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Summaries of Arkansas Cotton Research 2002

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Edited by Derrick M. Oosterhuis

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2002

Edited by Derrick M. Oosterhuis

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PREFACE

The average yield in Arkansas in 2002 was 871 lb lint/acre from 920,000 harvested acres (960,000 planted) for a total of 1.67 million bales at a value of $336.5 million. This yield was second only to the record 877 lb lint/acre achieved in 1994. Last year's crop yield, and the five-year average, on a per acre basis are exceeded in the U.S. Cotton Belt only by California and Arizona. Cotton yields in Arkansas increased steadily during the eighties, but in the last decade yields have leveled off. Furthermore, the last five years have had extreme year-to-year variability in yields, which is a major point of concern with cotton producers.

The lint quality of the 2002 crop was good as measured by tenderable bales produced, i.e. there was sufficient quality to meet delivery on New York No. 2 futures contracts. Furthermore, the quality of all tenderable cotton produced in Arkansas exceeded that of all other states in the Mid-South, i.e., LA, MO, MS, and TN. Although total production in Mississippi exceeded that of Arkansas by approximately 260,000 bales, Arkansas farmers produced over 145,000 more bales of tenderable cotton than Mississippi. The 2002 season-average cotton price was $0.42, which is far below the 10-year average of $0.565. Season-average cotton prices during the last ten years exceeded that of the 2002 crop in 9 of the last 10 years.

The cotton crop had a difficult start with very poor stands due to extremely wet conditions and cool temperatures during late April and the first half of May (even some frost occurred on 19 May!). This resulted in a proportion of the crop being planted in late May. However, unseasonably moderate temperatures in July and August and timely rainfall (see the weather patterns in Fig. 1) resulted in excellent boll growth and fiber development that established an extremely high yield potential. High night temperatures during boll development are thought to be a major contributor to low yields in the Mid-South, but in 2002 the night temperatures were significantly lower than normal. Insects were the usual, but not unexpected, problem. There were continuous flights of cotton bollworm and tobacco budworm, with greater numbers of tobacco budworm in northeast Arkansas. Almost 85% of the cotton crop was planted with a Roundup-Ready cultivar and 60% of the crop contained the Bt gene. Heavy rains in late August resulted in some yield loss and detracted from the record yields that were forming. However, temperatures and soil moisture levels in September were almost ideal for fiber development to continue through the entire month resulting in the high average yield recorded for the state.

Derrick Oosterhuis and Bill Robertson

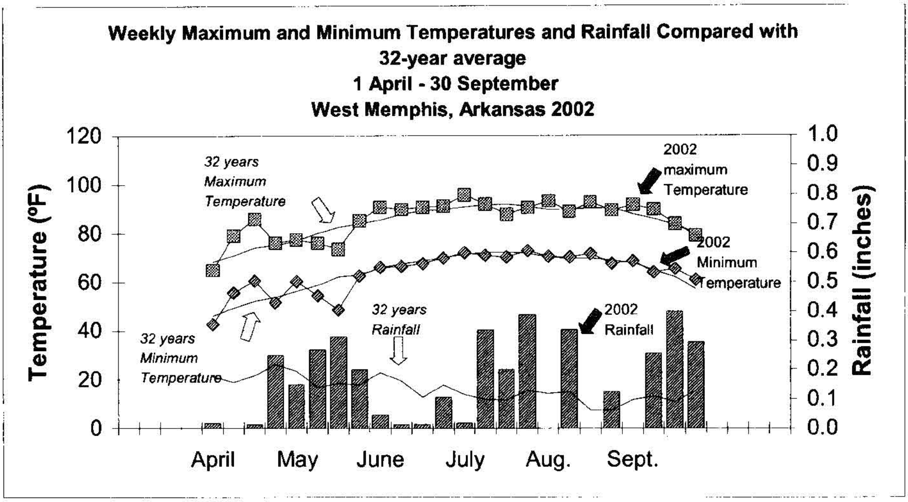

Fig. 1. Weekly maximum and minimum termperatures and rainfall for 2002 compared with the long-term 31-year averages at West Memphis.

ARKANSAS COTTON RESEARCH GROUP

2002/2003

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, 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, Glenn Studebaker, Tina Teague, Chris Tingle, Phil Tugwell, Seth Young

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

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ACKNOWLEDGMENTS

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

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research – 2002* 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 Cary, 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 part, 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 2002.

Project	Principal investigator	Amount funded 2002	2003
Proceedings Arkansas research meeting and graduate student award	Oosterhuis	6,500	6,500
Cottonseed pool — Arkansas	Cotton Inc.	5,520	5,520
Control of reniform nematodes	Kirkpatrick	19,118	19,118
Plant stress	Teague	10,000	14,649
New petiole sampling	Oosterhuis	6,370	--
Plant bug feeding	Greene	8,000	--
Agronomic systems	Tingle / Greene	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	15,228	15,228
Plant breeding: yield and quality	Bourland	25,935	25,935
Campaign for Agriculture	Welch	1,000	1,000
Stink bug thresholds	Greene	15,500	15,500
Large-scale variety evaluations	Guy	10,000	10,000
Aphid thresholds	Kring	5,541	11,787
Totals:		304,228	300,753

SUMMARIES OF
ARKANSAS COTTON RESEARCH
- 2002 -

UNIVERSITY OF ARKANSAS COTTON BREEDING PROGRAM - 2002 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 which 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 which are highly adapted to Arkansas environments and possess good host plant resistance traits. Bourland (2002) 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

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[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, host plant resistance, 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.

RESULTS AND DISCUSSION

Breeding Lines

The primary focus of the 2002 breeding line crosses was to enhance yield components and improve resistance to root knot nematode. The F_1 seed are being advanced to F_2 generation in a winter nursery. In 2002, all F_2 populations (from crosses made in 2001) were hot water (65°C) treated to provide selection for resistance to seed deterioration. Unfortunately, bacterial blight inoculation was not successful in 2002. Instead of individual plant selection, mass selection was conducted within each population. Individual plant selections will be made from subsequent F_3 populations in 2003. In addition, population advances of 30 populations, which have at least one root knot-resistant parent, were made by harvesting one boll from each plant then bulking by population. These advanced populations will be screened for field resistance to root knot nematode in 2003.

Based on harvested yields at Clarkedale and Keiser, Verticillium wilt incidence, and morphological traits, 195 of 584 first-cycle progeny rows were selected in 2002. In 2003, individual plant selections will be made from the best (based on yields at Rohwer and Keiser) of these progeny. Also in 2002, 805 plants were selected from 89 advanced progeny. These will be tested as second-cycle progeny rows in 2002. From 970 second-cycle progeny in 2002, 72 were selected and will be evaluated in replicated preliminary strain tests in 2003. An additional 162, will be evaluated for yield at Keiser and Rohwer in 2003 before being advanced to strains.

Strain Evaluation

In 2002, 98 strains were evaluated in replicated strain tests at multiple locations. Within each test, strains were compared to standard cultivars (PSC 355 and SG 105). Based on their performance, 36 of the strains were selected and entered into 2003 strain tests. The superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality. Also, six advanced strains were evaluated in the 2002 Arkansas Cotton Variety Test (Bourland et al., 2003).

Selection Criteria

In 2002, work continued to establish selection criteria in four specific areas: Root-knot nematode resistance, thrips resistance, yield components, and bract trichomes.

Root-Knot Nematode (RKN) Resistance

Greenhouse evaluation of resistance to root-knot nematode was not successful. Apparently, we were unable to maintain the greenhouse warm enough when unseasonable cool temperatures occurred in May. No root symptoms were found on known susceptible lines. Populations having root-knot resistant parentage were planted at Keiser and advanced to the next generation. Mass selection was not conducted to ensure that root-knot resistant plants were preserved in the population. Previous work has indicated that root-knot resistance can be lost if selection is done for superior agronomic appearance in the absence of the pest. These populations will be screened in a root-knot nematode infested field in 2003.

Thrips Resistance

New and advanced strains were evaluated for yield in adjacent plots having thrips control (in-furrow insecticide) and no thrips control in 2002. Thrips infestations were relatively high, and infested plots yielded ca. 65% as much as control plots. However, the strain by treatment interaction was not significant in either test. Therefore, no difference in resistance to thrips could be detected.

Yield Components

Strains were evaluated with regard to relative influence of basic yield components of seed per acre and lint index (weight lint per 100 seed). An additional index trait, LS ratio, was determined by dividing lint index by seed index. This index should standardize lint per seed for different sizes of seed. A genetic evaluation of yield component study was initiated by crossing parents which varied greatly in relative contributions of lint per seed and seed per acre required for yield. Results of this study should assist breeding of lines that produce yield more efficiently. In addition, a yield component study was initiated to evaluate relative yield components of 10 cotton lines at four plant densities. Yield components on a whole plot and selected individual boll basis are being evaluated.

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. Visually rating of bract trichomes was improved in 2001 and 2002 by using a magnifying glass and a dark background. Environment does not appear to greatly influence the bract trichome trait. Over four years, a cultivar by location interaction was only found one year when a severely stressed environment was included. In a two-year 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 (avoid highly stressed environment) on one sampling date at one plant position. Variation in bract trichomes of breeding lines is being evaluated. Multiple generations including backcross populations are being developed to determine the inheritance of bract trichomes.

Release of Material

Data are being summarized for germplasm and/or cultivar releases in 2003.

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.

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Arkansas Planting and Tillage Trends

William C. Robertson

RESEARCH PROBLEM

In the last ten years, the technologies available to producers in the way of herbicide- and insect tolerant-cultivars have changed the face of agriculture drastically. The technologies were led by Buctril-tolerant cultivars. Bollgard and Roundup Ready traits dominate today's market. Around the corner many new and specific traits are in the process of being developed or are on the verge of being released.

BACKGROUND INFORMATION

In 2002, seven cultivars made up just over 80% of the cotton plantings in the state based on USDA estimates (Table 1). Six of the seven cultivars were tolerant to Roundup while four of the seven contain the Bollgard gene. All seven possessed herbicide-tolerant traits. As evident in this group of seven, many of the popularly planted cultivars are stacked or contain both Roundup Ready and Bollgard traits. The percentage of cultivars planted in Arkansas based on USDA estimates that contains either Bollgard, Roundup Ready, or Buctril traits is shown in Table 2.

RESEARCH DESCRIPTION

Surveys completed by County Extension Agents (CEA) track very close to estimates compiled by USDA. The percentages of the crop by technologies in 2002 match closely to one another (Table 3). In 1997, 80% of the acreage was planted to cultivars possessing no transgenic traits while over 80% of the crop contained the Roundup Ready trait in 2002 based on CEA estimates. The enhanced use of the Roundup Ready trait has had a significant impact in tillage systems utilized by Arkansas producers as

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well. The combined percentage of no-till and reduced tillage systems surpassed that of conventionally tilled in 2001 and will likely continue to increase in the future (Table 4).

PRACTICAL APPLICATION

As existing technologies continue to improve with the onset of Bollgard II and Roundup Ready Flex and with new traits around the corner, it will become increasingly important to monitor the crop closely for not only pests but for interactions with vegetative and reproductive development as well. Boll weevil eradication efforts combined with improved plant-based traits can often result in situations with very high retention levels at first flower. The importance of a crop advisor in keeping abreast of the current field-to-field situation is greater now than it ever has been. The tools available to this person such as COTMAN, irrigation scheduling programs, nematode and fertility sampling, AG-Dia kits, aphid fungus surveys, nutrient monitoring programs and many other IPM related programs are there for the taking. In order for a crop advisor to utilize these tools to their fullest extent, the procedures employed by the advisors and their compensation must also evolve much as we have seen technology shift in the field. The tools available to crop advisors today will make it possible for the clients to see a return on their investment in crop advisors unmatched by those ever seen in the past.

Table 1. Top seven cultivars planted in Arkansas based on USDA estimates for 2002.

Variety	Percentage
ST 4793R	18.16
ST 4892BR	15.16
PM 1218BG/RR	14.79
DP 451B/RR	13.04
SG 215BG/RR	9.24
ST BXN47	6.99
PM 1199RR	2.74
Total	**80.12**

Table 2. Percentage of acres planted in Arkansas to cotton containing any of the following technology traits either alone or in combination with any other trait based on USDA estimates for 2002.

Technology groups	Combined percentage
BXN	8
Bt	59
RR	82

Table 3. Shifts in technologies available in cotton planting seed from 1997 to 2002 grown in Arkansas based on County Extension Agent Surveys conducted yearly.

Technology	1997	1998	1999	2000	2001	2002
Conventional	80	56	29	24	18	7
BXN	2	30	46	34	13	5
Bt	13	11	14	15	8	1
RR	5	2	7	7	10	28
Bt + RR	T	1	4	20	51	59

Table 4. Shifts in tillage systems for cotton from 1999 to 2002 in Arkansas based on County Extension Agent surveys conducted yearly.

System	1999	2000	2001	2002
No-till	4	6	9	15
Reduced	31	37	43	44
Conventional	65	57	48	41

Genetic Diversity of Arborescent *Gossypium* Species Based on RAPDs and AFLPs

Chunda Feng, James McD. Stewart, and Mauricio Ulloa[1]

RESEARCH PROBLEM

The genus *Gossypium* L. (Malvaceae) is the repository of genetic diversity for future cotton improvement. A complete understanding of the available diversity, traditionally represented as taxonomic species, is essential to optimally utilize this resource. Traditional measures of genetic diversity are based on morphological, cytological, and agronomic performance criteria. In recent years, molecular measures of diversity within DNA have been shown to correlate well with other measures of diversity and often are a more sensitive measure of relatedness or divergence among genotypes. The arborescent *Gossypium* relatives of cotton native to Mexico are a significant germplasm resource for cotton improvement, but their genetic diversity is not well understood. This report presents a measure of molecular diversity and phylogenetic relationship within these species.

BACKGROUND INFORMATION

The genus *Gossypium* contains a vast range of genetic diversity residing in 49 currently recognized species grouped into eight genome groups. Three centers of *Gossypium* diversity are recognized, i.e. Africa/Arabia, Australia, and Mexico. Traditional taxonomy is based on morphological and cytological characteristics. However, molecular methods provide an additional tool to measure relatedness in taxonomy and evolution, and most molecular data are concordant with traditional taxonomic divisions (Wendel and Albert, 1992; Wendel et al., 1995; Hanson et al., 1998; Small and Wendel, 1998; Small et al., 2000). *G. aridum*, as it is currently recognized taxonomically, is the most widely distributed of the New World diploid species ranging from central Sinaloa to eastern Oaxaca in Mexico. We have observed morphological variation among 19 accessions of *G. aridum* growing under greenhouse conditions, and one of us

[1] Research associate and professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; and research geneticist, USDA, ARS, Shafter, CA, respectively.

(JMS) has observed this variation among herbarium specimens and among populations in their natural habitat. Recently, extensive new seed collections were made of *Gossypium* species of southern Mexico. This has allowed an evaluation of the genetic diversity and phylogenetic relationships within *G. aridum* and other *Gossypium* species within section *Erioxylum* based on molecular techniques.

RESEARCH DESCRIPTION

The *Gossypium* species examined in this study are listed in Table 1. Nine accessions were from the USDA, ARS Cotton Wild Species Germplasm Collection, whereas the remaining accessions were collected by the two co-authors in 2002. Dr. Jonathan F. Wendel (ISU) kindly donated leaf samples of five accessions so that the representatives from the full range of the distribution of *G. aridum* could be included.

The seeds were sown in pots in a greenhouse at Fayetteville, AR DNA was extracted from young leaves. Random amplified polymorphic DNA (RAPD) was generated in polymerase chain reactions (PCR) with 27 individual 10-mer primers. The products were separated by electrophoresis through a 1% agarose gel. Development of amplified fragment length polymorphisms (AFLP) was based on the manufacturer's procedure, and DNA fragments were separated by electrophoresis on 6% denaturing polyacrylamide gel. Four primer combinations were amplified with ^{33}P labeling and visualized by autoradiography, whereas twelve were visualized with silver staining. Presence or absence of an amplified fragment was recorded as 1 or 0, respectively. The data were analyzed with NTSYS 2.0 software to obtain an estimate of genetic similarity and generate a phylogenic dendrogram.

RESULTS AND DISCUSSION

Each of the 27 primers revealed DNA polymorphism among the plants. The number of PCR products amplified by each primer averaged 7.8 (range = 4 to 16). The 33 accessions yielded 210 usable loci among which 172 (81.9%) were polymorphic. The 16 primer combinations used to generate AFLP gave 766 bands with an average of 48 bands per combination (range = 23 to 86). Of the 967 bands produced by RAPD and AFLP, 865 bands (89.45%) were polymorphic. Many bands were specific to a species or an accession, for example, 97 bands were specific to subsection *Selera* (*G. gossypioides*), 35 were specific to subsection *Erioxylum*, 33 were specific to accession US72, and 30 were specific to accession DJD168.

Estimates of genetic distance among the 33 accessions are presented in Table 2. The two *G. gossypioides* accessions (subsection *Selera*) had a genetic distance of only 0.01, but they were genetically distinct from subsection *Erioxylum* accessions (range = 0.64 to 0.84). In subsection *Erioxylum*, *G. schwendimanii* was close to *G. laxum* judged by genetic distances from 0.12 to 0.15. The genetic distance between *G.*

schwendimanii and other subsection *Erioxylum* accessions ranged from 0.32 to 0.48. The five *G. laxum* accessions were quite similar, however, the genetic distances between *G. laxum* accessions and *G. aridum* or *G. lobatum* accessions ranged between 0.32 and 0.50.

