.

The specific primers were also used in PCR reactions using DNA from different *Gossypium* species or hybrids (Table 1) to explore for other potential restorer-gene sources.

RESULTS

Sequence analysis and development of sequence tagged site (STS) markers

The 3 RAPD fragments linked with cotton CMS restorer gene Rf_1, following cloning and sequencing, were found to be 1346bp, 726bp, and 500bp in length. Forward and reverse STS primers were designed that gave fragment lengths of 1343bp, 717bp, and 475bp, respectively.

These STS primer pairs were used to test the original segregating testcross population. STS_{1346} primers amplified a PCR fragment from each fertile plant, but no product from sterile plants. STS_{475} primers amplified one fragment from fertile plants, but no band from sterile plants. The STS_{717} primer pair amplified one fragment from each sterile plant but two fragments from fertile plants, one of which was the specific Rf_1-associated fragment. The two fragments had slight differences in length (Fig. 1). Subsequent sequence analysis showed that these two bands were homologues from the D and A subgenomes. All specific STS markers were located at the same chromosomal positions as the original RAPD markers.

STS Markers in Cotton Species and Some Interspecies Progeny

When PCR was used to amplify DNA from other *Gossypium* species using the STS primer pairs, the STS_{1346} primer pair amplified the same size fragment from (D_{2-1}xAD_4), D_{2-2}, D_4, (D_5xAD_4), D_9, and (D_{10}xAD_1) as the restorer line, a larger fragment from 2(A_2xD_1) and D_8, but no fragment from other species. The STS_{475} primers amplified the specific fragment from 2(A_2xD_1), D_{2-2}, (D_5xAD_4), D_8, D_9, and (D_{10}xAD_1), a

larger fragment from D_4, and no fragment from other species. The STS_{726} primers amplified the specific band from C_1, $D_{2\text{-}2}$, D_8 and a smaller fragment from other species.

Among the species or hybrids examined, *G. harknessii* contained all three STS markers found in the fertile plants of the population. *G. trilobum* also contained three STS fragments, two that corresponded to the fragment in fertile, restored plants, but the fragment amplified by STS_{1346} was larger than that from fertile plants. (D_5xAD_4), D_9, ($D_{10}xAD_1$) and (A_2xD_1) each contained two specific fragments, whereas ($D_{2\text{-}1}xAD_4$) and D_4 contained only one specific band (Fig. 2).

PRACTICAL APPLICATION

For breeding restorer lines, the fertility restoration ability of each plant must be tested by hybridizing these plants as pollen source with CMS lines, a process that is expensive, laborious, and time-consuming. The STS markers developed in this study can be used to select fertile plants from a segregating population in the seedling stage. Plants with Rf_1-associated molecular markers can then be used for backcross or forward breeding without testing for restoration in each generation. These three markers will be useful to accelerate the transfer of the restorer gene to elite male parental lines. Zhang and Stewart (2001) found a RAPD marker that was 1.8cM from the male fertility restorer gene Rf_2. Thus, it is possible to pyramid two restorer genes, Rf_1 and Rf_2, into a single elite parental line through the indirect selection with these molecular markers. Moreover, these STS fragments may be used as landmarks to screen a *G. harknessii* genomic library for clones that may contain the specific Rf_1 gene. The full length of the Rf_1 gene could then be obtained through the technique of "chromosome walking."

ACKNOWLEDGMENTS

Support from Monsanto Company for part of this research is gratefully acknowledged.

LITERATURE CITED

Mohan M., S. Nair, A. Bhagwat, T.G. Krishna, M. Yano, C.R. Bhatia, and T. Sasaki. 1997. Genome mapping, molecular markers and marker-assisted selection in crop plants. Mol. Breed. 3:87-103.

Zhang, J. and J.McD. Stewart. 2001. Identification of RAPD markers linked to the fertility restorer genes for CMS-D8 in cotton (*Gossypium hirsutum* L.). Crop Science 42: (in press).

Table 1. *Gossypium* species or hybrids used to screen for potential cotton CMS restorer genes with STS primers.

Species or crosses	Genome	Species or crosses	Genome
G. herbaceum	A_2	(*G. tuneri* x *G. hirsutum*)	$D_{10}X AD_1$
2(*G. arboreum* x *G. thurberi*)	$A_2 X D_1$	*G. stocksii*	E_1
G. anomalum	B_1	*G. longicalyx*	F_1
G. capitis-viridis	B_3	*G. nelsonii*	G
G. sturtianum	C_1	*G. bickii*	G_1
(*G. armourianum* x *G. hirsutium*)	$D_{2-1} x AD_1$	*G. nobile*	K
G. harknessii	D_{2-2}	*G. pulchellum*	K
G. davidsonii	D_{3-d}	*G. hirsutum* (TM-1)	AD_1
G. aridum	D_4	*G. barbadense* (57-4)	AD_2
(*G. raimondii* x *G. mustelinum*)	D5xAD4	*G. tomentosum*	AD_3
G. gossypioides	D_6	*G. mustelinum*	AD_4
G. trilobum	D_8	*G. darwinii*	AD_5
G. laxum	D_9		

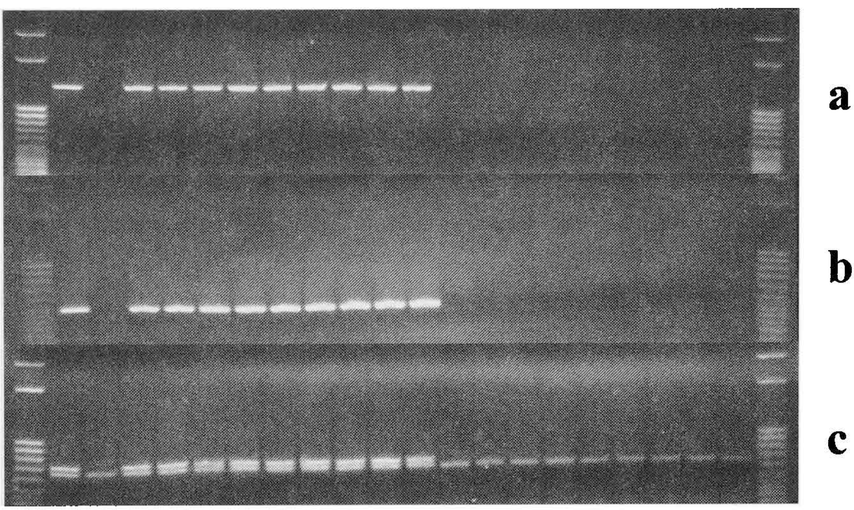


Fig. 1. Profiles of STS markers associated with cotton CMS restorer gene Rf_1. a. STS_{1343}; b. STS_{475}; c. STS_{717}. Lanes 1 and 22: 100 bp molecular weight marker (Promega); Lane 2: Rf_1 bulked; Lane3: rf_1 bulked; Lane 4-12: fertile plants; Lane 13-21: sterile plants.