Based on genetic distance between some well-recognized species (Table 2), 0.32 is a conservative estimate of genetic distance that distinguishes species in subsection *Erioxylum*. The genetic distance between accession US72 and all other accessions exceeded 0.32 (range of 0.42 to 0.54), suggesting that this accession potentially is an undescribed species. The genetic distance among *G. aridum* accessions, as currently taxonomically circumscribed, ranged from 0.02 to 0.46 (Table 3). The genetic distances between the Colima accession and those from other regions were higher than 0.32, and the genetic distances between Oaxaca accessions and those from Jalisco and Sinaloa also exceeded the conservative estimate. These results suggest that these accessions may also represent distinct taxa.

The dendrogram (Fig. 1) based on genetic distance shows the phylogenetic relationship among section *Erioxylum* species. Subsection *Selera* accessions are distinct from all accessions in subsection *Erioxylum*. In subsection *Erioxylum*, *G. schwendimanii* clustered with *G. laxum*, whereas *G. lobatum* was closer to *G. aridum*, and US72 was intermediate to these four species. The Oaxaca accessions formed one clade, and the two accessions from Colima formed a clade. Guerrero and Michoacán accessions separated into different subgroups despite small genetic distances. These results indicate that *G. aridum*, as it is currently circumscribed, has extensive molecular diversity. The question of appropriate circumscription of this species merits additional investigation.

PRACTICAL APPLICATION

The polymorphisms amplified by RAPD and AFLP cover most of the genome of the taxa, hence they provide a robust measure of diversity. The intermediate character of accession US72 to species *G. aridum*, *G. lobatum*, *G. laxum* and *G. schwendimanii*, suggests that it is either ancestral to these or resulted from resent homoploid speciation. The genetic diversity among taxa designated as *G. aridum* exceeded the diversity among other currently recognized species of subsection *Erioxylum*, indicating that the taxonomic treatment of the *Gossypium* genus, in general, and *G. aridum* in specific, is incomplete. Based on these results additional investigation on comparison of morphological and cytogenetic characteristics among subsection *Erioxylum* species will be used to establish the taxonomic placement of these species.

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Table 1. Accessions of arborescent *Gossypium* species.

No.	Species	ID	Origin	No.	Species	ID	Origin
1	*G. aridum*	DJD168-1	Colima	18	*G. aridum*	US-41	Oaxaca
2	"	DJD172	Jalisco	20	"	US-76	Guerrero
3	"	DJD185	Jalisco	21	"	US-78	Guerrero
4	"	HC4	Sinaloa	22	"	US-80	Guerrero
5	"	HC10	Sinaloa	23	"	US-81	Guerrero
6	"	DJD122	Guerrero	24	"	US-83	Michoacán
7	"	DJD123	Michoacán	25	*G. lobatum*	US-86	Michoacán
8	"	DJD168-2	Colima	26	*G. laxum*	US-65	Guerrero
9	"	DJD179	Jalisco	27	"	US-66	Guerrero
10	"	US-4	Puebla	28	"	US-67	Guerrero
11	"	US-5	Puebla	29	"	US-68	Guerrero
12	"	US-10	Oaxaca	30	"	US-70	Guerrero
13	"	US-11	Oaxaca	31	*G. schwendimanii*	US-84	Michoacán
14	"	US-12	Oaxaca	32	*G. gossypioides*	US-43	Oaxaca
15	"	US-13	Oaxaca	33	"	US-46	Oaxaca
16	"	US-15	Oaxaca	19	*G. sp. nov.*	US-72	Guerrero
17	"	US-17	Oaxaca				

Table 2. Genetic distance coefficients (ranges) among 33 accessions of *Gossypium* species.

	D4	US72	D7	D9	D11	D6
D4	0.02-0.54					
US72	0.43-0.54					
D7	0.26-0.39	0.49				
D9	0.32-0.50	0.42-0.43	0.33-0.35	0.02-0.04		
D11	0.32-0.48	0.48	0.32	0.12-0.15		
D6	0.74-0.80	0.83-0.84	0.71-0.73	0.67-0.71	0.60-0.65	0.01

Table 3. Genetic distances (ranges) among *G. aridum* accessions from different states of Mexico.

	Col.	Jal.	Sin.	Guer.	Pueb.	Mich.	Oax
Colima	0.08						
Jalisco	0.28-0.40	0.10-0.23					
Sinaloa	0.35-0.38	0.22-0.26	0.05				
Guerr.	0.30-0.37	0.14-0.32	0.19-0.31	0.07-0.24			
Puebla	0.29-0.34	0.15-0.21	0.23-0.25	0.15-0.27	0.04		
Mich.	0.30-0.34	0.17-0.25	0.23-0.27	0.09-0.17	0.16-0.19	0.19	
Oaxaca	0.36-0.46	0.23-0.38	0.32-0.39	0.11-0.35	0.26-0.32	0.20-0.30	0.02

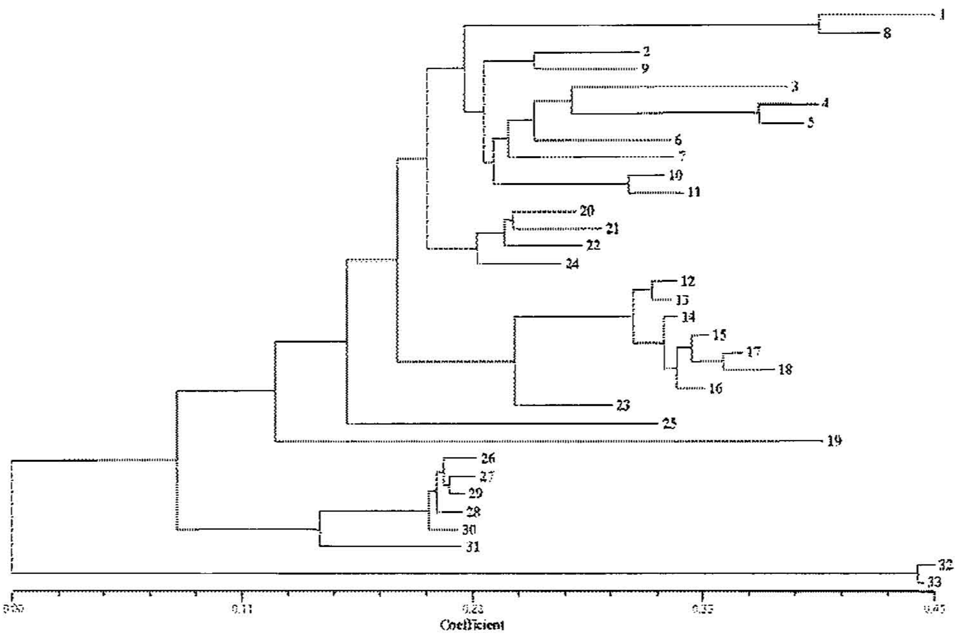

Fig. 1. Dendrogram of 33 arborescent *Gossypium* accessions based on UPGMA analysis of 972 RAPD and AFLP loci. The numbers correspond to the accessions numbers in Table 1.

Comparison of Stacked-Gene and Glyphosate-Resistant Cotton Cultivars: Arkansas 2002

Kelly J. Bryant, William C. Robertson, and George Hackman[1]

RESEARCH PROBLEM

Cotton cultivars containing the Bt gene have the potential to impact yield and cost, thereby affecting profit. Monitoring their impact on profit is important to Arkansas' cotton producers. Economic comparisons of stacked-gene cotton cultivars to single-gene glyphosate-resistant cotton cultivars are needed to aid Arkansas producers in variety selection and insect management decisions.

BACKGROUND INFORMATION

The number of transgenic cotton cultivars available for commercial production has increased greatly in recent years. Cotton producers now have multiple choices when choosing transgenic cotton cultivars. The choice of cultivar now dictates the insect and weed control programs that will or can be used. It is estimated that, in 2002, 55% of Arkansas' cotton acreage was planted to a stacked-gene cultivar while an additional 27% was planted to a single-gene glyphosate-resistant cultivar (Anonymous, 2002).

The University of Arkansas, in cooperation with Arkansas cotton producers, county agents, and industry representatives, has implemented side-by-side comparisons of Bt cotton cultivars to non-Bt cultivars each year beginning in 1996. In 2002, stacked-gene cultivars were compared to single-gene glyphosate-resistant cultivars. This article presents the economic results of those comparisons.

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RESEARCH DESCRIPTION

Seven cotton growers in six Arkansas counties planted fields in each technology group. In all counties, fields were chosen that were very similar in nature. Each field was managed using Best Management Practices for that field and cultivar. The primary differences in management between the two fields being compared in each observation involved insect control due to the presence or absence of the Bt gene.

Partial budgeting was used to quantify the change in profit associated with growing the stacked-gene cultivar rather than the single-gene cultivar. Input prices paid by the cotton producer were used when supplied. Otherwise, input prices listed in the cotton budgets (Bryant and Windham, 2001) or obtained from local suppliers were used. Four of the seven producers provided loan value or HVI information on the cultivars after harvest. Those loan values were used to value the lint harvested. For the remaining three comparisons, a loan rate of $0.52 per pound was used to value the yield.

RESULTS AND DISCUSSION

The partial budgeting results are displayed in Table 1. The "change in gross return" column lists the changes in gross returns associated with growing the stacked-gene cultivar instead of the single-gene cultivar. This change in returns is the result of the yield difference between the two cultivars and, in some cases, loan value differences due to cotton grade. Change in gross return is positive in six of the seven observations. The stacked-gene cultivar out-yielded the single-gene cultivar in all six of these observations by at least 50 lb/acre.

The "change in variable cost" column lists the increase or decrease in variable cost associated with growing the stacked-gene cultivar instead of the single-gene cultivar. These changes are mostly the result of differences in seed costs, technology fees, and insecticide programs. However, small changes in growth regulator and defoliation use are also included when appropriate. In the top four observations, growing the stacked-gene cultivar reduced variable cost.

The "change in profit" column lists the increase or decrease in profit associated with growing the stacked-gene cultivar instead of the single-gene cultivar. These changes in profit are the result of the changes in gross returns and the changes in variable costs. Changes in profit are positive in six of the seven observations.

In four out of seven observations in Arkansas in 2002, the stacked-gene cultivar resulted in larger gross returns and smaller variable cost than did the single-gene cultivar. In two observations, the stacked-gene cultivar had larger variable cost, but it also had larger yields that more than offset the larger costs. In one observation, the stacked-gene cultivar resulted in smaller gross returns and larger variable cost. The stacked-gene cultivars averaged $46.06/acre more profit than the single-gene cultivars.

PRACTICAL APPLICATION

Economic comparisons of Bt cultivars to non-Bt cultivars allows researchers to monitor the change in profit associated with the use of these cotton production systems. Comparisons from 1996 through 2001 have typically shown that cultivars containing the Bt gene have not increased profits in central and north Arkansas. In 2002, however, the stacked-gene cultivars, which contain the Bt gene, out-performed their single-gene non-Bt counterparts even in the nothern Arkansas counties of Poinsett and Mississippi.

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Table 1. Location, cultivar, change in gross returns, change in variable cost, and change in profit when comparing stacked-gene cultivars to single-gene cultivars. Arkansas, 2002.

Location	Cultivars	Change in gross returns	Change in variable cost	Change in profit
		($)		
Poinsett Co.	SG 215 BG/RR			
	SG 521 R	40.62	-37.86	78.48
Desha Co.	ST 4892BR			
	ST 4793R	49.92	-22.99	72.91
Lonoke Co.	SG 215 BG/RR			
	PM 1199 RR	49.40	-11.38	60.78
Lonoke Co.	ST 4892BR			
	ST 4793R	44.22	-15.00	59.22
Mississippi Co.	SG 215 BG/RR			
	SG 521 R	67.01	24.29	42.72
Ashley Co.	ST 4892BR			
	ST 4793R	48.57	7.25	41.32
St. Francis Co.	ST 4892BR			
	ST 4793R	-18.88	14.11	-32.99
Average		40.12	-5.94	46.06

Transgenic and Conventional Cotton Production Systems Evaluation

Kelly Bryant, Chris Tingle, Jeremy Greene, Glenn Studebaker, Chuck Capps, Frank Groves, and Ken Smith[1]

RESEARCH PROBLEM

The goal of the state variety testing program 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 respective 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 2002, the USDA-AMS Cotton Division reported that approximately 94% of the cotton acreage in Arkansas was planted to transgenic cultivars (Anonymous, 2002). More

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specifically, 3% were planted to *Bt*, 7% were planted to BXN, 27% were planted to Roundup Ready, and 55% were planted to *Bt* + Roundup Ready cultivars.

Although these cultivars are widely adopted among growers, they have undergone only limited university research when 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. Previous work with these cultivars consisted mainly of weed control and crop tolerance evaluations. There is current need for systems-level research evaluating how these cultivars will perform under a wide variety of pest complexes and cultural methods.

RESEARCH DESCRIPTION

Field studies were initiated in 2002 at the Northeast Research and Extension Center (NEREC) and the Southeast Branch Experiment Station (SEBES). Cotton was planted on 31 May at NEREC and 21 May at SEBES. Plot size was 4 rows (97 cm) by 15 m long. The experimental design was a randomized complete block with 4 replications.

Cultivars, consisting of conventional, Roundup Ready, BXN, *Bt*, and Roundup Ready/*Bt*, were chosen based on performance in the 2001 University of Arkansas Official Variety Tests (Benson et al., 2001) and percentage of acreage planted in Arkansas (Anonymous, 2001). These included: Stoneville ST 474, Stoneville ST 4793 R, 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, Deltapine 20 B, and Paymaster PM 1218 BR.

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 for insects weekly. As with the herbicide systems, insecticide applications were based on the genetic capabilities of each cotton cultivar. At both locations, the two center rows of each plot were machine harvested.

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 a loan rate of $0.524/lb were used to determine net returns.

RESULTS AND DISCUSSION

Paymaster 1199 R was the highest yielding variety at both locations in 2002 (Tables 1 and 2). At NEREC, three other varieties produced yields not significantly

different from Paymaster 1199 R. At SEBES, seven other varieties produced yields not significantly different from Paymaster 1199 R. Stoneville BXN 47 yielded at or near the bottom at both locations. Three of the top four yielding varieties at NEREC contained the Roundup Ready gene. Two of the three lowest yielding varieties at SEBES contained the Roundup Ready gene.

Economic information for the eleven varieties at NEREC are displayed in Table 1. At this location, the herbicide costs for the RR program are $26.40/acre less than for the conventional program. Thus, after paying the $9 technology fee, the RR program still seems to save $17.40/acre. The number of trips across the field is the same for all treatments. Therefore, there is no difference in application cost across the herbicide treatments. The conventional program applied Staple and Assure II broadcast. Had these chemicals been applied on an 18-in. band over the crop and the middles cultivated, the herbicide costs for the conventional system would have been $16.72 less, making the cost of the two programs much closer. The plots at NEREC were farmed as no-till, making the RR varieties better suited.

The Bollgard varieties saved $14.45/acre in insecticides and $4.00/acre in application costs when compared to the conventional varieties. This is not sufficient to offset their increased cost in seed and technology, making them approximately $10.00 to $12.00/acre more expensive than the non-*Bt* varieties.

The least expensive treatments were the RR varieties, followed by the stacked-gene varieties and the BXN 47 variety, then by the conventional varieties and finally the Bollgard varieties.

Returns over treatment costs followed yields except on two occasions. The four Roundup Ready varieties had the greatest returns over treatment costs. This is due to their high yields and low costs. The two Paymaster and one Suregrow varieties had the highest yields. The ST 4793R variety yielded less than three other varieties, yet its lower cost made it more economical.

Economic information for the eleven varieties at the SEBES are displayed in Table 2. These plots experienced very little weed pressure. All treatments received a blanket preemergence application and a blanket lay-by application. No post-emergence applications were made on any of the treatments. This makes the conventional varieties the most economical by six to nine dollars per acre.

The only insecticide applications were two applications to all varieties for plant bugs. This makes the non-*Bt* varieties the most economical by approximately $30/acre. The only cost difference among these treatments then is the cost of the seed and technology.

As one would expect in this situation, the least expensive treatments were the conventional varieties, followed by the BXN and RR varieties, then by the Bollgard varieties and finally the stacked gene varieties.

Returns over treatment costs followed yields except on two occasions. In those two situations a conventional variety was out-yielded by a Bollgard variety yet saved enough money on the technology fee to usurp the Bollgard variety in returns.

PRACTICAL APPLICATION

Transgenic cultivars have certainly gained popularity in Arkansas. Choosing the most productive and economical cotton production system is important. Testing certain transgenic and non-transgenic varieties within their respective systems gives researchers and producers more information, increasing their ability to make good decisions.

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Table 1. Yields, revenues, treatment costs, and returns, Northeast Arkansas (NEREC[z]), 2002.