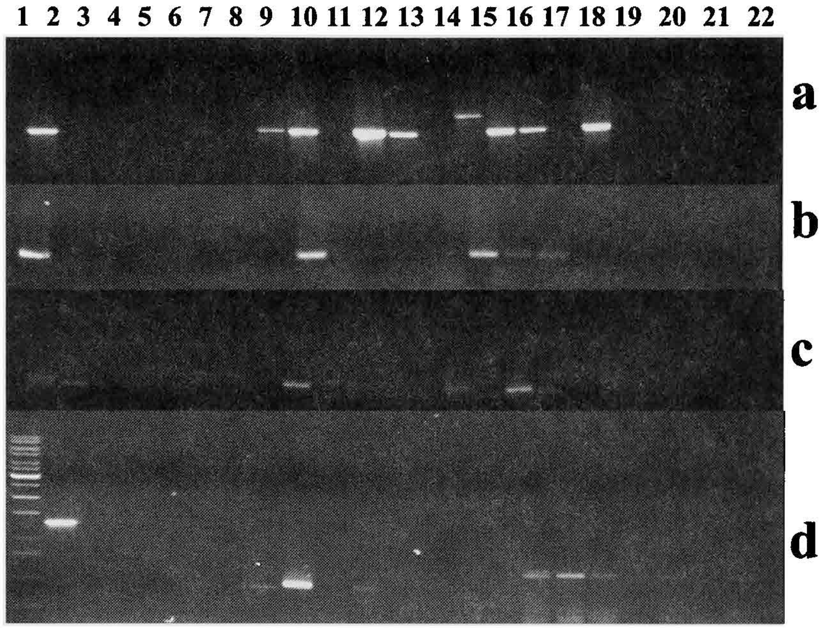


Fig. 2. Profile of fragments from different species or hybrids following PCR with STS primers. a. STS_{1375}; b. STS_{475}; c. STS_{717}. Lane1 to 22 (left to right): Rf_1, rf_1, A_1, $2(A_2XD_1)$, (B_1XA_1), B_3, C_1, $(D_{2\text{-}1}XAD_4)$, $D_{2\text{-}2}$, $D_{3\text{-}d}$, D_4, $(D_5x\ AD_4)$, D_6, D_8, D_9, $(D_{10}XAD_1)$, E_1, F_1, G, G_1, K, K. d. Lane1 Marker, then profiles of STS amplified by 3 pairs of STS primers each in turn on fertile bulked DNA (lanes 2, 9 and 16), sterile bulked DNA, AD_1 through AD_5.

ECONOMIC ANALYSIS OF ULTRA-NARROW-ROW COTTON

Kelly Bryant, Claude Kennedy, Jimmy Hornbeck, and Rodrick Robinson[1]

RESEARCH PROBLEM

Ultra-narrow-row cotton production continues to be of interest to Arkansas growers. Several producers are growing sizeable acreages. Some are investing in harvesting and spraying equipment with prolonged ultra-narrow-row cotton production in mind. Most of these farmers are producing ultra-narrow-row cotton under dryland conditions on marginal ground that cannot support conventional cotton and where soybean yields are low.

BACKGROUND INFORMATION

Ultra-narrow-row cotton is defined as "cotton planted in 10-inch (0.254 m) rows or narrower with approximately two plants per foot (6.56 plants m^{-1}) (120,000 plants ac^{-1}; 296,400 plants ha^{-1})" (Perkins, 1998). It is often planted with a grain drill and harvested with a cotton stripper using a finger-type header. The ultra-narrow-row system of cotton production has been purported to have a lower cost of production and an earlier maturity date than conventional cotton.

METHODS

This study consisted of a replicated experiment and cost and return analysis of the data it generated. The experiment consisted of three treatments replicated four times. The treatments were ultra-narrow-row cotton, conventional cotton, and soybeans. Each was produced using best management practices. All treatments were non-irrigated. A field located at the Cotton Branch Experiment Station in Marianna, Arkansas, was selected for the test. The Cotton Branch Station was chosen because of its

---

[1] Area extension specialist - farm management, Southeast Research and Extension Center, Monticello; resident director and research specialist, Cotton Branch Station, Marianna; and agriculture student, Arkansas State University, Jonesboro.

close proximity to many ultra-narrow-row cotton producers in the state, and because the Station Director has experience with this cotton production system. The field was chosen because of its marginal quality. Much of the soil at the Cotton Branch Experiment Station is good-quality cotton soil. This field, however, contains mixed soil types not as suited to conventional cotton production. Our hypothesis was that ultra-narrow-row cotton will produce greater net returns than conventional cotton or soybeans on non-irrigated fields with marginal soil types.

Accurate field records were kept throughout the season. The field plots were 38 feet by 500 feet in size. The middle 12.67 feet (the equivalent of 4 rows) were harvested from each plot. The soybeans were harvested using a plot combine equipped with a weigh scale. The cotton treatments were harvested with commercial 4-row harvesters and the basket dumped into a boll buggy equipped with scales. The remainder of each cotton plot was then harvested and the seedcotton from all four replications, and all 38 feet in each replication, was ginned at the local commercial gin. The gin provided turnout, grade, and loan value information for ultra-narrow-row cotton and conventional cotton.

Returns, costs, and net returns were estimated using the Mississippi State Budget Generator (Laughlin and Spurlock, 2000). Loan values were obtained from the gin report and used to value cotton production. The loan rate of $5.40 per bushel was used to value soybean production. Input prices were obtained from the University of Arkansas 2001 enterprise budgets (Bryant and Windham, 2001).

RESULTS

Crop yields are displayed in Table 1. Thirty bushels per acre for non-irrigated soybeans is a good yield. On a seedcotton basis, the conventional cotton out-yielded the ultra-narrow-row cotton by 33%. However, the gin reported a 37.93% turnout for the ultra-narrow-row cotton, and only a 28.84% turnout for the conventional cotton. This is contrary to what one would normally expect. The ultra-narrow-row cotton was harvested with a cotton stripper that had a bur extractor on board. Perhaps that lint cleaning was sufficient to give the ultra-narrow-row cotton an advantage on turnout when it reached the gin. A local cotton producer indicated that the same thing occurred with his ultra-narrow-row cotton in 2001.

Information on cotton grade and value is displayed in Table 2. One bale of ultra-narrow-row cotton had a loan value greater than both of the conventional cotton bales, while the other ultra-narrow-row bale had a loan value considerably less than the conventional cotton bales. This was the result of high micronaire. The loan values averaged across the two bales for each treatment are 51 cents per pound for ultra-narrow-row cotton and 48.92 cents per pound for conventional cotton. The cotton weights presented in Table 2 are for the entire plots of all four replications. All four replications combined comprise approximately 1.75 acres under each treatment. Therefore, these weights translate to yields of 607 lb/acre for the ultra-narrow-row cotton and 524 lb/acre for the conventional cotton.

Estimated costs and returns for ultra-narrow-row cotton, conventional cotton, and soybeans are displayed in Tables 3, 4, and 5, respectively. The two cotton treatments resulted in approximately the same net returns. The soybean treatment resulted in net returns approximately $70/acre greater than the two cotton treatments.

PRACTICAL APPLICATION

The year 2001 was a good year for non-irrigated soybeans in this study. This soybean crop was inexpensive to grow and had a very good yield. The ultra-narrow-row cotton had less seedcotton per acre than the conventional cotton, but surprisingly it had a much higher turnout, resulting in similar lint yields between the two treatments. Total specified expenses were also similar between the two cotton treatments. The-ultra-narrow row treatment had total specified expenses of $20/acre less than the conventional cotton treatment.

The use of a growth regulator on the ultra-narrow-row cotton in 2001 may have been excessive thereby increasing costs and reducing yield. However, this is also a reflection of the uncertainty involved in ultra-narrow-row cotton production. The growth regulator was applied in anticipation of future rains that did not materialize.

REFERENCES

Bryant, K.J., and T.E. Windham. 2001. Estimating production costs in Arkansas. Univ. of Arkansas, Division of Agriculture, Coop. Ext. Ser. AG-615-12-00, AG-626-12-00, AG-632-12-00.

Laughlin, D.H., and S.R. Spurlock. 2000. Mississippi State Budget Generator V 5.4. Department of Agricultural Economics. Mississippi State University.

Perkins, W.R. 1998. Three-year overview of UNRC vs. conventional cotton. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. p. 91.

Table 1. Yield for ultra-narrow-row cotton, conventional cotton, and soybeans.

	Ultra-narrow-row cotton		Conventional cotton		Soybeans	
	Seedcotton	Lint[z]	Seedcotton	Lint[y]	Yield	
	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)	(lb/acre)	(bu/acre)
Rep 1	1389.33	526.97	1946.44	561.35	1131.99	21.69
Rep 2	1293.04	490.45	1746.99	503.83	1279.50	24.51
Rep 3	2049.61	777.42	2414.14	696.24	1860.60	35.64
Rep 4	1471.87	558.28	2166.54	624.83	1902.69	36.45
Average	1550.97	588.28	2068.53	596.56		29.57

[z] Based on a 37.93% turnout as reported by the cotton gin.
[y] Based on a 28.84% turnout as reported by the cotton gin.

Table 2. Cotton grade information, bale weights, and bale value; ultra-narrow-row cotton and conventional cotton.

Bale number	Net weight[z]	Grade	Leaf	Staple length	Micronaire	Loan value[y]	
	(lb)			(in.)		($/bale)	(cents/lb)
			Ultra-narrow-row cotton				
1	501	31	4	34	4.4	264.38	52.77
2	561	42	4	33	5.3	224.51	40.02
			Conventional cotton				
1	460	32	3	33	4.5	221.81	48.22
2	457	31	3	33	4.5	226.76	49.62

[z] The entire plots, including the samples harvested for the yield data, were harvested and ginned together. This resulted in two bales of cotton from each of the cotton systems.
[y] Loan value from gin reports.

Table 3. Estimated costs and returns per acre, Cotton Branch Experiment Station, Marianna, AR, 2001.

Item	UNRC	Conventional cotton	Soybean
	($/acre)		
Total income			
ultra-narrow-row cotton	300.02[z]		
conventional cotton		291.84[y]	
soybean			162.00[x]
Direct expenses			
Crop seed	45.20	11.30	25.00
Custom work	8.00	8.00	4.50
Fertilizer and lime	32.11	28.24	14.82
Growth regulators	20.50	8.20	
Harvest aids	18.37	18.37	
Herbicides	19.05	18.14	9.76
Insecticides	35.41	35.41	
Technology fee	38.00	38.00	
Operator labor	15.97	14.17	5.01
Diesel fuel	14.12	15.85	5.99
Repair and maintenance	18.77	31.68	8.36
Interest on operating capital	15.19	11.60	4.66
Total direct expenses	280.76	239.09	78.16
Returns above direct expenses	19.26	52.75	83.83
Total fixed expenses	39.80	61.55	21.57
Total specified expenses	320.56	300.64	100.04
Returns above total specified expenses	-20.54	-8.80	61.95

[z] Using a price of $0.51/lb for 588.28 lb cotton per plot.
[y] Using a price of $0.4892/lb for 596.56 lb cotton per plot.
[x] Using a price of $5.40/bu for 30 bu soybean per plot.

CHARACTERISTICS OF COTTON RENTAL ARRANGEMENTS IN ARKANSAS: SURVEY RESULTS

Joao E. Mutondo, Lucas D. Parsch, Bruce L. Dixon, Bruce L. Ahrendsen, and Ralph W. Bierlen

RESEARCH PROBLEM

The majority of cotton is grown on leased cropland in eastern Arkansas. Nevertheless, information regarding the terms and characteristics of typical cropland leases is not available to tenants and landlords. Unlike readily-available market information on commodity prices and input costs, leases are negotiated without knowledge of a market norm for cropland rental. This research reports preliminary results of a survey that was designed to identify the terms and characteristics of cropland rental arrangements in eastern Arkansas. It provides tenants and landlords with detailed information to enable them to be better informed when negotiating leases. By being more knowledgeable about leasing practices, tenants and landlords can make better-informed decisions to improve profitability and reduce risk.

BACKGROUND INFORMATION

Rented land is a significant factor of production for crops in Arkansas. Forty-three percent of all U.S. agricultural land is leased, with even greater proportions of leasing in states that exhibit crop-intensive agriculture (Bierlen and Parsch, 1996). Throughout all of Arkansas, 55% of agricultural land is leased with even higher proportions of rented land in the eastern part of the state where field crops are the primary agricultural enterprises (USDA, 1999).

With large proportions of leased cropland, both producers and landlords need to evaluate how the type of cropland rental arrangement (cash rent, straight share, cost share) and the terms of a cropland lease affect profitability and risk. In spite of the fact that leased land is the single most valuable input to crop production, this information is not regularly published and thus is not readily available to landlords and tenants. In

[1] Graduate research assistant, associate professor, professor, associate professor, and former research associate, Department of Agricultural Economics and Agribusiness, Fayetteville.

order to furnish this information, a survey of crop producers was conducted in eastern Arkansas in late 1997 and early 1998. The purpose of the survey was to: 1) identify the types, frequency, and characteristics of cropland rental arrangements that are prevalent in eastern Arkansas; 2) characterize the provisions (i.e., terms) of a typical straight share, cost share, and cash rental arrangement; and 3) estimate tenant and landlord economic returns under each of the rental arrangements in (2) above.

The data from the survey are presently being analyzed for the major field crops (soybeans, rice, cotton) grown in eastern Arkansas. This report presents preliminary results by providing information on the frequency and characteristics of cotton leases.

METHODS

In November 1997, a cropland rental arrangement was mailed to a sample of 1,500 commercial row-crop producers in the 26 counties comprising crop reporting districts 3, 6, and 9 in the Mississippi Delta region of eastern Arkansas. The sample list of producers was developed in cooperation with the Arkansas Agricultural Statistics Service. The eight-page questionnaire, targeted at the farm operator, was divided into three general categories, namely: 1) farm information including acreage owned and rented, crop mix, and business organization; 2) lease-specific information for each of the three largest leases on the farm containing soybeans, rice, and cotton; and 3) demographics and financial information about the farming operation.

The purpose of the survey was to find out what types of rental arrangements are being used in eastern Arkansas and to learn how rental arrangements differ by crop. A key objective was to characterize the provisions of a typical cash rent, straight share, and cost share rental arrangement for soybean, rice, and cotton. *Cash* leases are defined as those arrangements in which rent is paid annually on a $/acre basis. *Straight share* leases are those in which the landlord receives a percentage of the tenant's crop and government payments. In *cost share* arrangements, the landlord shares input costs with the tenant in addition to receiving a percentage of the tenant's crop and government payments. For share rental arrangements, tenants were asked to describe the proportion of costs and/or returns (by input category) that are borne by the landlord. The results of the survey are expected to be used in estimating tenant cost of production for each type of cropland rental arrangement, and to estimate net returns and risk.

The survey data were coded and are being subjected to standard statistical procedures in SAS (sample statistics, frequencies, cross-tabulations, and regression) for specified variables of interest for the identified sub-sample of cotton rental arrangements. However, this report presents the preliminary results, which include descriptive statistics of characteristics of cotton rental arrangements.

RESULTS

Of the 1,500 surveys that were mailed out, 326 (21.7%) questionnaires were returned of which 201 were categorized as tenant producers. *Tenant producers* includes the following: growers who produce only on rented land (pure tenants); growers who produce on both owned and rented land (owner-tenants); growers who produce on owned and rented land, but who also own land that is rented out to others (owner-tenant-landlords); and finally, growers who produce only on rented land, but who also own land that is rented out to others (tenant-landlords). This tenant sample provided detailed information on 327 leases of which 57 (17.4%) were cotton. Among cotton leases, 16 (28.1%), 27 (47.4%), and 14 (24.6%) were cash rent, straight share, and cost share, respectively. These 57 cotton leases represented 12.4% of the total acreage of soybeans, rice, and cotton, which comprised the three largest leases for the surveyed farms.

Table 1 presents general characteristics of cotton rental arrangements based on the survey sample. The reported acreage per cotton lease averaged 360 acres. Although the most popular lease–*straight share*–had the highest average acreage (398 acres/lease), it nevertheless resulted in the lowest reported lint yield (778 lb/acre). By contrast, the least popular leasing arrangement–*cost share*–resulted in the highest yield (850 lb/acre), surpassing the yield of straight share by over 9%.

Survey respondents were asked a number of questions concerning their lease contract including how long they had leased each parcel of land, whether the agreement was for multiple years, and whether their lease agreement with the landlord was written or oral. Table 1 shows that the length of time leasing the same tract of land ranged from 12.0 years under cash rent and increased to 15.6 years under cost share. However, the cash rent lease was the one exhibiting the greatest proportion (80%) of multi-year contracts in comparison to the two share rental arrangements. The length of lease ranged from 3.0 years per agreement for straight share to 4.4 years for cash rent.