Variety	Yield[y]	Revenue[x]	Herbicide costs	Insecticide costs	Tech fee and seed costs	Application costs	Combined costs	Returns
	(lb/acre)	($)						
PM 1199R	992 a	519.81	42.18	31.34	20.35	21.85	115.72	404.09
PM 1218BR	908 ab	475.79	42.18	16.89	46.40	17.85	123.32	352.47
SG 215BR	906 ab	474.74	42.18	16.89	47.12	17.85	124.04	350.70
DPL 20B	890 abc	466.36	68.58	16.89	39.36	17.85	142.68	323.68
Phytogen 355	873 bc	457.45	68.58	31.34	11.00	21.85	132.77	324.68
ST 4691B	872 bc	456.93	68.58	16.89	40.26	17.85	143.58	313.35
ST 4793R	849 bc	444.88	42.18	31.34	21.25	21.85	116.62	328.26
ST 4892BR	838 bc	439.11	42.18	16.89	51.04	17.85	127.96	311.15
FIBERMAX 66	811 bcd	424.96	68.58	31.34	11.55	21.85	133.32	291.64
ST BXN47	788 cd	412.91	56.38	31.34	17.60	21.85	127.17	285.74
ST 474	716 d	375.18	68.58	31.34	12.10	21.85	133.87	241.31

[z] NEREC = Northeast Research and Extension Center, Keiser, AR.

[y] Lint yield determinations based on 39%. Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[x] Revenue calculated using a loan value of $0.524/lb.

Table 2. Yields, revenues, treatment costs, and returns, Southeast Arkansas (SEBES[z]) 2002.

Variety	Yield[y]	Revenue[x]	Herbicide costs	Insecticide costs	Tech fee and seed costs	Application costs	Combined costs	Returns
	(lb/acre)	($)						
PM 1199R	2014 a	1,055.34	32.77	28.13	18.91	15.09	94.90	960.44
ST 4691B	1967 a	1,030.71	32.77	28.13	38.60	15.09	114.59	916.12
ST 474	1948 a	1,020.75	32.77	28.13	11.00	15.09	86.99	933.76
PhytoGen 355	1922 ab	1,007.13	32.77	28.13	10.00	15.09	85.99	921.14
ST 4892BR	1896 ab	993.50	32.77	28.13	48.98	15.09	124.97	868.53
DPL 20B	1867 abc	978.31	32.77	28.13	37.79	15.09	113.78	864.53
PM 1218 BR	1836 abc	962.06	32.77	28.13	44.45	15.09	120.44	841.62
FIBERMAX 66	1787 abc	936.39	32.77	28.13	10.50	15.09	86.49	849.90
ST 4793R	1649 bc	864.08	32.77	28.13	19.72	15.09	95.71	768.37
SG 215BR	1644 bc	861.46	32.77	28.13	45.17	15.09	121.16	740.30
ST BXN47	1588 c	832.11	32.77	28.13	16.00	15.09	91.99	740.12

[z] SEBES = Southeast Branch Experiment Station, Rohwer, AR.

[y] Lint yield determinations based on 39%. Means followed by the same letter within a column are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[x] Revenue based on $0.524/lb.

Hybridization of Exotic Cotton Germplasm Carrying Resistance to Reniform Nematode

Nilesh D. Dighe, James McD. Stewart, and Robert T. Robbins[1]

RESEARCH PROBLEM

Reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira) in upland cotton (*Gossypium hirsutum* L.) 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 might approach 50%. No commercial cultivar of upland cotton has been reported to have resistance to reniform nematode (Wang, 2001). Currently the only means for controlling the reniform nematode population in the field is through nematicide application and crop rotation. The genetic transfer of the resistance trait from diploid cotton germplasm into upland cotton will be the best solution to the reniform nematode problem in cotton The objectives of this project are to: (1) make hybrid combinations that will facilitate the transfer of reniform nematode resistance from diploid cotton germplasm into upland cotton, 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; Stewart and Robbins, 1994). Stewart and Robbins (1994, pers. comm.) identified a number of sources of resistance to the reniform nematode in the secondary germplasm pool, especially within *G. arboreum* (A_2), *G. herbaceum* (A_1), and *G. longicalyx* (F_1), the last of which has a very high resistance. Transfer of genes between diploid A and tetraploid AD genome cottons has been achieved only on a limited scale because of the difficulty in obtaining hybrids between

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the two (Stewart and Hsu, 1978). Raghavan (1977) in a review of the applied aspects of embryo culture pointed out that embryo culture is used to overcome barriers that occur in situ. 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 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 were pursued simultaneously using nematode-resistant diploid cotton. In our first approach resistant accessions of diploid A_1 and A_2 and the most resistant plants from an F_2 population of reniform nematode-resistant A_2 x susceptible A_2 F_1 hybrid were crossed with D-genome wild species. A successful hybridization would result in a diploid AD hybrid that, upon having its chromosome number doubled, would be directly compatible with upland cotton. Our second approach involved 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. In another approach, the resistant diploid was crossed directly with tetraploid upland cotton. The resulting hybrid is expected to be a sterile triploid and require extensive additional manipulation before introgression into cotton can proceed. In our fourth approach, an attempt was made to cross a *G. longicalyx* x *G. armourianum* tetraploid hybrid with upland cotton. Because most of these crosses will not develop on the mother plant, pollinated ovules were placed on culture medium for *in ovulo* embryo culture rescue of any hybrid embryos (Stewart and Hsu, 1978).

Since bulk segregant analysis was used in identifying molecular marker (RAPDs) associated with reniform resistance, the ten most resistant and the ten most susceptible plants of a 96 F_2 population from a cross between a reniform nematode-resistant A_2 line and a highly susceptible line were selected. DNA samples from each of these resistant and susceptible plants were pooled into resistant and susceptible bulks. Six hundred random primers were used to perform polymerase chain reactions (PCR) on the two DNA samples. The PCR products from each primer/sample were separated by electrophoresis and examined to detect DNA polymorphism associated with resistance.

A reniform nematode-screening test was also conducted on twenty-one BC2-F1 progeny of a *G. longicalyx* x *G. arboreum* hybrid in order to identify the most resistant plants from the segregating population. A sucrose centrifuge-floatation method (Jenkins, 1964) was used for reniform extraction in the reniform screening tests.

RESULTS AND DISCUSSION

Seventeen reniform-resistant diploid AD-hybrids were obtained from approximately one thousand crosses involving a number of parental combinations. Of these seventeen AD hybrids, fourteen were obtained from just twenty-two crosses between reniform resistant accession A_2-194 and *G. trilobum* (D_8), where D_8 was used as the pollen source. These two parents provide a good choice for making synthetic allotetraploids in future work. One diploid AD hybrid was obtained from a cross between one of the most resistant plants of the susceptible x resistant F_2 population and *G. aridum* (D_4), while the other two AD hybrids were obtained from a cross between A_1 and D_4. The hybrids of A_2 and A_1 with D_4 were the first report of this interspecific hybrid combination. No embryos were obtained through the ovule culture technique.

The DNA bulks from the resistant and susceptible plants were screened with 600 random, 10-nucleotide base primers. Among these, 3 potential polymorphisms were detected between the two bulks DNA samples. Of these 3 potential primers, UBC_{97} has shown polymorphism amongst the individual plant DNA samples of the bulks in the form of an extra band in the susceptible samples. If the results are confirmed and repeatable, the association of these markers with resistance will be confirmed by testing their presence or absence in individual plants from the F2 segregating population.

After comparing the results of reniform nematode screening on twenty-one BC_2-F_1 progeny of *a G. longicalyx* (F_1) x *G. arboreum* (A_2-21) hybrid with its BC_1-F_2 progeny tests (unpublished data), we identified 2 plants that showed high resistance in all three tests.

PRACTICAL APPLICATION

The need for genetic resistance to the reniform nematode is widely recognized. After doubling the chromosome number of the seventeen reniform nematode-resistant diploid AD hybrids, they will be crossed and backcrossed with upland cotton to introgress reniform nematode resistance genes into upland cotton. 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.

ACKNOWLEDGMENTS

The financial support of the Delta and Pine Land Company is gratefully acknowledged.

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Histopathology of Reniform Nematode on *Gossypium longicalyx* and Interspecific Cotton Hybrids

Paula Agudelo, A. Forest Robinson, James McD. Stewart, and Robert T. Robbins[1]

RESEARCH PROBLEM

The reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira 1940) is an economically important parasite of cotton (*Gossypium hirsutum* L.) (Yik and Birchfield, 1984; Robinson and Percival, 1997). Useful resistance to reniform nematode in *G. hirsutum* appears to be very limited (Yik and Birchfield, 1984; Robinson and Percival, 1997), so there has been increased interest in the introgression of resistance to this nematode from *G. longicalyx* Hutchinson & Lee and other diploid *Gossypium* species into cultivated genotypes. The objective of this work is to describe the histopathology of reniform nematode penetration and development on roots of *G. longicalyx*, *G. hirsutum*, and interspecific *Gossypium* hybrids to gain insight into possible mechanisms of resistance.

BACKGROUND INFORMATION

Gossypium longicalyx is highly resistant to reniform nematode. However, the mechanisms for resistance are not known, and no observations on the cellular changes induced by the nematode in the plant have been published. Parasitism involves the formation of syncytia to provide nutrition for the female, and the events that occur at this feeding site may determine the degree of susceptibility of cotton plants to reniform nematode. In as much as hybrids have been developed between *G. longicalyx* and other *Gossypium* species, segregating populations of these are included in the present study to determine if the histopathological phenomena associated with resistance in the diploid is also observed in hybrid combinations.

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RESEARCH DESCRIPTION

Seedlings of susceptible upland cotton (CAMD-E), *G. longicalyx* (F1-1), and two interspecific hybrids (ADDF and AADF) were established in 500 ml pots containing a 6:1 mixture of fine sand (<400 l particle size) and vermiculite supplemented with 5 g/kg pelletized limestone in a growth chamber programmed to provide 14 h of light per day with a daily temperature maximum of 30°C and minimum of 26°C. When plants were 8 to 10 weeks old, they were carefully removed from pots so as to keep the root ball and associated soil entirely intact and slipped into pot-shaped sleeves made from plastic window screen (1.2 mm mesh) of the exact dimensions as the inside of the pots. Sleeved root balls were transplanted into 6-liter pots filled with sand mix prepared as before but infested with approximately 10,000 reniform nematodes per pot. Roots were collected and prepared for observation 6, 14, and 22 d after inoculation by removing sleeved root balls from the pots and cutting segments of young roots that had grown out through infested soil since transplanting.

Root segments were fixed with Karnovsky's fixative and dehydrated in an ethanol series. Short lengths of roots with observable female nematodes attached were further dehydrated with 100% propylene oxide and embedded in Spurr's epoxy resin. Thick sections (1 m) were stained with toluidine blue (1%) and examined with a phase-contrast light microscope.

RESULTS AND DISCUSSION

In *G. longicalyx* roots, penetration by female nematodes was confirmed. Incipient swelling of the females, indicating initiation of maturation of the reproductive system, was observed (Fig. 1). Maturation up to the formation of a single embryo inside the female body was frequent, but no maturation beyond this was observed. In the hybrids, diverse responses were observed among plants. Reactions ranged from highly compatible (susceptible), with the formation of active syncytia and full development of females, to incompatible (resistant) and no apparent development of the female. Compatible plants showed characteristic hypertrophied cells, enlarged nuclei, dense cytoplasm, and partial dissolution of cell walls (Fig. 2). Incompatible plant reactions included lignification of the cells adjacent to the nematode head, or the complete collapse and necrosis of the cells involved.

These results indicate that the resistance found in *G. longicalyx* has a relatively simple inheritance pattern and that the mechanism(s) of resistance is expressed in hybrid combinations. Lignification of cells in the area of penetration indicates a physical barrier to the nematode is erected. Cell collapse and necrosis in the area where a syncytium would normally form suggest that the plant undergoes a type of hypersensitive reaction that denies the female nematode a feeding site in the plant. Once the female has penetrated the root, she cannot migrate to another location, and because she does not receive nourishment she cannot reproduce. Thus, the nematode population does not increase.

The relationship between plant/nematode compatibility reactions and nematode reproduction needs to be examined in more detail. Data on nematode reproduction should be combined with observations on cellular changes in the root to fully characterize resistant reactions.

PRACTICAL APPLICATIONS

Gossypium longicalyx is not immune to the reniform nematode as previous literature would indicate, but it is highly resistant. Different levels of resistance among plants of a segregating population from hybrids containing *G. longicalyx* indicate that the resistance is heritable and can probably be transferred to upland cotton. Resistant reactions can be characterized to aid in selection for resistant plants within a segregating population during the introgression process. For definitive correlation of anatomical phenomena with resistance, the histological observations should be combined with nematode reproduction data.

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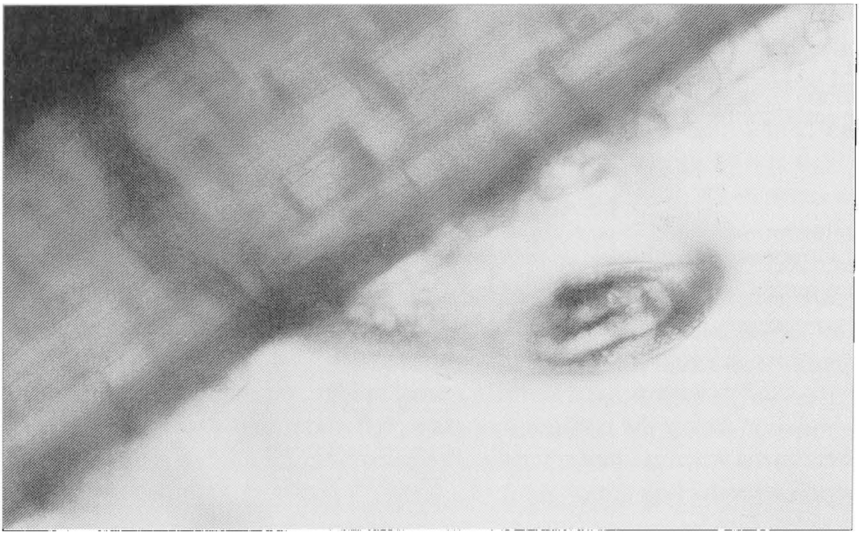

Fig. 1. Reniform nematode female with embryo and abnormal maturation in *Gossypium longicalyx* (F1-1) root, 14 days after inoculation (X 250).

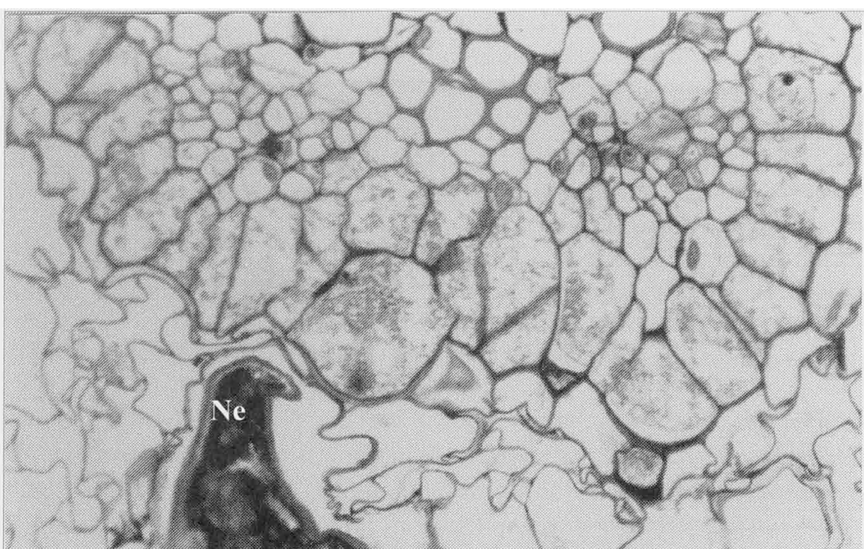

Fig. 2. Cross section of an active syncytium formed by reniform nematode in susceptible *Gossypium hirsutum* (CAMD-E) root, 14 days after inoculation (X 200). (Ne: nematode).

Weed Management Programs with Trifloxysulfuron (Envoke®) in Cotton

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

RESEARCH PROBLEM

Glyphosate-tolerant cotton (Roundup Ready) is a boon to cotton producers in that it allows postemergence control of a wide range of grass and broadleaved weeds. However, because glyphosate is weak on some weed species, other herbicides may need to be added to a glyphosate weed control program to provide maximal season-long control. Additionally, some producers may choose to use conventional cotton cultivars with conventional weed management programs. Trifloxysulfuron (Envoke™) is a relatively new herbicide that can be used in either Roundup Ready or conventional cotton. The objective of this research was to determine the best fit for trifloxysulfuron in either system.

BACKGROUND INFORMATION

Trifloxysulfuron (formerly CGA-362622), or Envoke™, is a sulfonylurea herbicide developed for postemergence (POST) over-the-top or post-directed applications in cotton. Pyrithiobac (Staple™) is thus far the only herbicide labeled for POST over-the-top control of emerged weeds in either conventional or Roundup Ready (glyphosate-tolerant) cotton (Porterfield et al., 2002). Metolachlor may be applied over-the-top but is ineffective for control of emerged weeds. The spectrum of control of pyrithiobac covers several important weeds in cotton (Jordan et al., 1993), but control of sicklepod (*Senna obtusifolia*), tall morningglory (*Ipomoea purpurea*), and several other weeds is poor (Jordan et al., 1993; Porterfield et al., 2002; Wilcut et al., 2000). Trifloxysulfuron controls several economically important weeds in cotton, including pitted morningglory, Palmer amaranth, hemp sesbania, and sicklepod, at very low use rates ranging from 0.1 to 0.25 oz/acre (Branson et al., 2002; Wells, 2000). Cotton injury, manifested as yellowing and stunting, normally dissipates quickly and does not affect yield (Holloway,

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2001). Trifloxysulfuron also has preemergence activity, but injury has been a concern (up to 49% injury) (Branson et al., 2002) and it is not labeled for preemergence use in cotton. Studies are ongoing in Arkansas to define the fit of trifloxysulfuron in Arkansas cotton production.