In general, the vast majority (70.9%) of cotton leases were written leases implying that cotton rental arrangements tend to be contracts that are more formal. However, it is also noteworthy that the more popular straight share leases–with their greater acreage and lower yields–show a much greater proportion of oral leases (44.0%) than for either cash rent (12.5%) or cost share (21.4%). The mean annual rent paid was $64.36/acre for all cotton cash leases in the survey. However, the range of values reported by survey respondents was dramatic. Annual cash rent paid ranged from as low as $25 per acre to $120 per acre. Irrigation explained part of the divergence in reported cash rent. For irrigated parcels, annual cash rent averaged $73.44/acre compared to $48.00/acre for non-irrigated cotton leases (not shown in Table 1).

Tenants were asked to rate their satisfaction with their cotton leasing arrangement on a scale of 1 to 4 representing the following: poor (1), adequate (2), good (3), and excellent (4). Tenants rated the 57 leases as follows: poor (7.3%), adequate (21.8%), good (52.7%), excellent (18.2%). However, although 71% of all cotton leases were rated as either good or excellent, larger portions of tenants rated share leases as being either

poor or adequate than did tenants with cash rent (Table 1). In general, cash rent leases received a slightly higher rating than did share leases. The mean response for cash leases was 3.1 (on a scale of 1 to 4) compared to 2.7 for straight share and 2.6 for cost share. This implies a higher level of satisfaction with cash leases.

PRACTICAL APPLICATION

The results of the cropland rental arrangements survey will provide tenants and landlords with information about leasing terms in eastern Arkansas to enable them to be better informed when negotiating leases. By being more knowledgeable about leasing practices, tenants and landlords can make better-informed decisions to improve profitability and reduce risk.

LITERATURE CITED

Bierlen, R., and L.D. Parsch. 1996. Tenant satisfaction with land leases. Rev. of Agric. Econ. 18(3):505-513.

U.S. Department of Agriculture (USDA). 1999. 1997 Census of Agriculture: Volume 1, Geographic Area Series (Arkansas) Part 4.

Table 1. Frequency of lease types, characteristics of leases, and tenant perception of lease fairness, Arkansas cropland rental arrangement survey, 1997.

	Type of cotton lease			
Item	Cash rent	Straight share	Cost share	All leases
Number of leases	16	27	14	57
Proportion of leases (%)	28.1	47.4	24.6	100.0
	Lease characteristics			
Acres of cotton in lease, mean (acres)	319	398	335	360
Average cotton yield, mean (lint/acre)	805	778	850	804
Number of years acreage was leased, mean (years)	12.0	12.4	15.6	13.1
Proportion of leases which are written (%)	87.5	56.0	78.6	70.9
Proportion of leases which are oral (%)	12.5	44.0	21.4	29.1
Proportion of leases which are annual (%)	20.0	66.7	60.0	50.0
Proportion of leases which are multi-year (%)	80.0	33.3	40.0	50.0
Length of lease contract for multi-year lease, mean (years)[z]	4.4	3.0	4.3	4.1
Annual cash rent paid, mean ($/acre)	64.36	N/A	N/A	64.36
	Tenant perception of lease fairness			
Number of respondents	16	25	14	55
Poor (%)	12.5	8.0	0.0	7.3
Adequate (%)	0.0	24.0	42.9	21.8
Good (%)	50.0	56.0	50.0	52.7
Excellent (%)	37.5	12.0	7.1	18.2
Fairness of the lease, mean (scale 1-4)[y]	3.1	2.7	2.6	2.8

[z] Only one-half of the tenants with multiyear leases responded to this question.

[y] Mean values for satisfaction were based on the following scale: 1=poor, 2=adequate, 3=good, 4=excellent.

2001 COTTON RESEARCH VERIFICATION PROGRAM DEMONSTRATIONS

Donald E. Plunkett, William C. Robertson, and Kelly Bryant[1]

INTRODUCTION

The University of Arkansas Cooperative Extension Service and Agricultural Experiment Station have been conducting the Cotton Research Verification Program (CRVP) since 1980. This is an interdisciplinary effort in which recommended production technology is applied in a timely manner to a specific farm field.

BACKGROUND INFORMATION

General field information regarding location, acres per field, planting date, variety, yield and soil type is included in Table 1. The northernmost field was in Mississippi County and the most southern was in Desha County. This spread allowed the CRVP program to monitor the highly variable crop and environmental conditions throughout Arkansas in 2001. Field size ranged from approximately 37 acres in Jefferson County (Bonds) to 80 acres in Desha county (Walt). The average field size was about 54 acres for these six irrigated fields. The most diverse soils were those in the Mississippi and Poinsett county fields. Blowing sand from the fine sandy loam portions of the Poinsett County field caused seedling damage, but replanting was not conducted.

RESEARCH DESCRIPTION

There were six fields enrolled in the 2001 CRVP demonstrations. All were irrigated. Two of the fields had center-pivot irrigation and four were furrow-irrigated. The fields were located from Desha (Walt) in the southern part of the state to Mississippi (Chandler) in the northeast part of the state.

---

[1] Cotton verification coordinator and cotton specialist, Cooperative Extension Service, Little Rock; and area extension specialist, Southeast Research and Extension Center, Monticello.

RESULTS AND DISCUSSION

Since the inception of the CRVP in 1980, there have been 185 irrigated fields in the program. Average field size for the 2001 CRVP ranged from 37.5 acres (Jefferson-Bonds) to 80 acres (Desha-Walt). The yield of the six irrigated fields in the 2001 CRVP demonstrations had a weighted average of 939 pounds of lint per acre. The 2001 Arkansas state average is 823 pounds of lint per acre.

There were more nitrogen application problems during the 2001 CRVP demonstrations than normal and subsequently more N deficiency than normal. Four of the six fields showed N deficiency at some point during the season with most damage noted in mid- to late-season. The Jefferson-Bonds field had the lowest N levels during late season, but was the highest yielding.

Small boll shed was heavy throughout the state and more noticeable in fields where N deficiency was seen. Small boll shed was also noted in the two fields that did not indicate N stress through petiole analysis.

Bollworm/tobacco budworm pressure was relatively low in CRVP fields. This may have been due to the fact that five of the six fields had a cotton cultivar with the *Bt* gene. One field had an outbreak of armyworm and cotton bollworm during late season. Plant bugs and stink bugs were noted in all fields. Some pressure was extremely heavy at times. In other fields pressure was very erratic throughout the season. All six fields were planted to Roundup Ready varieties.

Yield and quality factors are the most commonly reported results cotton producers have been taught to examine. In 2001, there was a statewide problem with high micronaire cotton. This impacted directly on price received by producers who were already hurt by incredibly low cotton prices that resembled prices of decades ago. The weighted average yield for all six fields was computed to be 939 pounds per acre with a high of almost 1147 pounds lint per acre and a low of 767 pounds lint per acre (Table 1).

Fiber Quality

Color grade information is presented in Table 2. Of the 689 total bales from all fields, 84% graded white with 80% grading 41 and better. Almost 63% of the bales graded 31 and better.

Short staple and high micronaire was a cause of concern throughout the state in 2001. Approximately 95% of all CRVP bales measured greater than a 34 staple length (Table 3).

High micronaire bales–measuring greater than 5.0–were evident in just over 34% of all bales (Table 4). Of the high micronaire bales, approximately 31% came from the three fields that used the PM 1218 BG/RR variety. This variety was the most widely used variety in the state during 2001.

Strength (Table 5) was good in most fields with over 97% of all bales averaging greater than 25.5 g/tex. About 3% of all bales fell into the premium range for strength with measurements of 29.5 g/tex and higher.

Economics

Table 6 shows the average breakeven prices needed above specified expenses. Direct expenses listed in Table 6 are those expenditures that would generally require annual cash outlays and would be included on an annual operating loan application. Direct expenses for the six irrigated CRVP fields ranged from $287.05 per acre for Poinsett county to $421.36 per acre for Desha county and averaged $337.55 per acre. Direct expenses per pound of lint ranged from $0.28 in Mississippi county to $0.48 in Desha county and averaged $0.36 per pound.