RESEARCH DESCRIPTION

Experiments were conducted at Marianna and Fayetteville, AR, on silt loam soil to evaluate trifloxysulfuron in conventional and Roundup Ready (glyphosate-tolerant) cotton herbicide systems and to compare efficacy of trifloxysulfuron and pyrithiobac (Staple). Each experiment was conducted in a randomized complete block design with four replications. Plots were 13 by 40 ft at Marianna and 3.3 by 27 ft at Fayetteville, except for the trifloxysulfuron/pyrithiobac comparison at Fayetteville, which was a multispecies experiment with 12 species planted across 6.5-ft-wide plots. Cotton (Paymaster 1218BR) was planted 21 May at Marianna and 2 June at Fayetteville. The multispecies experiment at Fayetteville was planted 10 June. Treatments in conventional cotton were prometryn + pendimethalin (1 + 0.75 lb ai/acre) PRE or metolachlor, 0.95 lb ai/acre + fluazifop-P, 0.125 lb ai/acre over-the-top (OT) applied to one- to two-leaf cotton (EOT) followed by (fb) trifloxysulfuron, 0.0071 lb ai/acre OT to five- to six-leaf cotton, alone or fb prometryn + trifloxysulfuron (A12474), 0.8 lb ai/acre at layby. In Roundup Ready cotton, glyphosate (Touchdown™), 0.75 lb ae/acre or glyphosate + metolachlor, 0.95 lb/acre was applied OT to one- to two-leaf cotton fb trifloxysulfuron, 0.0071 lb/acre OT or 0.0094 lb/acre post-directed (DIR) to seven- to eight-leaf cotton. In trifloxysulfuron/pyrithiobac comparison experiments, trifloxysulfuron was applied OT at 0.0071 lb/acre to two-leaf cotton and 0.0094 lb/acre to four-leaf cotton, pyrithiobac at 0.063 OT to two- and four-leaf cotton, and trifloxysulfuron, 0.0047 lb/acre or pyrithiobac, 0.063 lb/acre + glyphosate, 0.75 lb ai/acre to two- and four-leaf cotton. Trifloxysulfuron was applied with nonionic surfactant at 0.25% vol/vol. Herbicides were applied with a tractor-mounted or backpack sprayer at 15 to 20 gal/acre carrier volume. Data were analyzed by analysis of variance, and means were separated by LSD at the 0.05 level of significance.

RESULTS

Conventional programs that used metolachlor + fluazifop-P early over-the-top (EOT) as a prior treatment for trifloxysulfuron were generally ineffective because the metolachlor program failed to control *Amaranthus* species early in the season (Table 1). At Fayetteville, all broadleaved species in plots with EOT treatments were uncontrolled, and trifloxysulfuron was not effective on large weeds. Metolachlor should be applied before weeds emerge or after cultivation to be effective. Trifloxysulfuron following a PRE treatment and fb A12474 at layby controlled pitted morningglory (*Ipomoea lacunosa*), velvetleaf (*Abutilon theophrasti*), and prickly sida (*Sida spinosa*) 88 to 99%.

In the Roundup Ready experiment, two applications of glyphosate (Touchdown™) controlled Palmer amaranth (*Amaranthus palmeri*) better than glyphosate fb trifloxysulfuron at Marianna (91% vs 60% with OT application and 70% with DIR application) (data not shown). For control of annual grasses, a follow-up glyphosate application or metolachlor with the one- to two-leaf glyphosate application was needed. A12474 was also effective for late-season Palmer amaranth and grass control (>90%). Control of pitted morningglory (83 to 100%), velvetleaf (95 to 100%), sicklepod (88 to 95%), and prickly sida (75 to 100%) did not differ among treatments.

Trifloxysulfuron and pyrithiobac controlled *Amaranthus* species, pitted morningglory, and velvetleaf equally in the trifloxysulfuron/pyrithiobac comparison experiment at Marianna (Fig. 1). At Fayetteville, control of Palmer amaranth and velvetleaf was better with pyrithiobac treatments than with trifloxysulfuron. Pitted morningglory was controlled better with trifloxysulfuron (83% averaged over treatments) than pyrithiobac (58% average), a difference more pronounced at the four-leaf than two-leaf cotton stage. Control of barnyardgrass (*Echinochloa crus-galli*), seedling johnsongrass (*Sorghum halepense*), and sicklepod was better with trifloxysulfuron than with pyrithiobac, but prickly sida control was better with pyrithiobac treatments (Fig. 2).

Cotton injury is a concern with trifloxysulfuron applied over-the-top. In the conventional tests, injury was 5 to 20% 1 week after trifloxysulfuron application to five- to six-leaf cotton but was <3% by 2 weeks after treatment (WAT). Injury in the trifloxysulfuron/pyrithiobac comparison tests was 18 to 30% 1 wk after four-leaf treatments. After 3 weeks, injury was 13 to 18% at Marianna and 0 to 15% at Fayetteville, with the higher injury from trifloxysulfuron + glyphosate. Injury from trifloxysulfuron DIR was <11% 1 WAT, while injury from OT applications was as high as 39% in tank mixture with glyphosate. Pyrithiobac injury was not as severe as trifloxysulfuron injury in most experiments, and cotton recovered from visual symptoms from both herbicides.

PRACTICAL APPLICATION

Trifloxysulfuron can be used postemergence in either conventional or Roundup Ready cotton. Preemergence herbicides will usually be needed for effective control with trifloxysulfuron in conventional cotton. If metolachlor postemergence is used as a prior treatment for trifloxysulfuron, weeds should be cultivated before metolachlor application because it is not effective on emerged weeds. Glyphosate plus metolachlor applied early over-the-top followed by trifloxysulfuron is a good program for broad-spectrum control in Roundup Ready cotton. Barnyardgrass, seedling johnsongrass, and sicklepod are controlled better with trifloxysulfuron than with pyrithiobac, but prickly sida control is very poor with trifloxysulfuron. Visual cotton injury from trifloxysulfuron can occur, and trifloxysulfuron should probably not be applied in tank mixture with glyphosate for over-the-top applications.

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Table 1. Control of Palmer amaranth (AMAPA), pitted morningglory (IPOLA), velvetleaf (ABUTH), and prickly sida (SIDSP) with trifloxysulfuron (Envoke) programs 2 wk after layby treatments in conventional cotton at Marianna (M) and Fayetteville (F), AR, 2002.

	AMAPA		IPOLA		ABUTH		SIDSP	
Treatment[z,y]	M	F	M	F	M	F	M	F
	(%)							
PRE only	54	88	73	34	91	76	81	88
fb Envoke	68	96	94	77	95	93	79	91
fb Envoke fb layby	65	96	95	92	95	88	90	95
fb Envoke + Staple	65	100	95	92	95	98	78	99
EOT only	55	0	80	0	85	0	80	0
fb Envoke	61	53	94	42	95	53	78	23
fb Envoke fb layby	65	55	95	60	95	58	82	30
LSD (0.05)	NS	7	11	24	NS	16	NS	11

[z] PRE = prometryn+pendimethalin; EOT = metolachlor+fluazifop-P at 1-lf cotton; fb = followed by; layby = prometryn+Envoke (A12474); Staple = pyrithiobac at 0.031 lbai/acre.

[y] Envoke applied at 0.0071 lb ai/acre at 5- to 6-leaf cotton.

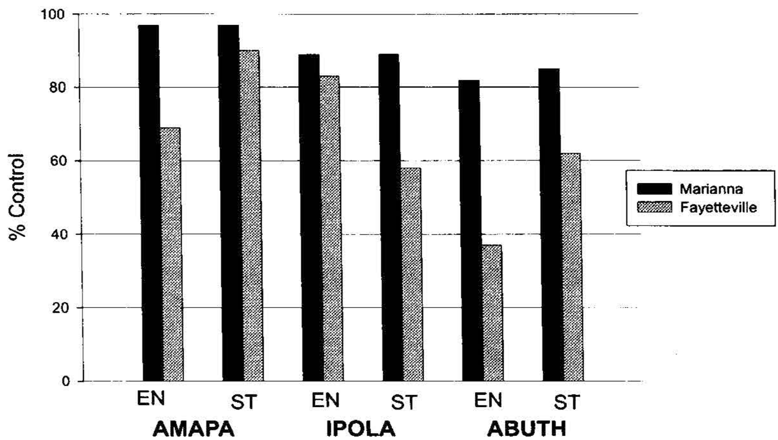

Fig. 1. Control of Palmer amaranth (AMAPA), pitted morningglory (IPOLA), and velvetleaf (ABUTH) with Envoke and Staple, averaged over the herbicides alone and with glyphosate, 3 to 4 wk after 4-lf treatments at Marianna and Fayetteville. (Rates and timing listed in Research Description).

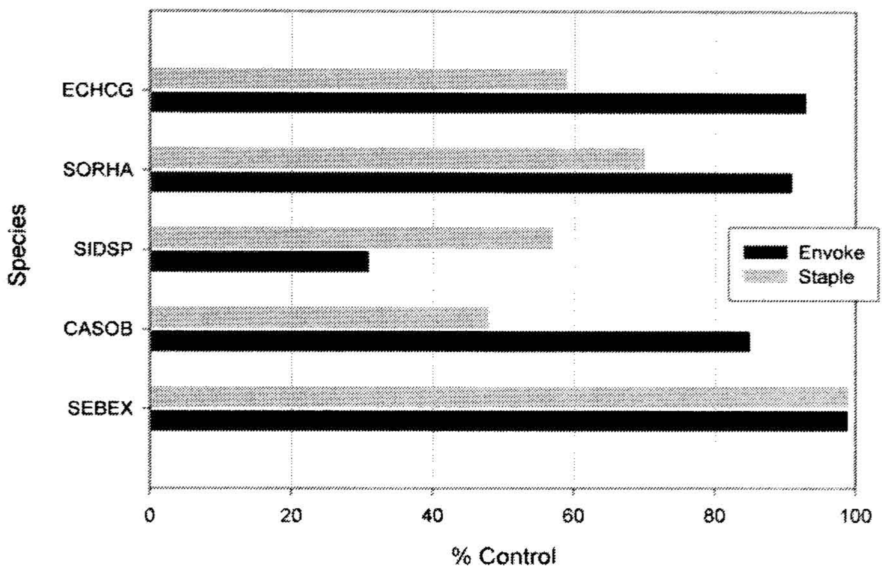

Fig. 2. Control of hemp sesbania (SEBEX), sicklepod (CASOB), prickly sida (SIDSP), seedling johnsongrass (SORHA), and barnyardgrass (ECHCG) with Envoke and Staple, averaged over the herbicides alone and with glyphosate, 3 to 4 wk after 4-lf treatments at Marianna and Fayetteville. (Rates and timing listed in Research Description).

Glyphosate- and Trifloxysulfuron-Based Weed Control Programs in Roundup Ready® Cotton

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

RESEARCH PROBLEM

The advent of herbicide-resistant cotton (*Gossypium hirsutum*) cultivars has allowed foliar postemergence control of many problematic weed species in cotton. Situations still remain in which a residual herbicide program may be beneficial in Roundup Ready cotton. When the first glyphosate application has to be made early in the season, residual herbicides may provide better control of larger weeds. Situations that do not promote rapid canopy development such as wider row spacings, dryland production, early-season insects, and unfavorable growing conditions may justify the use of residual postemergence (POST) herbicides. The objective of this experiment was to evaluate POST applications of metolachlor plus glyphosate followed by trifloxysulfuron for weed control in Roundup Ready® cotton.

BACKGROUND INFORMATION

Roundup Ready cotton has been commercially available for many years. Glyphosate provides broad-spectrum control of many weed species; however, the lack of residual weed control fuels the on going question about the use of preemergence (PRE) herbicides. In using a PRE herbicide, growers have to deal with the potential of crop injury under cool wet conditions, and also crop failure options are limited once a PRE herbicide is applied. It was found that residual herbicides offered flexibility in timing later herbicide applications (McClelland and Barrentine, 1999). Residuals also tend to reduce germinating weed populations; however, additional postemergence herbicides were needed for season-long control (Welch, 1997). Some of the postemergence non-salvage options for broadleaf weed control in cotton are glyphosate, metolachlor, and trifloxysulfuron. It has been well documented that glyphosate provides adequate control of most weed species initially. Metolachlor provides residual

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control of grass, sedge, and small-seeded broadleaf weeds. Trifloxysulfuron provides control of morningglories that are too large to control with glyphosate (Wells et al., 2001). There may be an advantage with respect to weed control in adding metolachlor to postemergence applications of glyphosate followed by postemergence applications of trifloxysulfuron in Roundup Ready cotton.

RESEARCH DESCRIPTION

An experiment was conducted in 2002 at the Cotton Branch Experiment Station, Marianna, AR, on a silt loam soil. The study design was a randomized complete block with four replications. Experimental units were 12.7- by 40-ft plots that were overseeded with seed of Palmer amaranth (*Amaranthus palmeri*), pitted morningglory (*Ipomoea lacunosa*), prickly sida (*Sida spinosa*), and large crabgrass (*Digitaria sanguinalis*). Following incorporation of weed seed, cotton cultivar Paymaster 1218BR was planted at a rate of 60,000 seed/acre at a depth of 1.5 inches accompanied by an in-furrow application of the insecticide Temik® at 4 lb/acre.

Herbicide treatments consisted of a broadcast over-the-top application of glyphosate at 0.75 lb acid equivalent (ae)/acre to one- to two-leaf cotton followed by (fb) glyphosate at 0.75 lb ae/acre to four- or eight-leaf cotton or trifloxysulfuron at 0.0071 or 0.0094 lb active ingredient (ai)/acre. Glyphosate was also applied at 0.75 lb ae/acre plus metolachlor at 0.95 lb ai/acre fb trifloxysulfuron at 0.0071 or 0.0094 lb ai/acre to five- to six-leaf cotton or seven- to eight-leaf cotton. Treatments were applied using a tractor-mounted sprayer calibrated to deliver 20 gal/acre.

Data collected consisted of crop injury and weed control ratings by species on a percentage scale of 0 to 100 with 0 being no weed control or crop injury and 100 being complete weed control or total crop destruction. Data were subjected to analysis of variance, and treatment means were separated using Fisher's Protected Least Significant Difference (LSD) at the 0.05 level of significance.

RESULTS AND DISCUSSION

General observations in this study were that early timings of glyphosate to one- to two-leaf fb 4-leaf cotton did not control later germinating weeds; later glyphosate applications were more effective with respect to control of Palmer amaranth (Table 1). Although inadequate, a single application of glyphosate + metolachlor was better than or equal to early application timings of glyphosate (Table 2). The addition of metolachlor to POST applications of glyphosate provided enough suppression of Palmer amaranth and pitted morningglory to allow for later applications of trifloxysulfuron without sacrificing weed control. With respect to morningglory control, the addition of metolachlor to early POST applications of glyphosate improved control of pitted morningglory when trifloxysulfuron applications were delayed to the eight-leaf stage of cotton. This

improvement in control was evident early in the season (Table 1) and even more late in the season (Table 2). Trifloxysulfuron when applied alone was weak on prickly sida. The addition of metolachlor to POST applications of glyphosate improved prickly sida control from subsequent applications of trifloxysulfuron. The addition of metolachlor increased both early- and late-season control of large crabgrass (Tables 1 and 2) and goosegrass (data not presented). There appears to be a trend for higher cotton yields with the addition of metolachlor to POST applications of glyphosate. Later applications of glyphosate were more beneficial than early applications for controlling later germinating weeds and attaining season-long weed control.

PRACTICAL APPLICATION

It appears that the addition of metolachlor to POST applications of glyphosate did allow for some flexibility in timing later application of trifloxysulfuron. The addition of metolachlor to glyphosate without a follow-up treatment was comparable to many treatments that received two herbicide applications. The use of this herbicide treatment could allow the grower to avoid some of the early-season injury due to cold, wet conditions and also shift the usefulness of the metolachlor to the more rapid growth stages of cotton, possibly allowing for increased metabolism and decreased injury from metolachlor. Application timings of glyphosate + metolachlor should be further evaluated with trifloxysulfuron and in combination with Roundup Ready Flex® cotton to evaluate the need for layby herbicide treatments.

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Table 1. Weed control after a broadcast over-the-top application of glyphosate (glypho) or glypho plus metolachlor (meto) at one- to two-leaf cotton followed by (fb)glyphosate or trifloxysulfuron, Marianna, AR, 2002.

Treatment	Rate[z]	Timing	Method[y]	Weed control 6 weeks after planting			
				Palmer amaranth	Prickly sida	Pitted morningglory	Large crabgrass
	(lb/acre)			(%)			
Glypho[x] POST fb							
Glyphosate	0.75	4-lf cotton	POST	80	20	90	56
Glyphosate	0.75	8-lf cotton	PDIR	95	62	86	86
Trifloxysulfuron	0.0071	5-6 lf cotton	POST	93	27	90	55
Trifloxsulfuron	0.0071	7-8 lf cotton	POST	73	50	66	58
Trifloxysulfuron	0.0094	7-8 lf cotton	PDIR	80	47	80	48
Glypho plus meto[z] POST fb							
None			POST	92	10	78	75
Triufloxysulfuron	0.0071	5-6 lf cotton	POST	98	92	95	100
Trifloxysulfuron	0.0071	7-8 lf cotton	POST	95	53	79	95
Trifloxysulfuron	0.0094	7-8 lf cotton	PDIR	94	54	84	100
LSD (0.05)				10	25	12	27

[z] Rates for glyphosate expressed in lb acid equivalent (ae) acre^{-1} and all other rates are expressed in lb active ingredient (ai)/acre.

[y] POST = postemergence over-the-top; PDIR = post-directed.

[x] Glyphosate applied at 0.75 lb ae/acre; metolachlor applied 0.95 lb ai/acre; fb = followed by.

Table 2. Weed control and seed-cotton yields after a broadcast over-the-top application of glyphosate (glypho) or glypho plus metolachlor (meto) at one- to two-leaf cotton followed by (fb) glyphosate or trifloxysulfuron, Marianna, AR, 2002.

Treatment	Rate[z]	Timing	Method[y]	Weed control 18 weeks after planting				Seed-cotton yield
				Palmer amaranth	Prickly sida	Pitted morningglory	Large crabgrass	
	(lb/acre)			(%)				(lb/acre)
Glypho[x] POST fb								
Glyphosate	0.75	4-lf cotton	POST	13	0	15	0	1341
Glyphosate	0.75	8-lf cotton	PDIR	98	87	96	85	3198
Trifloxysulfuron	0.0071	5-6 lf cotton	POST	56	13	59	38	2217
Trifloxsulfuron	0.0071	7-8 lf cotton	POST	28	20	30	5	2055
Trifloxysulfuron	0.0094	7-8 lf cotton	PDIR	59	58	78	36	1988
Glypho plus meto[x] POST fb								
None			POST	40	31	18	50	2161
Triufloxysulfuron	0.0071	5-6 lf cotton	POST	94	75	94	98	2977
Trifloxysulfuron	0.0071	7-8 lf cotton	POST	88	61	93	98	2589
Trifloxysulfuron	0.0094	7-8 lf cotton	PDIR	90	75	98	95	2687
LSD (0.05)				25	30	25	29	783

[z] Rates for glyphosate expressed in lb acid equivalent (ae)/acre and all other rates are expressed in lb active ingredient (ai)/acre.

[y] POST = postemergence over-the-top; PDIR = post-directed.

[x] Glyphosate applied at 0.75 lb acid equivalent (ae)/acre, metolachlor applied 0.95 lb active ingredient (ai)/acre; fb = followed by.

The Effect of Seeding Rate and Glyphosate Application Timing and Rate on Fruiting Patterns and Yield of Roundup Ready® Cotton

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RESEARCH PROBLEM

The advent of herbicide-resistant cotton (*Gossypium hirsutum*) cultivars has allowed foliar postemergence (POST) control of many problematic weed species in cotton; however, foliar applications of glyphosate must be made before the fifth true leaf. Glyphosate applications are also limited to 1.0 lb ai/acre or 0.75 lb ae/acre in a single application. There must also be 10 days and two nodes of growth between sequential applications. The in-crop total should not exceed 4 lb of glyphosate/acre. If growers were able to apply glyphosate over-the-top later in the season this might allow for "easy" weed control. The objective of this experiment was to see if increasing seeding rate would increase the number of nodes to the first fruiting branch thus allowing for later applications of glyphosate.

BACKGROUND INFORMATION

Recommended applications of glyphosate did not change plant height, nodes to first fruiting branch, or the location of cotton bolls (Murdock and Sherrick, 2000; Dotray and Keeling, 1997; Matthews et al., 1998). Off-labeled applications of glyphosate shortened the anther column, resulting in increased distance from anthers to stigma (Pline et al., 2002), and in poorly pollinated breeding positions. Roundup Ready cotton compensates for fruit loss from late applications of glyphosate by setting fruit higher and/or at outer positions (Sanders et al., 2002; McCloskey and Moser, 2002; Kalaher and Coble, 1998; Reynolds et al., 1999). The question to answer is: can we somehow raise the node to the first fruiting branch? It was found by several researchers that the number of nodes to the first fruiting branch increases with an increase in seeding rate (Choudhary and Bordovsky, 2002). In contrast, plant height, number of nodes, and number of

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fruiting branches decreased as plant population increases (Guthrie, 1991); however, the number of bolls per acre increases (McKnight, 2002) with increases in seeding rate. It was reported earlier that close spacing was conducive to early maturity because of a higher percentage of first-position bolls. This is important in that first-position bolls contribute 50 to 80% of harvested yield, and this yield comes from nodes 8 through 12 (Burch and Krieg, 2002). We hypothesized that glyphosate-resistant cotton grown under higher plant populations may have a higher number of nodes to first fruiting branch, thus allowing for later applications of glyphosate.

RESEARCH DESCRIPTION

An experiment was conducted in 2002 at the Cotton Branch Experiment Station, Marianna, AR, on a silt loam soil. The study design was a randomized complete block with four replications with a factorial arrangement of treatments. The three factors were: 1) seeding rate with levels of 5, 10, and 15 lb/acre; 2) glyphosate application rate with levels of 0, 1 and 2 lb ai/acre; and 3) glyphosate application timing of four-, six-, and eight-leaf cotton. All plots received a preplant incorporated application of trifluralin at 0.5 lb ai/acre, and all plots were hand-weeded. All plots received a layby application of diuron at 0.8 lb ai/acre. The cotton cultivar used was DP 451BR with an in-furrow application of Temik® at 4 lb/acre. Treatments were applied using a tractor-mounted sprayer calibrated to deliver 20 gal/acre.

Data collected consisted of number of monopodial branches, monopodial bolls, nodes to first fruiting branch, percent boll retention, highest sympodial node with first and second fruiting positions, and seed cotton yield. Data were subjected to analysis of variance, and treatment means were separated using Fisher's Protected Least Significant Difference (LSD) at the 0.05 level of significance.

RESULTS AND DISCUSSION

Seeding rate alone did not increase the number of nodes to first fruiting branch (Table 1). This finding was in direct contrast to what was expected. We found that increases in seeding rate decreased the number of monopodial branches and thus the number of monopodial bolls (Tables 2 and 3). This trend was seen over glyphosate rates and application timings. Off-labeled applications of glyphosate decreased retention of bolls on first five sympodia (Table 4). The increase in seeding rate alone did not affect the percent retention of first-position fruit; however, when glyphosate applications where delayed past the four-leaf stage there was a trend for decreased fruit retention with increases in cotton leaf stage at application, glyphosate rate, and seeding rate. When glyphosate was applied at the labeled application timings (four-leaf stage) but off-labeled rates (2 lb/acre) were used, there was a substantial decrease in fruit retention at the high seeding rate (15 lb/acre); however, when lower seeding rates

(5 and 10 lb/acre) were used there was no decrease in boll retention when glyphosate was applied at the four-leaf stage regardless of glyphosate rate (Table 4). We saw the same type of trend with respect to percent retention of first-position bolls on higher sympodial branches; however, the decreases were more subtle (Table 5). There was also a trend for greater retention of outer bolls under lower plant densities when off-labeled applications of glyphosate are made (Table 6). The potential for compensation by setting fruit higher on the cotton plant was less in high plant densities (15 lb/acre) than in low plant densities (5 lb/acre) (Table 7). Seed cotton yield was not affected by application timing under low seeding rates and labeled rates of glyphosate. However, yield was decreased when glyphosate applications were made after the four-leaf stage at the higher seeding rates. There was no reduction in cotton yield when higher seeding rates were used and no glyphosate was applied. In fact seeding rates of 10 and 15 lb/acre had significantly higher yields than seeding rates of 5 lb/acre (Table 8).

In this study, increases in seeding rate did not significantly increase the nodes to first fruiting branch. In direct contrast with our hypothesis, it appears that cotton at lower seeding rates was able to compensate or tolerate off-labeled applications of glyphosate better than higher cotton seeding rates. This phenomenon may have been due to fruit being set at higher positions, or more retained outer bolls. It is also possible that lower concentrations of glyphosate are translocated to potential fruiting positions allowing for greater dispersion of glyphosate through sink competition for glyphosate because of more fruiting positions per plant. The main point gained from this research is to follow the Roundup Ready cotton label. There was no advantage to increasing seeding rate to overcome the incomplete tolerance of Roundup Ready cotton to foliar applications of glyphosate. There may be some usefulness in reducing seeding rate; however, issues such as inconsistent stands from reduced seeding rates and late-season weed control may be limiting factors.

PRACTICAL APPLICATION

If off-labeled applications of glyphosate are ever labeled as a salvage treatment, there may be greater yield loss under higher seeding rates (15 lb/acre) and higher glyphosate rates (2 lb /acre) as compared to lower seeding rates (5 lb/acre) and labeled rates. Again, the main message from this experiment is to follow the Roundup Ready cotton label.

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Table 1. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the nodes to first fruiting branch, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)							
5	6.3 cf[y]	6.2 df	6.0 ef	5.9 f	6.4 bf	6.6 ad	6.2 df
10	6.4 cf	6.5 bf	6.6 ad	7.1 a	6.2 df	6.4 cf	6.6 ad
15	6.5 bf	7.0 ab	6.4 cf	6.5 bf	6.3 cf	6.3 cf	6.8 ac

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).

[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 2. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the number of monopodial branches, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)							
5	2.10 ac[y]	2.13 ac	2.40 ab	2.13 ac	2.40 ab	2.67 a	2.60 a
10	1.79 be	1.27 df	1.87 bd	1.80 be	1.67 cf	1.87 bd	1.60 cf
15	1.49 df	1.87 bd	1.60 cf	1.06 f	1.20 ef	1.47 df	1.60 cf

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).

[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 3. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the number of monopodial bolls, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)							
5	3.50 ab[y]	2.70 b	4.80 a	4.30 ab	3.30 ab	4.50 a	4.30 ab
10	0.86 c	0.13 c	1.00 c	0.80 c	0.53 c	0.86 c	0.67 c
15	0.18 c	0.20 c	0.33 c	0.20 c	0.00 c	0.07 c	0.27 c

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).

[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 4. The effect of seeding rate, glyphosate rate, and glyphosate application timing on percent retention of first position bolls on sympodial branches 1 through 5, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)	(%)						
5	57 ad[y]	68 a	40 ej	35 gk	49 bg	29 il	12 mn
10	50 bg	45 ch	17 ln	25 jm	47 ch	11 mn	8 n
15	47 ch	57 ad	32 hl	36 fj	20 kn	7 n	12 mn

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).
[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 5. The effect of seeding rate, glyphosate rate, and glyphosate application timing on percent retention of first position bolls on sympodial branches 6 through 10, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)	(%)						
5	67 ad[y]	72 ac	76 a	73 ae	73 ae	63 de	76 ae
10	60 ae	65 ad	59 be	59 be	65 ad	64 ad	69 ac
15	59 be	59 be	71 ac	60 ae	71 ac	56 ce	59 be

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).
[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 6. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the number of outer bolls retained, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)							
5	1.33 ef[y]	1.80 cf	2.20 ae	1.93 bf	1.60 df	2.47 ad	2.93 ab
10	0.93 f	1.20 ef	1.80 cf	2.07 be	1.33 ef	2.73 ac	3.27 a
15	0.58 fg	0.93 f	2.20 ae	1.13 ef	1.13 ef	1.67 cf	1.20 ef

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).
[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 7. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the highest sympodial node with first and second fruiting positions, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)							
5	10.0 be[y]	10.9 ac	10.5 ae	10.6 ad	10.1 ae	10.7 ac	11.3 ab
10	10.4 ae	11.0 ac	10.8 ac	10.6 ad	9.9 ce	11.4 a	11.1 ac
15	8.86 ef	8.3 f	9.3 df	9.1 ef	10.0 be	10.1 ae	9.9 ce

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).
[y] Means followed by the same range of letters are not significantly different (P=0.05).

Table 8. The effect of seeding rate, glyphosate rate, and glyphosate application timing on the seed-cotton yield, Marianna, AR, 2002.

	Glyphosate rate[z] and timing						
	0 lb	1 lb			2 lb		
Seeding rate		4-leaf	6-leaf	8-leaf	4-leaf	6-leaf	8-leaf
(lb/acre)	(lb/acre)						
5	3045 eg[y]	3145 e	3274 bd	3203 ce	3274 bd	2827 fg	2898 f
10	3260 bd	3527 a	3327 bc	3115 e	3339 b	2727 fh	2851 fg
15	3244 bd	3203 ce	3145 e	2815 fg	3162 de	2762 fh	2662 h

[z] Glyphosate rates are in lb ai/acre; glyphosate used was Roundup Ultra (4 lb ai or 3 lb ae/ gallon).
[y] Means followed by the same range of letters are not significantly different (P=0.05).

Glyphosate (Roundup Weathermax®) Tank-Mix Partners in Roundup Ready® Cotton

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

RESEARCH PROBLEM

The advent of herbicide-resistant cotton (*Gossypium hirsutum*) cultivars has allowed foliar postemergence control of many problematic weed species in cotton. Situations still remain in which a residual herbicide program may be beneficial in Roundup Ready cotton. When the first glyphosate application has to be made early in the season, residual herbicides may provide better control of larger weeds. Situations that do not promote rapid canopy development such as wider row spacings, dryland production, early-season insects, and unfavorable growing conditions may justify the use of post-directed residual herbicide programs. The objective of this experiment was to evaluate weed efficacy of selected tank-mix partners of residual herbicides with the new glyphosate formulation Roundup Weathermax in Roundup Ready cotton.

BACKGROUND INFORMATION

Glyphosate is an excellent broad-spectrum herbicide for use in transgenic Roundup Ready crops and allows for total postemergence weed control (Culpepper and York, 1998). Roundup Weathermax, developed by Monsanto, is the potassium salt of glyphosate and is formulated as a soluble liquid with 5.5 pounds of the active ingredient glyphosate or 4.5 pounds acid equivalent per gallon. Although a total glyphosate program, with Weathermax or other glyphosate formulations, is sufficient in some situations, glyphosate has no residual soil activity. Therefore, some producers prefer to use a herbicide with residual activity to allow flexibility in timing postemergence applications (Ellis and Griffin, 2002). Studies have been conducted for several years in Arkansas to evaluate various glyphosate programs for our state's cotton producers (Branson et al., 2001; McClelland et al., 2001).

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RESEARCH DESCRIPTION

An experiment was conducted in 2002 at the Cotton Branch Experiment Station, Marianna, AR, on a silt loam soil. The study design was a randomized complete block with four replications. Experimental units were 12.7- by 40-ft plots that were overseeded with seed of Palmer amaranth (*Amaranthus palmeri*), pitted morningglory (*Ipomoea lacunosa*), prickly sida (*Sida spinosa*), velvetleaf (*Abutilon theophrasti*), sicklepod (*Senna obtusifolia*), and large crabgrass (*Digitaria sanguinalis*). Following incorporation of weed seed, cotton cultivar Paymaster 1218BR was planted at a rate of 66,000 seed/acre at a depth of 1.5 inches accompanied by an in-furrow application of the insecticide Temik® at 4 lb/acre.

Herbicide treatments consisted of a broadcast over-the-top application of Weathermax at 0.75 lb acid equivalent (ae)/acre followed by (fb) post-directed weed control regimes of Weathermax at 0.75 lb ae/acre applied once or twice; and Weathermax at 0.75 lb ae /acre applied alone or in combination with Direx (diuron) at 0.25 lb ai/acre, Aim (carfentrazone) at 0.012 or 0.0036 lb ai/acre, Amplify (cloransulam) at 0.016 lb ai/acre, Valor (flumioxazin) at 0.063 or 0.032 lb ai/acre, Firepower (glyphosate+oxyfluorfen) at 1.06 lb ai/acre, Strongarm (diclosulam) at 0.025 lb ai/acre, or Envoke (trifloxysulfuron) at 0.0118 or 0.0071 lb ai/acre targeting three- to five-inch weeds. Treatments were applied using a tractor-mounted sprayer calibrated to deliver 20 gal/acre.

Data collected consisted of crop injury and weed control ratings by species on a percentage scale of 0 to 100 with 0 being no weed control or crop injury and 100 being complete weed control or total crop destruction. Data were subjected to analysis of variance, and treatment means were separated using Fisher's Protected Least Significant Difference (LSD) at the 0.05 level of significance.

RESULTS

There were no significant differences in control of Palmer amaranth or prickly sida among treatments that received more than one application of glyphosate, regardless of tank-mix partner (Table 1). As expected, follow-up treatments plus Weathermax provided better control of weed species evaluated than a single over-the-top application of Weathermax. There were no advantages to adding a tank-mix partner to Weathermax, except for the control of pitted morningglory. Weathermax (0.75 lb ae/acre) + Aim (0.012 lb ai /acre), Valor (0.032 lb ai/acre), or Strongarm (0.025 lb ai/acre) tended to provide greater control of pitted morningglory than two applications of Weathermax alone. Late-season weed control ratings revealed that Weathermax + Strongarm provided better control of pitted morningglory than two applications of Weathermax. However, by 12 weeks after planting, there were no differences between this tank mixture and three applications of Weathermax (92 and 89%, respectively). There appeared to be a trend for antagonism with Weathermax + Aim (0.0036 lb/acre), compared to sequential applications of Weathermax alone, but no antagonism was

evident when the rate of Aim was increased to 0.012 lb/acre. There was no yield advantage to adding a tank-mix partner to post-directed applications of Weathermax.

PRACTICAL APPLICATION

There appears to be no advantage to adding tank-mix partners to Roundup Weathermax for control of Palmer amaranth, large crabgrass, or prickly sida. The addition of Aim, Valor, or Strongarm to the post-directed application of Weathermax tended to provide better control of pitted morningglory than sequential applications of Weathermax alone. There may be some antagonism when Weathermax is applied in tank mixture with lower rates of Aim. There was no yield advantage to adding a tank-mix partner to Weathermax; however there is an innate increase in herbicide cost from the addition of a tank-mix partner.