The fixed expenses category in Table 6 is the cost of owning and using farm equipment. Fixed expenses for the six irrigated fields ranged from $76.29 per acre for Lee County to $111.77 per acre for Mississippi County and averaged $93.34 per acre. High fixed expenses can be the result of numerous trips across the field, twice-over picking, and/or center-pivot irrigation.

Total specified expenses are calculated to give the true picture of expenses. Not included in the total specified expenses in Table 6 are charges for land, risk, overhead, and management. Total specified expenses per acre for the six irrigated fields ranged from $379.80 for Lee County to $500.56 for Desha County. Total specified expenses per pound of lint ranged from $0.36 to $0.60 and averaged $0.46 for the six fields.

Table 6 presents the cost of production per pound of lint after 25% of the yield is given to the landlord. (This is not meant to imply that this arrangement is normal or that it should be used in place of existing arrangements. It is simply a consistent measure to be used across all trials.). These break-even prices ranged from $0.48 per pound in Jefferson County to $0.80 per pound in Phillips County. The average cost of production for the six fields was $0.61 per pound.

SUMMARY

A close look at the overall yields and quality factors of the 2001 CRVP fields indicates above average quality although yields were lower than expected in mid-season of each field. Small boll shed affected final yields in all fields. Although four of the six fields were N deficient at some point in the growing season, N deficiency alone did not necessarily cause the small boll sheds.

Quality factors of whiteness grade, staple, length, micronaire, and strength were above average and most CRVP cooperators' grade sheets indicated above loan-price quality existed.

Low commodity prices, however, were noted in much of the country and prices fell throughout the production and harvest season. Four of the six fields showed some profit potential above total specified costs plus rent where a 58-cent season average price was used. Total cost of production averaged 61 cents per pound of lint across all fields. This economic information indicated that there is a need for higher prices for cotton to enable producers to remain viable for the next crop year.

Table 1. Irrigated field information, 2001 CRVP demonstrations.

County-farmer	Acres	Variety	Date of planting	Yield	Soil series
				(lint/acre)	
Desha-Walt	80.0	PM1218 BG/RR	30 April	875	Sharkey and Desha clays
Jefferson-Bonds	37.5	DP 451 B/RR	28 April	1147	Hebert and Rilla silt loams
Lee-McClendon	38.0	PM1218 BG/RR	10 May	879	Jeannerette silt loam; Marvell fine sandy loam; Zachary soils, frequently flooded
Mississippi-Chandler	75.0	ST 4793 R	5 May	1086	Dundee silt loam, Jeanerette silt loam, Sharkey silty clay loam, Sharkey-Steele comples, Steele loamy sand, Tiptonville and Dubbs silt loam
Phillips-Hargraves	56.0	ST 4892 BR	14 May	767	Convent silt loam
Poinsett-Baker	74.0	PM1218 BG/RR	2 May	917	Beulah fine sandy loam, Mhoon silt loam, Dundee silt loam

Table 2. Color grades of fields, 2001 CRVP demonstrations.

	Grade								
County	21	31	32	41	42	43	51	52	53
Desha	1	122	0	19	0	0	0	0	0
Jefferson	1	88	0	0	0	0	0	0	0
Lee	0	24	3	32	6	0	0	1	0
Mississippi	2	162	0	4	0	0	0	0	0
Phillips	0	0	6	1	74	5	0	0	0
Poinsett	0	34	0	62	9	0	29	3	1
Total	**4**	**430**	**9**	**118**	**89**	**5**	**29**	**4**	**1**

Table 3. Average staple length, all bales, 2001 CRVP demonstrations.

	Staple					
County	32	33	34	35	36	37
Desha	0	29	81	31	1	0
Jefferson	0	0	1	16	58	14
Lee	2	0	63	1	0	0
Mississippi	0	0	0	52	115	1
Phillips	0	1	17	46	21	1
Poinsett			70	68	0	0
Total	2	30	232	214	195	16

Table 4. Average micronaire values, all bales, 2001 CRVP demonstrations.

	Micronaire		
County	<3.5	3.5-4.9	>5.0
Desha	0	69	73
Jefferson	0	89	0
Lee	0	24	42
Mississippi	0	156	12
Phillips	1	74	11
Poinsett	0	39	99
Total	1	451	237

Table 5. Average strength, all bales, 2001 CRVP demonstrations.

County	Strength						
	<25.5	25.5-26.4	26.5-27.4	27.5-28.4	28.5-29.4	29.5-30.4	30.5-32.4
Desha	8	23	42	46	17	5	1
Jefferson	8	14	24	25	17	1	0
Lee	2	0	13	51	0	0	0
Mississippi	0	0	0	125	43	0	0
Phillips	1	6	17	29	21	9	3
Poinsett	0	24	52	62	0	0	0
Total	19	67	148	338	98	15	4

Table 6. Economic returns per acre: 2001 Cotton Research Verification Program.

	Desha	Jefferson	Lee	Mississippi	Phillips	Poinsett	Weighted average
Acres	80.0	37.5	38.0	75.0	56.0	74.0	360.5
Per acre yield	874.5	1146.8	878.60	1,086	766.80	917.00	939.25
Loan value	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Sales	$507.21	$665.14	$509.59	$629.88	$444.74	$531.86	$544.77
Total direct exp.	$421.36	$338.60	$303.51	$299.16	$358.35	$287.05	$337.55
Returns over dir. exp.	$85.85	$326.54	$206.08	$330.72	$86.39	$244.81	$207.22
Total specified exp.	$500.56	$415.51	$379.80	$410.93	$458.80	$388.71	$430.89
Returns over total exp.	$6.65	$249.63	$129.79	$218.95	($14.06)[z]	$143.15	$113.88
Rent (25% share)	$126.80	$166.29	$127.40	$157.47	$111.19	$132.97	$136.19
Returns over total exp. and rent	($120.15)	$83.35	$2.39	$61.48	($125.24)	$10.19	($22.32)

[z] Parentheses indicate negative value.

APPENDIX I

STUDENT THESES AND DISSERTATIONS RELATED TO COTTON IN PROGRESS IN 2001

Antoine, Wesner. Transformation of cotton by vacuum infiltration. (Ph.D., advisor: Dr. J. Stewart).

Benson, Ray. Effect of night temperature and other environmental stresses on boll development in cotton. (Ph.D., advisor: Dr. D. Oosterhuis).

Branson, Jeff. Characterization and utilization of CGA 362622 for broadleaf weed control in cotton. (M.S., advisor: Dr. K. Smith).

Brown, Scott. Genotypic and environmental effects on partitioning at the whole plant, boll and seed level for predicting yield and stress. (Ph.D., advisor: Dr. D. Oosterhuis).

Coker, Dennis. Soil and foliar potassium fertilization of water-deficit stressed cotton. (Ph.D., advisor: Dr. D. Oosterhuis).

Conway, Hugh. Inclusion of beneficial insects into the cotton aphid treatment threshold. (Ph.D., advisors: Dr. D. Steinkraus, and Dr. T. Kring).

Coy, Steven. Tarnished plant bug (*Lygus lineolaris*) injury and simulated injury to pre-squaring cotton. (M.S., advisor: Dr. Tim Kring).

Dighe, Nilesh. Introgressing reniform nematode resistance from wild cotton germplasm into the commercial Upland cotton and identify RAPD molecular markers closely associated with the reniform resistant gene. (M.S., advisor: Dr. J. Stewart)

Fairbanks, Mike. Host-plant interactions and resistance to thrips (*Thysanoptera*) feeding on cotton (*Gossypium hirsutum* L.) cultivars. (Ph.D., advisor: T. Kring).

Gomez, Karen. Physiological implications of aphid damage in cotton. (M.S., advisors: Dr. D. Oosterhuis and Dr. D. Johnson).