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Table 1. Weed control and seedcotton yields after a broadcast over-the-top application of Roundup Weathermax (WMx) at 3- to 5-inch weeds followed by Roundup Weathermax + tank-mix partners applied post-directed (DIR) at 3- to 5-inch weed regrowth, Marianna, AR, 2002.

Post-directed herbicide system following WMx over-the-top[z]	Rate[y]	Weed control 8 weeks after planting: Palmer amaranth	Prickly sida	Pitted morning-glory	Large crabgrass	Seed-cotton yield
	(lb/acre)	----------	----------	(%)	----------	(lb/acre)
No DIR	--	71	61	55	39	1050
WMx + Direx	0.25	94	95	93	90	3061
WMx + Aim	0.0036	93	95	79	91	2784
WMx + Aim	0.012	93	95	95	91	3106
WMx + Amplify	0.016	95	95	83	94	2829
Wmx + Valor	0.032	94	95	95	95	2593
Wmx + Valor	0.063	93	95	88	94	2735
Firepower	1.06	93	95	90	89	1949
Wmx + Strongarm	0.025	94	95	94	91	2338
Wmx + Envoke	0.0071	95	95	90	93	2717
Wmx + Envoke	0.0118	95	95	90	94	2700
Wmx	--	94	95	85	91	2867
Wmx fb Wmx[x]	--	95	95	81	93	3017
LSD (0.05)		3	2	8	8	769

[z] Roundup Weathermax (Wmx) was applied at 0.75 lb ae/acre. Wmx , glyphosate; Direx, diuron; Aim, carfentrazone; Amplify, cloransulam; Valor, flumioxazin; Firepower, glyphosate + oxyfluorfen; Strongarm, diclosulam; Envoke, trifloxysulfuron.

[y] Rates are for the tank-mix partner and are expressed in lb ai/acre.

[x] Wmx applied DIR twice.

Biology and Control of Yellow Nutsedge in Cotton

Frank E. Groves, Kenneth L. Smith, Nilda R. Burgos, and J. Brad Murphy[1]

RESEARCH PROBLEM

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

BACKGROUND INFORMATION

C. esculentus has been listed among the most troublesome weeds in the world. It is found in all 50 states and has been responsible for significant crop losses (Holm et al., 1977; Wills, 1985). In 2002, there were 372,000 ha of cotton harvested in Arkansas (Robertson, 2002, personal commun.). *Cyperus* species' were responsible for a 6% yield loss in the state. (Byrd, 2003, personal commun.).

Stoeller and Woolley (1983) reported that *C. esculentus* utilized a complex underground network of rhizomes, basal bulbs, and tubers to produce vegetative and reproductive growth. Individual *C. esculentus* 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 which coincide with basipetal translocation have increased herbicide efficacy in other species (Wilson et al., 2001; Ficke and Sosebee, 1981). Wills (1971) reported carbohydrate concentration in various parts of purple

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nutsedge (*C. rotundus*) was affected by maturity. Little has been reported on carbohydrate levels and translocation throughout the life cycle of *C. esculentus*.

RESEARCH DESCRIPTION

Studies were conducted in 2001 and 2002 to determine if a correlation exists between plant growth stage and basipetal translocation of carbohydrates. Greenhouse studies were conducted at the Arkansas Agricultural Research and Extension Center in Fayetteville, utilizing a completely randomized design. Three tubers were planted into a potting soil/sand mixture (50% v/v) contained in a 10-cm pot. Plants were collected from the 1- to 9-leaf stage. In one study, plants were dissected into various tissues for sugar analysis by high-performance liquid chromatography (HPLC). In a separate study, plants were chemically treated for herbicide efficacy. Plants selected for HPLC analysis were separated anatomically into tubers, shoots, old leaves, new leaves (upper three leaves), and secondary tubers. The plant parts were frozen, freeze-dried, and ground. Fructose, glucose, and sucrose were extracted by boiling ground tissues and analyzed using a HPLC with a refractive index detector. Sugars were quantified and expressed as µg/g fresh dry weight (FDW).

In a spray chamber, plants were treated with glyphosate at 0.84 kg ae/ha or trifloxysulfuron at 0.019 kg ai/ha + 0.25% non-ionic surfactant (NIS). Plants were returned to the greenhouse and evaluated at 10 days after treatment (DAT) for visual injury using a scale from 0 to 100 with 0 representing no injury. Treatments were applied at 140 L/ha using compressed air as the propellant and water as the carrier.

RESULTS AND DISCUSSION

Sucrose content was greater than that of the hexoses among all plant parts. However, the three sugars followed the same general trends when sugar content (µg/g FDW) was evaluated relative to plant growth stage. The sucrose content of the primary tuber gradually increased, reaching a maximum (>40 µg/g) at the 5- to 6-leaf stages. A sharp decrease to 10 µg/g FDW was observed at the 7-leaf stage and sucrose content remained low until the 9-leaf stage. The sucrose content of the new leaf was inversely related to sucrose content of the primary tuber. Sucrose content decreased sharply from 30 µg/g FDW to 22 µg/g FDW from the 5- to 6-leaf stages, respectively. Sucrose content of the new leaf increased gradually, reaching a maximum at the 8-leaf stage at >35 µg/g FDW and declined thereafter. A decrease in sucrose content among all plant parts occurred at the 8-leaf stage resulting in similar content in all tissues at the 9- leaf stage.

Glyphosate provided >65% control at the 2- to 4-leaf stage. Control decreased to <30% when glyphosate was applied at the 5- to 7-leaf stages and increased to >85% at the 8- and 9-leaf stages. Trifloxysulfuron provided >70% control for leaf stages 5

through 7. Control improved to >85% for the 8- and 9-leaf stages. In greenhouse studies, a correlation was observed between plant growth stage, sugar translocation, and herbicide efficacy. During the 5- to 6-leaf stage, sucrose content was the highest and glyphosate injury was lowest. At the 8- and 9-leaf stage, sucrose content was lowest while glyphosate and trifloxysulfuron injury was the greatest.

PRACTICAL APPLICATION

Optimal herbicide application rates and timings for the control of *C. esculentus* in *G. hirsutum* may be established utilizing a correlation between carbohydrate concentrations and plant growth stage of *C. esculentus*.

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Using an Integrated Pest Management Rotational Crop Program to Suppress Reniform Nematode

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RESEARCH PROBLEM

This paper will present information regarding the use of an integrated pest management approach to suppressing reniform nematode in one specific field near Altheimer, AR, during the production seasons of 1999 through 2002.

BACKGROUND INFORMATION

The Cooperative Extension Service, University of Arkansas, has conducted Cotton Research Verification Program (CRVP) demonstrations since 1980. The whole-field demonstrations of research-based Cooperative Extension Service recommendations have been used to bring new technology and production practices to farmer fields. Fields enrolled in the CRVP are selected based on specific criteria set by the Cooperative Extension Service.

A soil analysis is taken in the fall preceding initial enrollment of a cooperator and field into a research verification program. The analysis for the CRVP is for both fertility and nematode detection. Nematode pressure, usually rootknot nematode (*Meloidogyne incognita*) [RKN] or Reniform nematode (*Rotylenchulus reniformis*)[RN], can be yield-limiting problems for cotton producers. Reniform nematode presence was first reported in Arkansas (Robbins et al., 1989) in the late 1980s and was not a significant problem at that time. By 1994 the reniform nematode was reported to be a significant problem in the southern and mid-Mississippi and Arkansas Delta production areas (Stewart et al., 1994). Data in 1995 (Lorenz et al., 1995) indicated that reniform nematode ranked second only to RKN for economic yield loss in the United States. The reniform nematode is a

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root parasite that has a large host-plant range. They build up rapidly in cotton production fields and may survive well on soybean roots. Corn roots seem to be resistant to reniform nematode buildup and significant decreases in reniform nematode numbers are noted when corn is in a rotation with cotton. Levels also decrease well with rice rotations.

RESEARCH DESCRIPTION

To demonstrate the effectiveness of crop rotation in RN population reductions, a four-year crop rotation study was conducted through an Integrated Crop Research Verification Program (ICRVP) piloted during the four-year study of a research verification demonstration in Jefferson County, AR.

Field selection began in the fall of 1998 on a farm near Altheimer, AR. During enrollment of the new field for the 1999 CRVP in Jefferson County, Arkansas, a field was suggested for enrollment by the cooperator. That field (Field 1) was rejected due to what was deemed too high a population of reniform nematode for economical cotton production (Table 1). An adjacent field (Field 2) was selected that was planted to corn during 1998 and that showed no reniform nematode pressure after the corn crop.

Field 2 was rotated from corn in 1998 to cotton in 1999 and 2000. For nematode sampling in 1999 and 2000, the field was divided into north and south sampling divisions that represented approximately half the field each. In addition, during the 2001 season, Field 2 was again planted to corn in the pilot program of Integrated Crop Research Verification Program (ICRVP). Thirty-one grids (approximately 1.5 acres each) were designated using a Garmin 162 Global Positioning System for more intensive nematode sampling (Table 2). Field 2 was returned to CRVP in 2002.

Field 2 was sampled for nematodes each fall soon after crop harvest. In 2001 each of the 31 grids in Field 2 was sampled. Approximately 10 soil cores were collected from each block with a sampling tube (1-in. diameter). All cores were taken to a depth of 6 in. from the plant bed for cotton, while random samples were collected when corn was grown because the field had been disked prior to the time of sampling. The cores were bulked and mixed, and then soil was assayed using semi-automatic elutriation followed by centrifugal flotation.

RESULTS AND DISCUSSION

A fall 1998 nematode assay for Field 2 indicated a zero level of RN in a field-wide sample submission (Table 1).

Field 2 escalated from zero RN in the fall 1998 sample to an average of over 10,000 RN in 1999 after just one year in cotton. Samples were taken from both a north and south division of the field.

In 2000, Field 2 was planted to a second year of cotton. Nematode sampling for Field 2 was done while the field was extremely dry following a very dry and hot August

and September. There was a slight, but not significant, increase in the reniform nematode counts for Field 2 over those taken in 1999. Root systems of the cotton plants in 2000 were poor, possibly due to stress of a difficult emergence in the spring of 2000. Many plants did not have taproots. Some plants also exhibited abnormal development with many having an aborted terminal and double or triple terminal development.

Grid sampling of Field 2 after a year in the ICRVP (Corn) was performed and 31 sample sites were mapped with the Garmin 162 GPS. Thirteen sites tested positive for RN with the highest level being 1591 at one point. No site reached the Arkansas Cooperative Extension Service treatment threshold of 5,000 RN per pint of soil. Due to the field history of a rapid build-up of RN once cotton is in rotation behind corn on this farm, nematicides must be a recommended practice at the time of cotton planting even when RN levels are below treatment level as they were after corn in 2001.

A final grid sampling of Field 2 was performed after harvest of the 2002 cotton crop by re-locating the waypoints used for the 2001 sampling grid. There was a significant increase (Fig. 1) in the number of sites that exceeded the threshold of 5,000 RN per pint of soil that would cause a recommendation of nematicide for the next crop of cotton. Of the 31 sites sampled, two had no detectable levels of RN. Twenty-four of the sites were above the treatment threshold that triggers a recommendation of nematicide for cotton production. Five of the sites had RN levels below that which triggers nematicide use.

PRACTICAL APPLICATION

Crop rotation had a significant impact on reducing the numbers of reniform nematode in Field 1 and Field 2 from 1998 to 2001. While rotations significantly decreased the number of RN in control areas, a return to the susceptible crop, cotton, caused a rapid surge in the levels of RN after just one year back to cotton. Crop rotation may hold some promise for lowering reniform populations. Crops such as corn, grain sorghum, and rice are poor or non-hosts for this nematode, and rotation of cotton with these crops may lower reniform numbers for subsequent crops (Kirkpatrick et al., 1997). The sampling study over five falls on Field 2 near Altheimer, AR, indicates a rapid reduction in reniform numbers when corn is in rotation to cotton. This study also shows the rapid return of reniform populations after just one year back in the susceptible crop, cotton (Fig. 1). Further research is needed to determine interactions of disease and varietal responses of cotton grown in the rotations. In both 1999 and 2002 when cotton was planted after a corn rotation, Field 2 was planted to a conventional cotton variety. In 2000, the cotton variety was a stacked-gene *Roundup Ready* line that was susceptible to Bronze Wilt. More research is needed to determine the actual level at which reniform causeS economic yield losses in known infested fields.

ACKNOWLEDGMENTS

We gratefully acknowledge funding from Aventis Crop Science (Bayer Crop Science) for the site-specific (grid soil) nematode assays on the Sites CRVP ('99-'00)-C/ GSRVP ('02)- CRVP('02) rotational crop demonstration from 1999 through 2002.

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Table 1. Reniform nematode assay results, 1998-2000, Altheimer, AR, ICRVP.

	Field 1				
	Reniform nematode per pint of soil				
Year	N1	N2	S3	S4	Previous crop
1998	49,318	31,136	36,591	47,045	Cotton
1999	2,273	455	2,045	1,818	Rice
2000	31,136	16,591	26,364	30,227	Cotton
	Field 2				
	Reniform nematode per pint of soil				
Year	Whole field	N division	S division	Avg/field	Previous crop
1998	0	NA[z]	NA	0	Corn
1999	NA	12, 045	7, 273	9659	Cotton
2000	NA	13, 182	6, 591	9886	Cotton

[z] NA = not applicable.

Table 2. Reniform nematode assay results, Field 2, grid samples in 2001 after a year of corn; and in 2002 after a year of cotton, Altheimer, AR.

Reniform nematode					
Site North division	2001	2002	Site South division	2001	2002
	--- (no./pint) --			--- (no./pint) ---	
N1	909	2045	S20	909	26136
N2	0	22727	S21	0	26818
N3	0	1500	S22	682	11591
N4	455	8636	S23	455	0
N5	0	3864	S24	0	9091
N6	0	15455	S25	1136	12045
N7	0	909	S26	909	13182
N8	227	7045	S27	0	14318
N9	0	5227	S28	1591	15682
N10	682	4091	S29	0	0
N11	1136	11818	S30	0	16818
N12	0	10227	S31	227	8864
N13	0	1364			
N14	0	6136			
N15	0	19091			
N16	0	7727			
N17	0	5455			
N18	0	11591			
N19	455	1360			
Average	203	8409		492	12879

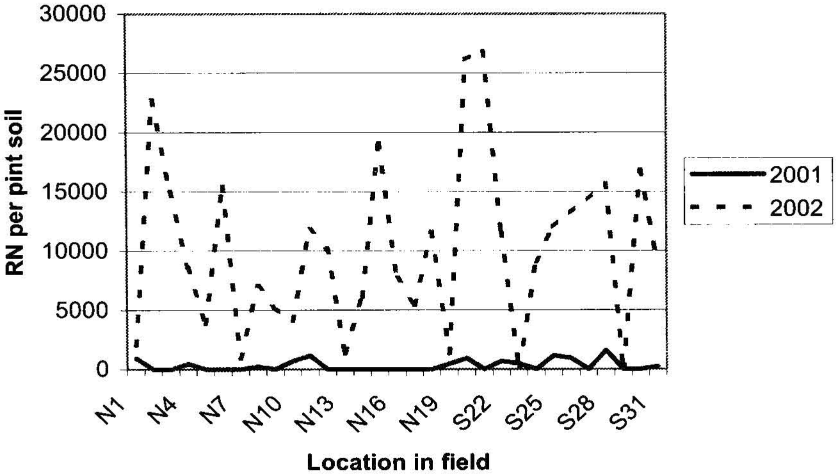

Fig. 1. Rotation comparison for Reniform nematodes (RN) per pint of soil for corn in 2001 and cotton in 2002.

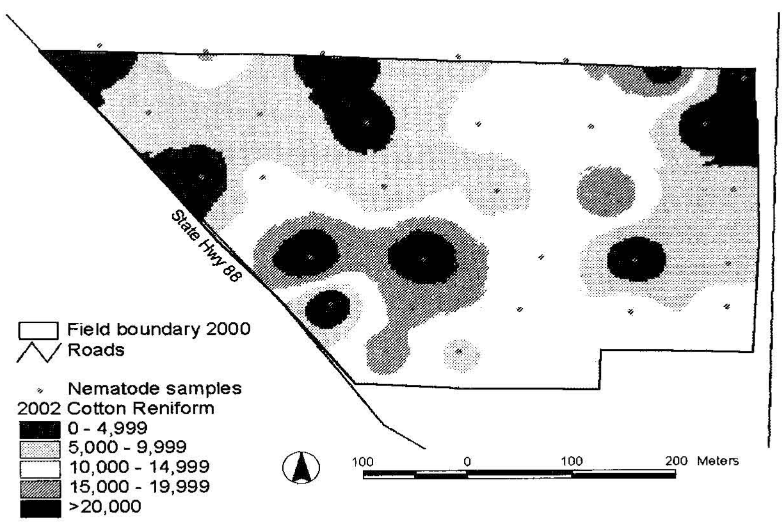

Fig. 2. 2002 Reniform Nematode Assay.

Varietal Responses of Cotton to Nitrogen Fertilization[1]

J.S. McConnell, B.A. Meyers, and M. Mozaffari[2]

RESEARCH PROBLEM

Optimizing yield and earliness of cotton (*Gossypium hirsutum* L.) with nitrogen fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985). Genetically engineered cotton cultivars are currently being used in large portions of the cotton-producing acreage, particularly 'Bollgard' and Roundup® Ready cultivars. New cotton cultivars developed using traditional plant-breeding techniques are also being utilized by producers. Advantages of these new cultivars include higher yield potential, enhanced pest resistance, resistance to herbicides, superior lint quality, faster maturity, and other new characteristics. With the increase in new cotton cultivars into Delta production systems, N requirements of the new cultivars are questioned by producers. The objective of this study was to determine the response of new cotton cultivars to N-fertilization; particularly in yield, earliness, and fiber quality response.

BACKGROUND INFORMATION

New cotton cultivars have increased the genetic diversity of cotton grown in the Delta. The genetic variability of currently available cultivars indicates that crop growing practices, such as fertilization, might differ from older cultivars to achieve optimal yields and earliness. Optimizing N fertilization for individual cotton cultivars is a possible way of tailoring production practices to achieve optimal economic returns.

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RESEARCH DESCRIPTION

Studies of the responses of cotton cultivars to N-fertilization were begun at the Southeast Branch Experiment Station in 1989 (McConnell et al., 1993). Tested cultivars have changed as new cultivars were introduced into the Delta region. Three years of data, 2000 through 2002, are available from the current test. Cultivars currently under evaluation are: Deltapine 747 (DP 747), a rapid maturing variety; Stoneville 474 (ST 474), a moderate-maturing variety; Deltapine 5415 (DP 5415), a full-season variety and the parent line of Nucot 32B; and Nucot 32B (NU32B), a full-season variety with genetic resistance to heliothis species.

Nitrogen fertilizer rates were 0, 50, 100, and 150 lb N/acre. The source of the N was urea. The N-fertilizer treatments were split applied with half the total N-rate applied after emergence and half when the crop reached the first-square stage. The urea-N was incorporated with shallow plowing after each application. The test was furrow-irrigated using tensiometers to trigger irrigation. The studies were planted on 18 May 2000, 5 June 2001, and 23 April 2002. In 2001, the initial stand was destroyed by an early June hailstorm. The study was replanted on 5 June 2001. Cotton planted this late frequently exhibits growth aberrant from normal, yet the 2001 yields were acceptable and the trends in yield due to the treatments were similar to other years. The soil (Hebert silt loam) at the test site was sampled and analyzed for nutrient content in 1999 (Table 1).

The measurements taken on the cotton cultivars included seed-cotton yield, plant-height, plant-population, and node-development information. All data were analyzed using the Statistical Analysis System (SAS). The experimental design was randomized complete block. F-tests and least significant differences (LSD) were calculated at the α=0.05 level of probability. Only yield responses of cotton to N-fertilization are presented in this report.

RESULTS AND DISCUSSION

The yield of cotton cultivars was not found to significantly interact with differing N-fertilization rates in any year of the current test (Table 2). The main effect of N-fertilizer rate significantly affected cotton yield each year with 100 lb N/acre producing maximal yield for all four cultivars. Non-significant numerical yield increases occurred between the 100 and 150-lb N/acre rates in 2000 and 2002.

Yields of cultivars were different two out of three years (2001 and 2002). The highest yielding variety was ST474 in 2001, while DP747 and NU32B had the greatest yields in 2002. No significant difference in yield of the cultivars occurred in 2000. No pattern was discerned that would indicate a substantial yield advantage of one variety over the others tested.

Although the interaction of cultivars and N-rates was not significant, a trend of increasing yield with increasing N rate was observed for ST474 through the 150 lb N/

acre treatment all three years of the test. Other cultivars appeared to respond to the 150 lb N/acre with increased yields occasionally but not with the same frequency as ST474.

PRACTICAL APPLICATION

The yields of all the cotton cultivars tested were maximized with N fertilization rates of 100 lb N/acre. Interactions between cotton cultivars and N-fertilization were not found to influence cotton yields. Occasionally, yields were increased in some cultivars with N-rates above 100 lb N/acre, especially ST474, but not significantly.

ACKNOWLEDGMENTS

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Table 1. Residual nitrate-nitrogen (NO_3^-N), phosphorus (P), potassium (K), and electrical conductivity (EC) to a depth of two feet in six-inch increments from the cultivar by N-fertilization rate in test site in 1999.

Depth	NO_3-N	P	K	pH	EC
(in.)	(lb/acre)	(lb/acre)	(lb/acre)	(pH units)	(µS/m)
0 - 6	1.8	70	260	6.3	26
6 - 12	1.7	30	125	6.4	20
12 - 18	1.7	29	149	6.1	21
18 - 24	2.4	22	243	6.0	44
LSD(0.05)	0.4	6	18	0.1	3

Table 2. Seedcotton yields (lint yield may be estimated by dividing by 3) of four cotton cultivars [Deltapine 747 (DP 747), Stoneville 474 (ST474), Deltapine 5415 (DP5415), and Nucot 32B (NU32B)] as affected by 0, 50, 100, and 150 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, from 2000 to 2002.

N fertilizer	Cotton cultivar				
rate	DP747	ST474	DP5415	NU32B	N rate mean
	(lb seedcotton/acre)				
2000					
150	4051	4353	4090	4255	4185
100	3899	4291	3821	3915	3995
50	3400	3173	3103	3483	3300
0	2287	1636	1611	1878	1853
Variety mean	3347	3311	3123	3383	--
LSD(0.05) variety[z] and N rate by variety interaction[y] were NS					195[x]
2001					
150	4012	4511	3456	3876	3902
100	3915	4123	3723	3978	3945
50	3381	3769	3439	3425	3496
0	2780	2624	2702	2789	2718
Variety mean	3514	3729	3310	3485	--
LSD(0.05) variety[z] = 182 lb/acre; N rate by variety interaction[y] was NS					214[x]
2002					
150	5392	5554	3877	5503	5057
100	5242	4788	4181	5063	4849
50	4124	3896	3814	4163	3999
0	2638	2314	1912	2454	2293
Variety mean	4439	4100	3333	4296	--
LSD(0.05) variety[z] = 288 lb/acre; N rate by variety interaction[y] was NS					404[x]

[z] LSD(0.05) for cultivar main effects.

[y] No significant differences observed between cultivar and N rate.

[x] LSD(0.05) for N-rate main effects.

Long-term Irrigation Methods and Nitrogen Fertilization Rates in Cotton Production: The Last Three Years of the McConnell - Mitchell Plots[1]

J.S. McConnell, B.A. Meyers, and M. Mozaffari[2]

RESEARCH PROBLEM

Nitrogen (N) and water management are two very important aspects of successful cotton (*Gossypium hirsutum*, L.) production. If cotton becomes N deficient, the plants may become chlorotic and not photosynthesize sufficiently to meet the demands of crop growth. Nitrogen deficiency of cotton typically results in reduced yields, premature cut-out, and reduced fiber quality. Few studies of the interactions of N fertilizer and irrigation have been conducted for cotton. This is especially true under the humid production conditions of southeast Arkansas (McConnell et al., 1988).

Objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of soil- and plant-N fertilization and dynamics under different irrigation methods.

BACKGROUND INFORMATION

Both over- and under-fertilization of cotton with N may result in reduced yield. Over-fertilization may also induce delayed maturity in cotton (Maples and Keogh, 1971). Reductions in yield and quality due to N deficiency may severely reduce the value of the crop and have adverse economic consequences for producers (Bondada et al., 1996; Radin and Mauney, 1984).

Generally, yields were found to increase with increasing N fertilization throughout the previous years of this test. The N treatments that usually resulted in the greatest yields were applications of 60- to 150-lb N/acre, depending upon the irrigation

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treatment and year. The yields of the High Frequency block during some years were significantly influenced by verticillium wilt. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N.

Adequate soil moisture is also necessary for cotton to achieve optimal yields. Early and mid-season water requirements of cotton should be met to avoid yield loss that may occur if the crop undergoes drought stress (Jordan, 1986; Wanjura, et al., 1996). If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn et al., 1981).

In the previous years of this study, irrigation generally increased cotton yields except during seasons when early season rainfall resulted in standing water that delayed the irrigated plants or when verticillium wilt was prevalent. The method of irrigation that maximized yield varied among years and therefore appeared to be less important than irrigation usage.

RESEARCH DESCRIPTION

An experiment to examine the interactions of N-rates and irrigation methods was initiated at the Southeast Branch Experiment Station on an Hebert silt loam soil in 1982. This experiment, the McConnell-Mitchell Plots, is conducted on the oldest continuous plots in Arkansas. The experimental design was a split block with irrigation methods as the main blocks. Four irrigation methods were used from 1982 until 1987. Five irrigation methods were employed from 1988 to 1993. Only three irrigation methods have been used since 1993 (Table 1).

Ten total N treatments were tested within each irrigation method. Six different N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested with different application rates and timings (Table 2). N-fertilization was discontinued for the 2000 and subsequent growing season to examine the effects of residual soil nitrate-nitrogen (NO_3^-N) on cotton development. Soil samples were taken from the plots and analyzed for residual NO_3^-N to a depth of five feet (Table 3).

The McConnell-Mitchell Plots were planted 14 May 1999, 18 May 2000, and 23 April 2002. The 2001 growing season was marked by an early June hail storm that destroyed the stand of cotton. The cotton was replanted on 15 June 2001, but seedling disease decimated the stand a second time. The crop was not replanted again and the plots were fallowed, as it was deemed too late to get meaningful results.

RESULTS AND DISCUSSION

Interaction of irrigation with N-treatments and residual N significantly impacted yields all three years of the study (Table 4). During the last three years, high frequency center-pivot irrigation increased cotton yields compared to furrow irrigation or dryland production. Addtionally, furrow-irrigated cotton produced greater yields than dryland cotton during this period.

Yields were found to increase with increasing N fertilization in each irrigation block in 1999 although there were a few reversals and not all differences were significant. Yields were maximized in both high frequency center-pivot and furrow-irrigated cotton with 150 lb N/acre (split two ways). Yield response of the cotton in the dry land block was limited due to lack of rainfall.

Plant response to residual N in 2000 seemed to mirror the N-fertilization of previous years. Yields were again maximum where the 150- and 120-lb N/acre treatments had been applied in the center-pivot and furrow-irrigated blocks and were influenced little in the dryland block.

In 2001, the test site was fallow for the first time in the history of the McConnell-Mitchell plots. Hail and seedling disease prohibited a successful stand. Weeds were controlled on the site season-long with Roundup®.

Cool, wet conditions in the 2002 growing season resulted in severe seedling disease but not stand loss. Near optimal growing conditions through the rest of the season resulted in acceptable yields; however, response to residual NO_3^-N was limited in 2002. Cotton grown under high frequency center-pivot irrigation did not significantly respond in yield to the residual soil NO_3^-N, and cotton under dryland and furrow irrigation had only minimal yield response. As the residual NO_3^-N is consumed by subsequent crops, it will have less impact on plant development and yield.

PRACTICAL APPLICATION

Irrigated cotton was generally found to produce higher yields than cotton grown under dryland conditions. Fertilizer nitrogen requirements of cotton for maximal yield tended to be greater under irrigated production conditions than under dryland production conditions. Residual soil N was sufficient the first year to maintain yields when previous years of N-fertilization were high. After two growing seasons and one fallow season, the yield response to residual NO_3^-N was much less.

ACKNOWLEDGMENTS

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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	--[y]
Dryland	Not irrigated	--	--	--

[z] PB = Peak bloom
[y] Not precise

Table 2. Nitrogen (N) fertilization treatments and timing for the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Arkansas.

Total N-rate	Preplant	First square	First flower
- (lb N/acre) -	-------------------	(lb N/acre)	-------------------
150	75	75	0
150	50	50	50
150	30	60	60
120	60	60	0
120	40	40	40
90	45	45	0
90	30	30	30
60	30	30	0
30	15	15	0
0	0	0	0

Table 3. Residual nitrate-nitrogen (NO_3^-N) to a depth of five feet in six-inch increments from five fertilization rates (split applied, half pre-plant and half at first square) under three irrigation methods of the McConnell-Mitchell study in 2000.

	Nitrogen fertilization rate						
Depth	0	30	60	90	120	150	Mean
- (in.) -	(lb NO_3^-N/acre)						
Furrow irrigated							
0 - 6	2.0	1.7	2.3	2.0	2.7	3.0	2.3
6 - 12	1.7	2.3	1.3	1.7	2.0	2.0	2.3
12 - 18	2.0	3.0	2.7	2.0	3.0	4.3	3.8
18 - 24	3.0	2.7	3.3	2.3	4.3	7.3	4.8
24 - 30	2.7	3.0	3.0	2.7	4.3	6.7	4.5
30 - 36	2.0	3.0	3.0	2.7	4.7	6.3	4.1
36 - 42	2.7	2.7	2.7	2.7	4.3	7.0	4.1
42 - 48	2.7	2.3	2.7	2.3	4.3	9.0	4.0
48 - 54	2.7	2.7	2.7	2.7	3.7	7.7	3.9
54 - 60	2.3	2.0	3.3	2.0	6.7	5.7	3.6
Mean	2.4	2.5	2.7	2.3	4.0	5.9	
Dryland							
0 - 6	6.0	6.0	6.0	28.7	87.3	65.0	29.4
6 - 12	5.0	8.7	6.0	32.7	107.7	102.0	39.1
12 - 18	4.3	6.0	5.0	35.0	138.3	134.7	45.9
18 - 24	3.7	5.0	6.0	36.3	125.3	110.7	46.2
24 - 30	3.7	3.7	5.7	31.0	90.7	104.3	46.9
30 - 36	2.7	3.3	5.0	21.7	58.3	67.7	31.7
36 - 42	2.7	3.0	3.7	11.7	54.0	36.7	22.3
42 - 48	2.3	2.7	3.0	7.0	36.7	21.3	13.0
48 - 54	2.7	2.7	4.0	6.0	21.0	14.7	9.1
54 - 60	13.0	6.0	30.3	2.0	33.3	56.7	24.6
Mean	4.6	4.7	7.5	21.4	75.2	71.4	
Center-pivot Irrigated							
0 - 6	1.0	1.0	3.0	3.0	2.0	1.7	1.9
6 - 12	1.3	1.0	2.3	3.0	3.3	5.3	3.1
12 - 18	1.7	1.3	3.0	2.7	3.3	11.0	4.9
18 - 24	2.0	1.3	2.0	1.0	2.3	19.7	5.4
24 - 30	2.0	3.3	1.7	2.0	3.3	18.0	6.0
30 - 36	1.7	2.7	1.3	2.7	3.7	9.7	5.5
36 - 42	2.0	2.3	1.7	2.7	4.3	7.3	7.7
42 - 48	2.0	2.3	2.7	3.3	5.7	6.3	7.5
48 - 54	1.7	2.7	1.7	3.3	5.7	4.0	5.0
54 - 60	6.0	3.7	2.0	2.3	5.0	6.7	4.1
Mean	2.1	2.2	2.1	2.6	3.9	9.0	

Table 4. Seedcotton yield response of cotton to 10 nitrogen (N) fertilization rates and splits under three irrigation methods from 1999, 2000, and 2002 at the Southeast Branch Experiment Station near Rohwer, Arkansas.

N rate						
PP[z]	FS[z]	FF[z]	HF[y]	FI[y]	DL[y]	Mean
---------- (lb/acre) ---------			----------------- (lb seed cotton[x]/acre) ----------------			
1999						
75	75	0	3805	3548	1505	3166
50	50	50	3437	3287	1796	3138
30	60	60	3560	3306	1607	3008
60	60	0	3674	3098	1394	2960
40	40	40	3693	3533	1772	3172
45	45	0	3278	3045	1757	2839
30	30	30	3299	2817	1694	2777
30	30	0	3383	2812	1757	2834
15	15	0	2556	1912	1786	2202
0	0	0	2459	1550	1389	1964
LSD(0.05)=358[w]						
LSD(0.05)=549[v]						
Mean			3344	2890	1646	
2000						
75	75	0	2968	2161	1245	2207
50	50	50	3034	2126	1295	2152
30	60	60	3138	2223	1255	2205
60	60	0	2783	1923	1186	2042
40	40	40	2882	1999	1382	2112
45	45	0	2753	1951	1233	1979
30	30	30	2541	2003	1314	1949
30	30	0	2784	1885	1182	1977
15	15	0	2329	1665	1312	1744
0	0	0	2643	1677	1027	1721
LSD(0.05)=244[w]						
LSD(0.05)=880[v]						
Mean			2801	1961	1242	
2002						
75	75	0	3847	3413	2901	3379
50	50	50	3900	3464	3114	3485
30	60	60	3864	3369	3202	3470
60	60	0	3692	3466	2998	3378
40	40	40	3886	3214	3391	3489
45	45	0	3733	3342	3204	3419
30	30	30	3616	3330	3245	3395
30	30	0	4041	3146	3056	3407
15	15	0	3602	3037	3297	3304
0	0	0	3481	2867	2886	3071
LSD(0.05)=340[w]						
LSD(0.05)=493[v]						
Mean			3766	3265	3128	

[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 seed cotton yield by 3.
[w] LSD(0.05) for comparing means within the same irrigation method.
[v] LSD(0.05) for comparing means within different irrigation methods.

Nitrogen Fertilization of Ultra-Narrow-Row Cotton: Final Report[1]

J.Scott McConnell, Morteza Mozaffari, Bryan A. Myers, Robert E. Glover, and Ray Benson[2]

RESEARCH PROBLEM

Recent developments in cotton (*Gossypium hirsutum* L.) production technology in the Delta include drill planting cotton in an ultra-narrow-row (UNR) production system. Ultra-narrow-row cotton is a low-input production system designed to maximize economic returns. The premise is that UNR cotton will be lower yielding, but the reduction in input costs will result in a larger profit margin. Research that provides information on production parameters is scant. Nitrogen (N) fertilization rates required to optimize yields and earliness for UNR cotton are unknown. The objectives of these studies were to determine optimal N fertilization for UNR cotton.