Groves, Frank. Biology and control of yellow nutsedge (*Cyperus esculentis*) in cotton (*Gossypium hirsutum*). (M.S., advisor: Dr. K. Smith).

Hornbeck, Jimmy. Variation in marginal bract trichomes in cotton. (M.S., advisor: Dr. F. Bourland).

Meek, Cassandra. Physiological and molecular characterization of cotton genotypes in response to water-deficit stress (Ph.D., advisor: Dr. D. Oosterhuis).

Mobley, Michelle. Evaluation of transgenic cotton under different production systems. (M.S., advisor: Dr. N. Burgos).

Sparks, Oscar. Weed and heliothine-complex management in transgenic cotton. (Ph.D., advisor: Dr. J. Barrentine).

Studebaker, Glen. Effect of selected insecticides on the insidious flower bug (*Orius insidious*). (Ph.D., advisor: Dr. T. Kring).

Yates, Chuck. Alteration of cotton plant stress dynamics by tarnished plant bug feeding. (M.S., advisor: Dr. Phil Tugwell).

APPENDIX II

RESEARCH AND EXTENSION 2001 COTTON PUBLICATIONS

BOOKS

Bell, A.A., Nichols, R.L., Albers, D., Baird, R., Brown, S., Colyer, P., El-Zik, K., Gwathmey, O., Lemon, R., Newman, M., Phipps, B.J., and Oosterhuis, D.M. 2001. Bronze wilt of cotton. Special Publication, Cotton Incorporated, Cary, NC. and Texas Coop. Ext., College Station, TX.

Kirkpatrick, T. L. and Rothrock, C.S. (eds.). 2001. Compendium of Cotton Diseases, 2nd edition. APS Press.

McMichael, B.L., Burke, J., Boman, R. Dotray, P. Hopper, N., Kaufman, H., Oosterhuis, D.M., Wheeler, T., and Zak, J. 2001. Cotton Root Disorders, Cotton Inc., Cary, NC.

Oosterhuis, D.M. 2001. Proceedings of the 2001 Cotton Research Meeting and Summaries of Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204. 269 pages.

CHAPTERS IN BOOKS

DeVay, J.E. and Rothrock, C.S. 2001. Control of Seedling diseases. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press. Pages 19-20.

McClelland, M.R. and L.R. Oliver. Herbicide injury. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press. Pages 63-65.

Oosterhuis, D.M. and Bourland, F.M. 2001. Development of the cotton plant. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press.

Oosterhuis, D.M. and Hake, K.D. 2001. Environmental disorders of the cotton crop. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press.

Oosterhuis, D.M. and Zhao, D. 2001. Effect of boron deficiency on the growth and carbohydrate metabolism of cotton. *In*: W.J. Horst et al. (eds.). Plant Nutrtion – Food Security and Sustainability of Agroecosystems. Kluwer Academic Publishers, Dordrecht, Netherlands.

Rothrock, C.S. 2001. *Rhizoctonia solani*. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press. Pages 15-16.

Rothrock, C.S. 2001. Pythium root rot. *In:* O.C. Maloy and T.D. Murray (eds.). The Encyclopedia of Plant Pathology. John Wiley and Sons, New York.

Rothrock, C.S. and Kirkpatrick, T.L. 2001. Bronze wilt. *In*: T.L. Kirkpatrick and C.S. Rothrock (eds.). Compendium of Cotton Diseases, 2nd edition. APS Press. Page 56.

REFEREED PUBLICATIONS

Bondada, B.R. and Oosterhuis, D.M. 2001. Canopy photosynthesis, specific leaf weight, and yield components of cotton under varying nitrogen supply. J. Plant Nutr. 24:469-478.

Elliot, M., Des Jardin, E., Batson, W. Jr., Caceres, J., Brannen, P., Howell, C., Benson, M., Conway, K., Rothrock, C., Schneider, R., Ownley, B., Canaday, C., Keinath, A., Huber, D., Sumner, D., Motsenbocker, C., Thaxton, P., Cubeta, M. Adams, P., Backman, P., Fejardo, J., Mueller, J., Newman, M., and Pereira, R. 2001. Viability and stability of biological treatments on cotton and snap bean seeds. Pest Management Science 57:695-706.

Godfrey, K., D. Steinkraus, and M. McGuire. 2001. Fungal pathogens of the cotton and green peach aphids in the San Joaquin Valley. Southwest. Entomol. 26:297-303.

Layton, M.B., J. L. Long, and D.C. Steinkraus. 2001. Influence of boll weevil eradication on cotton aphid populations in Mississippi cotton. Southwest. Entomol. Suppl. No. 24:57-67.

Oosterhuis, D.M. 2001. Physiology and nutrition of high yielding cotton in the USA. Informacoes Agronomicas 5:18-24.

Oosterhuis, D.M. and Bondada, B.R. 2001. Yield response of cotton to foliar nitrogen as influenced by sink strength, petiole and soil nitrogen. J. Plant Nutr. 24:413-422.

Zhao, D. and Oosterhuis, D.M. 2001. Comparison of cotton yield responses to Pix Plus and Pix. Journal of Plant Growth Regulation 19:415-422.

Zhao, D. and Oosterhuis, D.M. 2001. Influence of potassium deficiency on photosynthesis, chlorophyll content, and chloroplast ultrastructure of cotton plant. Phytosynthetica 39:103-109.

NON-REFEREED PUBLICATIONS

Agudelo, P., K.S. Kim, R.T. Robbins, and J.M. Stewart. 2001. Ultrastructural changes induced by *Rotylenchulus reniformis* in resistant and susceptible cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:35-37.

Barrentine, J.L., Tugwell, N.P., Danforth, D.M., Sparks, O.C., and McClelland, M.R. 2001. Responses of cotton in 2000 to stress associated with treatment levels of insect control, irrigation, and glyphosate. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:132-137.

Batson, Jr., W.E., Caceres, J., Benson, M., Cubeta, M.A., Elliott, M.L., Huber, D.M., Hickman, M.V., McLean, K.S., Ownley, B., Newman, M., Rothrock, C.S., Rushing, K.W., Kenny, D.S., and Thaxton., P. 2001. Biological seed treatment evaluations for control of the seedling disease complex of cotton, 2000. Biological and Cultural Tests for Control of Plant Diseases, 2001: F12, 2 pp. http://www.scisoc.org.online/B&Ctests/2001/.

Benson, N.R., E.D. Vories, K.J. Bryant, and V.D. Wells. 2001. Utilizing crop monitoring to evaluate the effects of PGRs on cotton growth, maturity, and yield in northeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:99-103.

Benson, N.R., T.L. Kirkpatrick, and F.M. Bourland. 2001. Using COTMAN™ to determine yield losses due to the root-knot nematode in cotton grown in northeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:104-109.

Bourland, F.M. and Oosterhuis, D.M. 2001. Addressing variability through research. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:8-12. Fayetteville.

Bourland, F.M. 2001. University of Arkansas cotton breeding program – 2000 progress report. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:29-34.

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 Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:129-131.

Bridges, R.L., D.R. Johnson, G.M. Lorenz, III, and J.D. Hopkins. 2001. Internet information delivery system for reporting heliothine moth trap catches in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:172-176.

Brown, R.S. and Oosterhuis, D.M. 2001. Effect of insecticide termination at varying heat units after cutout on yield, boll weight, fiber quality, and carbon movement. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis. Pages 546-548.

Brown, R.S., Oosterhuis, D.M., Bourland, F.M., and Coker, D.L. 2001. Removal of cotton fruit by chemical and mechanical means at insecticide termination to improve yields. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pages 544-546.

Brown, R.S., Oosterhuis, D.M., Bourland, F.M., and Coker, D.L. 2001. Removal of cotton fruit by physical and chemical means at insecticide termination to improve yields. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:66-72. Fayetteville.

Bryant, K.J. and L.D. Parsch. 2001. Maintaining profitability despite variable yields. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:20-24.

Coker, D.L. and Oosterhuis, D.M. 2001. Soil and foliar potassium fertilization of water deficit stressed cotton. *In*: R.J. Norman and S.L. Chapman (eds.). Arkansas Soil Fertility Studies 2000. University of Arkansas Agricultural Experiment Station, Research Series 480:78-83.

Coker, D.L., Oosterhuis, D.M., and Brown, R.S. 2001. Studies of PIX and foliar fertilization with KNO_3 in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pages 540-542.

Coker, D.L., Oosterhuis, D.M., and Brown, R.S. 2001. Effect of soil and foliar potassium fertilization on yield of water-deficit stressed cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:38-43.

Conway, H.E. and T. Kring. 2001. Development of cotton aphid threshold that incorporates natural enemies. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:195-199.

Gomez, S.K., Oosterhuis, D.M., Johnson, D., and Steinkraus, D. 2001. Physiological response of cotton to aphid damage. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:110-113.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Steward™ (indoxacarb) performance in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:177-184.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Performance of new and conventional insecticides in Bt cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:185-191.

Johnson, D.R., G.M. Lorenz, III, J.D. Reaper, III, J.D. Hopkins, G. Studebaker, and R. Edmund. 2001. Tarnished plant but, *Lygus lineolaris*, management in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:153-157.

Johnson, D.R., G.M. Lorenz, III, J.D. Reaper, III, J.D. Hopkins, G. Studebaker, and R. Edmund. 2001. Evaluation of thrips management options in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:200-205.

Kharboutli, M.S. 2001. Effect of duration of feeding by tarnished plant bug on small boll shed, lint yield, and fiber quality. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:210-216.

Kharboutli, M.S. 2001. Efficacy of selected insecticides against mid-season tarnished plant bug populations in southeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:224-228.

Kharboutli, M.S. 2001. Survival of noctuid caterpillars on Bollgard II, Bollgard, and conventional cotton varieties in southeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:229-233.

Kharboutli, M.S. and C.T. Allen. 2001. Chemical control and species composition of thrips in Arkansas cotton fields. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:217-223.

Kharboutli, M.S. and C.T. Allen. 2001. Validation of COTMAN™ system for insecticide termination in southeast Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:73-78.

Kharboutli, M.S. and S.R. Kelley. 2001. COTMAN™ for irrigation termination: studies to identify the irrigation termination window. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:92-98.

Lorenz, B.J., III, D. Johnson, J. Hopkins, J. Reaper, A. Fisher, and C. Norton. 2001. Bollgard II™ performance in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:163-166.

Lorenz, G.M., III, T. Kirkpatrick, C. Coker, J. Hopkins, D. Johnson, R.T. Robbins, A. Fisher, S. Rodery, M. Hamilton, J. Sites, C. Bonner, and J. Reaper. 2001. Large block Temik™ (aldicarb) sidedress studies in Arkansas, 1998-2000. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:158-162.

McClelland, M.R., Barrentine, J.L., Smith, K., and Burgos, N.R. 2001. Herbicide evaluation in Arkansas cotton, 2000. University of Arkansas Agricultural Experiment Station, Research Series 486. 116 pages.

McClelland, M., Barrentine, J., and Sparks, O. 2001. Summary of selected herbicide evaluations in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:124-128.

McClelland, M.R., J.L. Barrentine, O.C. Sparks, K.L. Smith, and J.W. Branson. 2001. Valor™ (flumioxazin) herbicide applied layby in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:138-142.

McConnell, J.S., W.H. Baker, and R.C. Kirst, Jr. 2001. Varietal responses of cotton to nitrogen fertilization. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:44-46.

McConnell, J.S., R.C. Kirst, Jr., R.E. Glover, and R. Benson. 2001. Nitrogen fertilization of ultra-narrow-row cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:47-50.

McConnell, J.S., W.H. Baker, and R.C. Kirst, Jr. 2001. Long-term irrigation methods and nitrogen fertilizationrates in cotton production: the last five years. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:51-55.

Meek, C.R. and Oosterhuis, D.M. 2001. Evaluation of Messenger™ in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:79-82.

Mobley, M.L., Burgos, N.R., and McClelland, M.R. 2001. The effect of different herbicide programs and row spacings for control of weeds in transgenic cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:143-145.

Oosterhuis, D.M. 2001. Environmental stress affects fruit shedding in cotton. Cotton Farming, June 2001.

Oosterhuis, D.M. 2001. Development of a cotton plant. *In*: R. Seagull and P. Asplaugh (eds.). Cotton Fiber Development and Processing: An Illustrated Overview. International Textile Center, Lubbock, TX, and Cotton Inc., Cary, NC.

Oosterhuis, D.M. and Bourland, F.M. 2001. Management to reduce stress. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:13-19.

Oosterhuis, D.M. and Brown, R.S. 2001. Effect of insecticide termination at varying heat units after cutout on yield, boll weight, and carbon movement. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:61-65.

Oosterhuis, D.M. and Galanopoulou, S. 2001. Organic cotton production in Greece and the USA. Proc. Organic Farming Conference, Volos, Greece.

Oosterhuis, D.M. and Gomez, S.K. 2001. Effect of foliar-applied CoRoN slow release nitrogen fertilizer on cotton yield. *In*: R.J. Norman and S.L. Chapman (eds.). Arkansas Soil Fertility Studies 2000. University of Arkansas Agricultural Experiment Station, Research Series 480:70-72.

Oosterhuis, D.M., Robertson, W.R., McConnell, J.S., and Zhao, D. 2001. Evaluation of soil and foliar fertilization with boron in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:56-60.

Parsch, L.D. and J.P. Malo. 2001. Net returns risk from cotton production in Arkansas counties. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:240-247.

Plunkett, D.E., W.C. Robertson, and K.J. Bryant. 2001. The Arkansas cotton research verification program: education in the field. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:253-258.

Rajguru, S. and J.M. Stewart. 2001. Transgenic expression and evaluation of plants transformed with a synthetic analog of magianin. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:234-239.

Reaper, J., III, J.D. Hopkins, D.R. Johnson, G.M. Lorenz, III, D.C. Steinkraus, and M.C. Norton. 2001. Two-spotted spider mite management in cotton. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:146-151.

Reaper, J., III., J.D. Hopkins, D.R. Johnson, and G.M. Lorenz, III. 2001. Heliothine control in cotton with new chemistry. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:167-171.

Ribera, L.A., LaFerney, P., Smith, K., Bryant, K., Cochran, M., and Oosterhuis, D.M. 2001. Comparison of feasibility and profitability of Roundup Ready® versus conventional cotton cultivars in Arkansas. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:248-252.

Robertson, W.C. 2001. Yield variability problem. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:5-7.

Stewart, M.J., J. Zhang, and G. Coyle. 2001. Introgression and inheritance of a red calyx trait. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:237-239.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Comparison of cotton plant response to square loss following manual removal orf tanished plant bug feeding results from field trials in 2000. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Tarnished plant bug mortality in field cages following applications of Centric, Steward, Calypso, and Leverage in cotton 2000. Arthropod Management Tests, 26:F http://www.entsoc.org/pubs/amt2001/.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Tarnished plant bug control in cotton after applications of Cetric, Actara, Steward, Calypso, and Leverage. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:192-194.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Cotton response to square loss prior to first flower: a comparison of manual removal and tarnished plant bug feeding. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:114-124.

Vories, E.D. and R.E. Glover. 2001. Defining the COTMAN™ target development curve for ultra-narrow-row cotton on clay soil. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:83-86.

Vories, E.D., R.E. Glover, N.R. Benson, V.D. Wells, and C.T. Allen. 2001. Refining end-of-season cotton irrigation recommendations. *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:87-91.

Wang, Q., Oosterhuis, D., and Coker, D. 2001. Comparison of nitrogen sampling analytical techniques for estimating cotton plant nitrogen status. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 534-537.

Wildy, D. 2001. What's happening in the real world? *In:* D.M. Oosterhuis (ed.). Proc. 2001 Cotton Research Meeting and Summaries of Cotton Research in Progress. University of Arkansas Agricultural Experiment Station, Special Report 204:1-4.

Zhao, D. and Oosterhuis, D.M. 2001. Boron deficiency at early cotton growth stages affects dry matter accumulation and partitioning and increases square shedding. *In*: R.J. Norman and S.L. Chapman (eds.). Arkansas Soil Fertility Studies 2000. University of Arkansas Agricultural Experiment Station, Research Series 480:73-77.

Zhao, D. and Oosterhuis, D.M. 2001. Cotton plant physiological and yield responses to nitrogen status. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 511-514.

PUBLISHED ABSTRACTS

Abaye, A., Herbert, A., Oosterhuis, D., Pitman, V., and Maitland, J.C. 2001. Compensation of cotton square removal. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Page 498.

Abaye, A., Maitland, J., Bryant, J., and Oosterhuis, D.M. 2001. Characterization of the cotton fruiting curve. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Page 557.

Abney, M.R., J.R. Ruberson, G.A. Herzog, T.J. Kring, and D.C. Steinkraus. 2001. Impact of natural enemies on the cotton aphid: implications for control. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 1029-1031.

Barrentine, J.L., Tugwell, N.P., Danforth, D.M., Sparks, O.C., and McClelland, M.R. 2001. Responses of cotton in 2000 to stress associated with treatment levels of insect control, irrigation, and glyphosate. *In*: Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pages 1234-1235.

Benson, N.R., F.M. Bourland, E.D. Vories, and W.C. Robertson. 2001. Timing defoliation based on heat units accumulated past cutout: a three-year summary. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 485.

Bridges, R.L., D.R. Johnson, G.M. Lorenz, III, and J.D. Hopkins. 2001. Internet information delivery system for reporting heliothine moth trap catches in Arkansas. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1054.

Brown, R.S., Oosterhuis, D.M., Coker, D.L., and Fowler, L. 2001. Genotypic and environmental effects on partitioning at the whole plant, boll and seed level for predicting yield and stress. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 460.

Coker, D.L., Oosterhuis, D.M., Brown, R.S., Earnest, L., and Fowler, L. 2001. Water deficit and potassium deficiency in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 460.

Fairbanks, M.W., D.R. Johnson, and T.J. Kring, 2001. Species composition and population increase of early season thrips on cotton. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 1069-1070.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Performance of new and conventional insecticides in *B.t.* cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1079.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Steward (indoxacarb) performance in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1081.

Hopkins, J.D., D.R. Johnson, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Performance of Bollgard II® cotton. Arkansas Crop Management Conference 2001. Little Rock, AR.

Johnson, D.R., J.D. Hopkins, G.M. Lorenz, III, and J.D. Reaper, III. 2001. Evaluation of thrips management options in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1086.

Johnson, D.R., G.M. Lorenz, III, J.D. Reaper, III, J.D. Hopkins, G. Studebaker, and R. Edmund. 2001. Plant bug, *Lygus lineolaris*, management in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1084.

Long, J.L., M.B. Layton, and D. Steinkraus. 2001. Influence of boll weevil eradication on aphid populations in Mississippi cotton: Year 3. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 855-858.

Lorenz, G., D.Johnson, J. Hopkins, J. Reaper, A. Frisher, and C. Norton. 2001. Bollgard II performance in Arkansas. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1116.

Lorenz, III., G.M., T.Kirkpatrick, C. Coker, J. Hopkins, D. Johnson, R.T. Robbins, A. Fisher, S. Rodery, M. Hamilton, J. Sites, C. Bonner, and J. Reaper. 2001. Large block Temik (aldicarb) sidedress studies in Arkansas, 1998-2000. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 126.

McClelland, M.R., Barrentine, J.L., and Sparks, O. 2001. Flumioxazin (Valor) applied layby in cotton. Proc. South. Weed Sci. Soc. 54:205.

McGuire, M.R., K.E. Grodfrey, and D.C. Steinkraus. 2001. Entomopathogenic fungi for control of aphids and *Lygus* in California. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 960-961.

Meek, C. and Oosterhuis, D.M. 2001. Physiological responses of common cotton cultivars to water-deficit stress. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Pages 459-460.

Meek, C., Oosterhuis, D., and Robertson, W. 2001. Effects of Messenger™ on cotton grown in the field and under controlled conditions. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis, TN. Pages 526-527.

Mobley, M.L., Burgos, N.R., and McClelland, M.R. 2001. Development and productivity of Roundup Ready cotton under conventional and narrow-row systems. Proc. South. Weed Sci. Soc. 54:131-132.

Mobley, M.L., Burgos, N.R., and McClelland, M.R. 2001. The impact of weed control programs on development of transgenic cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 445.

Mobley, M.L., Burgos, N.R., and McClelland, M.R. 2001. Efficacy of total postemergence weed control programs for transgenic cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1219.

Oosterhuis, D.M. 2001. Potassium management in cotton. Proc. International Symposium on the Importance of Potassium in Nutrient Management for Sustainable Crop Production. International Potash Institute. Delhi, India.

Oosterhuis, D.M., Abaye, O., Bednarz, C.A., Holman, E.M., and Gomez, K. 2001. Characterization of the target growth curve used in COTMAN™: Regional project summary. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 544.

Oosterhuis, D.M. and Gomez, K. 2001. Summary of CoRoN™ studies in Arkansas. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Pages 537-539.

Oosterhuis, D.M., Zhao, D., and Brunk, D. 2001. Effect of Pix Plus and *Bacillus cereus* on the physiology and yield of cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Pages 514-515.

Plunkett, D.E. and T.L. Kirkpatrick. 2001. Reniform reduction in CRVP fields through crop rotation. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis.

Reaper, III, J.D., J.D. Hopkins, D.R. Johnson, and G.M. Lorenz, III. 2001. Heliothine control in cotton with new chemistry. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1122.

Reaper, III, J.D., J.D. Hopkins, D.R. Johnson, G.M. Lorenz, III, D.C. Steinkraus, and M. C. Norton. 2001. Two-spotted spiker mite management in cotton. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 1125-1127.

Robertson, W.C., Oosterhuis, D.M., and McConnell, J.S. 2001. Evaluation of soil and foliar fertilization with boron in Arkansas. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Page 540.

Rothrock, C.S. 2001. Report of the Cottonseed Treatment Committee for 2000. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Pages 89-93.

Rothrock, C.S., Sealy, R.L., Kluepfel, D.A., and Yan, Z. 2001. Association of *Agrobacterium tumefaciens* with cottonseed. *In*: Proc. 2001 Beltwide Cotton Conf., National Cotton Council, Memphis. Page 116.

Rothrock, C.S., Winters, S.A., Bonnoua, S., and Nehl, D.B. 2001. Role of host exudates in the development of black root rot. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Page 130.

Steinkraus, D, D. Wildy, and D. Wells. 2001. Jump-starting epizootics of *Neozygites fesenii* in cotton aphid populations. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 1141-1143.

Steinkraus, D. and J. Zawislak. 2001. Spider mites on cotton in the Midsouth. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Page 1141.

Studebaker, G.E. and T.J. Kring. 2001. Effect of new insecticides on insidiuos flower bug. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 1143-1145.

Teague, T.G., N.P. Tugwell, and E.J. Villavaso. 2001. Mortality of tarnished plant bug nymphs following differential exposure to Centric, Steward, Calypso, and Leverage in field cages. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Pages 1157-1158.

Tingle, C.H., G.L. Steele, B.V. Ottis, and J.M. Chandler. 2001. Smellmelon (*Cucumis melo* L. Var. dudaim Naud.) control and competitive interactions in cotton (*Gossypium hirsutum*). Proc. South. Weed Sci. Soc. 54:129.

Zhao, D. and Oosterhuis, D.M. 2001. Changes in cotton plant growth and physiology during the development of boron deficiency. *In*: Proc. 2001 Beltwide Cotton Conf. National Cotton Council, Memphis. Page 540.

UofA

UNIVERSITY OF ARKANSAS

DIVISION OF AGRICULTURE