BACKGROUND INFORMATION

Crops grown in very narrow rows intercept and utilize sunlight more efficiently, but equipment, particularly for harvesting high-quality cotton, has always required wide rows. Technology development for UNR cotton production, including harvest equipment, has increased recently. Potential benefits of UNR cotton production include: reduced production costs, utilization of soils not ordinarily suited to cotton production, decreased soil erosion, and utilization of the same equipment for cotton, soybean, and cereal crops. Potential drawbacks of UNR cotton include: increased weed pressure in low-stand areas; different equipment is required from conventionally row-spaced cotton (precision drill planter, finger stripper harvester); and lint quality

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may decline. Variety differences, fertility requirements, effect of planting date, and other parameters for optimal growth and yield of UNR cotton are unknown.

RESEARCH DESCRIPTION

A pilot study of the responses of UNR cotton to N-fertilization was conducted in 1997 at the Southeast Branch Experiment Station (SEBES) near Rohwer, Arkansas. The current test was begun in 1998 with N-rates of 0-, 25-, 50-, 75-, 100-, and 125-lb urea-N/acre at SEBES. The experimental design was a randomized complete block. N-treatments were applied to the soil surface without incorporation when the crop reached the two true-leaf stage. The test was expanded for the 1999 growing season to include a second study site at the Northeast Research and Extension Center (NEREC) near Keiser, Arkansas. The test was planted on 26 May 1999 (SEBES), 23 May 1999 (NEREC), 16 May 2000, and 17 May 2001. The soil (Hebert silt loam) at the test site was sampled and analyzed for nutrient content at the SEBES site (Table 1).

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

RESULTS AND DISCUSSION

The results of the pilot study and the first year of the current experiment correlated well. The N- fertilization rate necessary to produce maximal yield, boll load, and boll weight was 50 lb N/acre. Although trends of higher values were observed with greater N rates, the differences were not always significant from the 50 lb N/acre treatment. Plant height increased with increasing N fertilization up to 100 lb N/acre.

Drought conditions masked the impact of N fertilization of the UNR cotton at SEBES in 1999 (Table 2). 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 2000 growing season at SEBES showed increased yields with N treatments up to 100 lb N/acre. Plant height and boll load increased throughout the range of N treatments. The 2001 growing season was marked by a prolonged period of water-saturated soil conditions and occasional plant submergence early in the growing season. These conditions retarded the growth, development and yield of the cotton. Because of these adverse growing conditions, no significant differences were observed in 2001.

Results from NEREC were similar to the first year's at SEBES (Table 3). Maximal yields were achieved with only 25 lb N/acre. Plant height was found to significantly increase up to 75 lb N/acre. No significant differences were observed in either the plant populations or boll loads at NEREC.

PRACTICAL APPLICATION

Current University of Arkansas N fertilizer recommendations for cotton use a base value of 100 lb N/acre. Subtractions from this base value are recommended with differences in soil texture, soil calcium content, and crop history of the field (Chapman, 2000). The N-fertilizer recommendation for the SEBES study site would be 90 lb N/acre to optimize cotton yield. The responses of UNR cotton to N fertilization treatments indicate that the N required for maximal yield will be less than the 90 lb N/acre recommended for cotton grown in conventionally spaced rows. Yields of UNR cotton were not often found to significantly increase with N rates above 50 lb N/acre. Additionally, the 50 lb N/acre treatment was usually found to maximize both the boll load and boll weight. The parameters measured in these studies suggest that the N fertilization to optimize UNR cotton is substantially different from the recommended N-rates for conventionally grown cotton.

ACKNOWLEDGMENTS

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Table 1. Initial soil analyses by depth for nitrate-nitrogen (NO_3^-N), phosphorus (P), potassium (K), and electrical conductivity (EC) at the ultra-narrow-row nitrogen fertility study site at the Southeast Branch Experiment Station near Rohwer, AR, from 1997 to 2001.

Depth	NO_3^-N	P	K	pH	EC
(in.)	(lb/acre)	(lb/acre)	(lb/acre)	(pH units)	(μS/m)
0 - 6	1.8	70	260	6.3	26
6 - 12	1.7	30	125	6.4	20
12 - 18	1.7	29	149	6.1	21
18 - 24	2.4	22	243	5.9	34
LSD (0.05)	0.4	6	18	0.2	3

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, 125 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, AR, from 1999 to 2001.

N-rate	Lint yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(in.)	(plt/acre)	(bolls/acre)	(g/boll)
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
2001					
125	231	7.9	246,854	75,024	3.00
100	246	9.4	284,608	88,093	3.05
75	247	9.4	198,451	88,738	2.74
50	212	9.5	231,123	101,646	2.42
25	170	8.4	189,981	87,125	3.36
0	156	8.2	191,191	85,915	3.02
LSD (0.05)	NS	NS	NS	NS	NS

Table 3. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with 0, 25, 50, 75, 100, 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)	(in.)	(plt/acre)	(bolls/acre)
125	989	20.7	212488	341499
100	1004	20.4	261816	333910
75	958	23.7	239049	314938
50	965	20.4	292171	417387
25	883	17.5	250432	394621
0	608	16.7	250432	318732
LSD (0.05)	267	2.7	NS	NS

Foliar Fertilization of Cotton

Bill Robertson, Leo Espinoza, and Brian Weatherford[1]

RESEARCH PROBLEM

Yield responses from supplemental soil or foliar nitrogen (N) applications are often erratic. The boll load or lack thereof can be an important factor in determining the positive outcome from foliar feeding (Oosterhuis and Bondada, 2001). Petiole sampling can give an accurate indication of the nutritional status of the plant. However, petiole sampling does not give the user any indication of the boll load or the impact of the boll load on plant development. The success rate of increasing yields and obtaining a return on investment would likely improve if greater efforts were made to evaluate boll load as well as the nutritional status in making supplemental foliar-N applications.

BACKGROUND INFORMATION

The Cotton Nutrient Monitoring (CNM) program in Arkansas was established to provide a tool producers could utilize to avoid over-fertilization of cotton. As prices of fertilizer have increased and producers better understand the role of N fertilization, the occurrence of over-fertilization is much more rare. With the onset of boll weevil eradication and the increased use of Bollgard technology, fruit retention rates often are very high at first flower. This situation presents a challenge to the producer to meet the enormous demands for water and nutrients after flowering begins to avoid significant shed of fruit. Utilizing the COTMAN program in conjunction with the CNM program, producers can better evaluate and predict the demand of the boll load on the plant in relation to the N status in making decisions on the need for supplemental N fertilization.

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RESEARCH DESCRIPTION

The study was conducted in producer fields with treatments being replicated four times over a period of five years. Petiole samples and COTMAN data were collected on a weekly basis beginning near match-head square (MHS). Foliar products were applied by ground beginning the second week of flowering and continued on a set schedule. Treatments included an untreated control (UTC), CoRoN (25-0-0), and a 23% urea solution (Table 1). Plots were harvested with the producer's picker or a plot picker and samples were taken for determining fiber quality. Lint fraction was determined from ginning hand harvested "grab" samples on a laboratory gin

RESULTS

In 1999, boll load resulted in NAWF values tracking parallel to the Target Development Curve (TDC) (Fig. 1). Trend lines from the CNM indicated deficient N status was impending prior to or at the third week of flower or sample period 5. A significant yield response was observed with foliar feeding. The CNM program recommended foliar N one week after treatment was initiated. The following year the boll load and growing conditions did not result in NAWF values tracking parallel to the TDC (Fig. 2). Trend lines from the CNM did not predict a deficient N situation until near sample period 7. Foliar feeding did not result in a yield response although a recommendation was made to apply foliar N by the CNM program.

During the course of this study with foliar N treatments being applied regardless of boll load and nutritional status, CoRoN numerically out-yielded the untreated control in four of the five years by an average of 32 pounds. The 23% urea treatment contained extra application expenses and was numerically better than the untreated control in three of the five years by an average of only 17 lb/acre (Table 2).

PRACTICAL APPLICATION

Numerical yield responses (averaging 17-32 lb lint/A) were obtained with foliar N fertilization without regard to boll load or petiole N status but may not be cost effective. Utilizing COTMAN to evaluate the demands placed on the plant during boll fill, coupled with knowledge of the nutritional status of the plant, can result in significant yield improvements. When boll retention is high and NAWF tracks parallel to that of the TDC, significant yield responses to foliar feeding are often observed.

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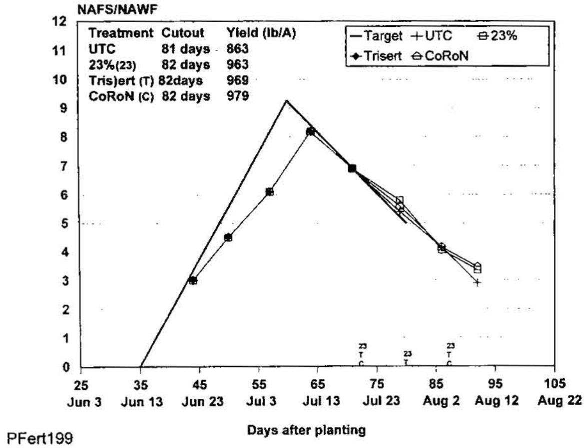
Table 1. Rates and timings of foliar feed products.

Treatment	Week of flowering 2	3	4
UTC	--	--	--
CoRoN	1 gal/acre	--	1 gal/acre
23% urea solution	3 gal/acre	3 gal/acre	3 gal/acre

Table 2. Lint yield means from foliar feeding treatments, 1998 to 2002, regardless of boll load.

	Lint yield					
Treatment	1998	1999	2000	2001	2002	5-year avg.
	(lb/acre)					
UTC	919	863	1062	924	1271	1008
CoRoN	957	979	1018	939	1306	1040
23% urea solution	955	963	1102	924	1183	1025
LSD (0.05)	NS	83	NS	NS	NS	NS



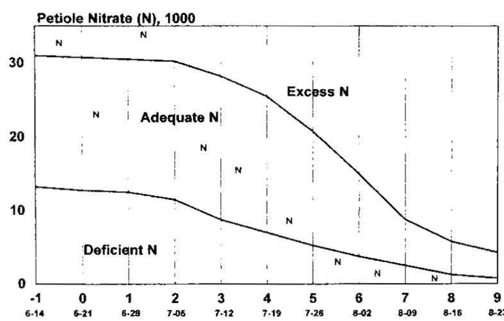
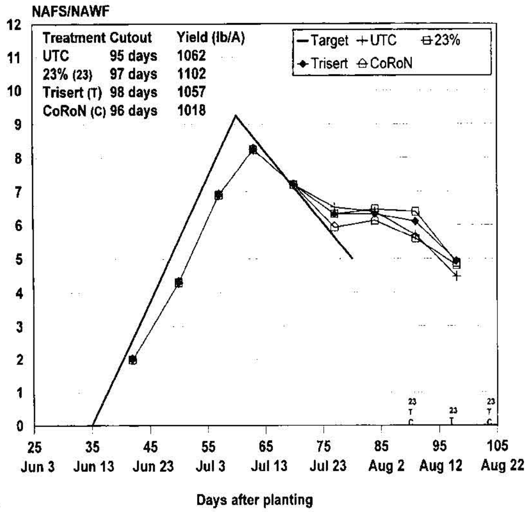


Fig. 1. COTMAN growth curves (top) and Cotton Nutrient Monitoring program output (bottom) in 1999.



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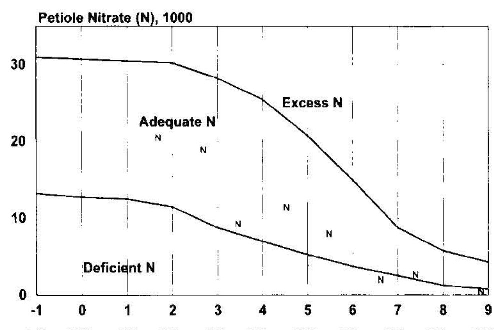

Fig. 2. COTMAN growth curves (top) and Cotton Nutrient Monitoring program output (bottom) in 2000.

Cotton Response to Nitrogen Fertilization in a Silt Loam[1]

Morteza Mozaffari, Michelle A. Henslee, Nathan A. Slaton, J.Scott McConnell, Edwin Evans, and Claude. Kennedy[2]

RESEARCH PROBLEM

Proper nitrogen (N) nutrition is a fundamental requirement for successful cotton (*Gossypium hirsutum* L.) production. Nitrogen deficiency limits cotton lint yield by limiting vegetative growth whereas excessive N will limit lint production by promoting excessive vegetative growth. A replicated field study was conducted to investigate the effect of N fertilizer application rate (0 to 120 lb N/acre) on cotton yield and petiole-N concentration.

BACKGROUND INFORMATION

Research conducted since the 1920s has clearly demonstrated that cotton yield in many Arkansas soils can be increased by application of N fertilizer (Maples et al., 1990). Nitrogen fertilization of cotton in Arkansas is based on preplant soil-test NO_3-N levels and petiole NO_3-N concentrations between first bloom and boll opening. Application of this diagnostic approach has enabled many Arkansas growers to produce high cotton yields. However, there have been many changes in cotton production practices during the past three decades that could potentially influence cotton response to N fertilization. Nitrogen requirements of new shorter-season varieties may be different than older cultivars previously used. Continuous research is needed to provide Arkansas growers' with up-to-date technical information concerning the response of new cotton cultivars to N fertilization. Therefore continuous evaluation of

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the effectiveness of the petiole-N monitoring program, as a decision aid tool for in-season N fertilizer application, is also necessary. The objectives of this research were to evaluate cotton yield and petiole NO_3-N response to N fertilization.

RESEARCH DESCRIPTION

A replicated field experiment was conducted on a Loring silt loam soil at the University of Arkansas Cotton Branch Experiment Station (CBES) located in Marianna, AR, during 2002. Prior to planting, two composite soil samples were collected from the top 6 inches of each plot; each composite sample consisted of eight 1-inch diameter samples from each of the eight cotton rows. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and concentration of elements in the soil extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Nitrate, pH, and EC were measured by standard University of Arkansas soil testing procedures. Cotton (cultivar Stoneville 4892) was planted on 21 May. The experimental design was a randomized complete block with four N rates (0, 60, 120, and 180 lb N/acre side-dressed at pinhead square stage as NH_4NO_3) and four replications of each treatment. Individual plots were 200 ft long and 25 ft wide. Phosphorus and K were applied as prescribed by University of Arkansas soil-test recommendations. Standard cultural practices for pest control and irrigation, as recommended by the University of Arkansas Cooperative Extension Service, were followed. Cotton petiole samples were collected for 10 consecutive weeks starting on 3 July and ending on 5 September. The first two weeks, 24 petioles from the fifth node from the top were randomly collected from each plot. The final eight weeks, 16 petioles from the fifth node from the top were randomly collected from each plot. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm sieve. A 0.1 g sub-sample was mixed with 30 mL aluminum sulfate spiked with 10 mg NO_3-N/kg and shaken for 30 minutes while stirring. Petiole NO_3-N concentration was determined using an ion-specific electrode. At maturity, seedcotton yield was determined from the center four rows of each plot with a 4-row cotton picker equipped with an AgLeader™ yield monitor. Analysis of variance was performed to evaluate the effect of N fertilizer rate on cotton yield and petiole NO_3-N concentration and significant treatment means were separated with the Waller-Duncan test.

RESULTS AND DISCUSSION

Selected chemical properties of soil in the experimental plots are listed in Table 1. According to current University of Arkansas guidelines, optimal cotton production at this site required 60 lb N/acre. However, seedcotton yields were not significantly increased by N application with yields ranging from 2420 to 2580 lb/acre (calculated lint yield ranged from 848 to 902 lb/acre, Table 2).

Petiole-N concentration increased early in the season, peaked one week after first bloom (24 July), and then decreased until one week after the cutout date, regardless of N rate (Table 3). Petiole-NO_3-N significantly increased with increasing N rate, regardless of sampling date. At first bloom, petiole-NO_3-N concentration was 30% higher at 180 lb N/acre compared to 60 lb N/acre and as the season progressed this difference became larger. Two weeks after cutout, petiole-NO_3-N in plants amended with 180 lb N/acre was seven times higher than plants amended with 60 lb N/acre (Table 3). Petiole-NO_3-N concentrations in the unfertilized control were consistently below the Arkansas lower sufficiency range indicating additional N was needed for optimal yield production, but we did not observe a yield response to sidedress N application rate. Foliar N application would have been erroneously recommended for plots amended with 60 lb N/acre after 31 July. These evidences suggest that the current Arkansas lower sufficiency levels for cotton petiole-NO_3-N may be too high for the shorter-season varieties currently in use.

PRACTICAL APPLICATION

In this field experiment petiole-NO_3-N concentrations increased as N rate increased. Petiole-NO_3-N in control plots was consistently below the current critical levels for Arkansas. However, plants with petiole-NO_3-N levels higher than the established lower sufficiency range did not produce higher cotton yields. This suggests that the current petiole-NO_3-N monitoring program may need revisions to be applicable to fast-fruiting cultivars currently in use.

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Table 1. Selected chemical properties before fertilizer application of the top 15 cm of a Loring silt loam used for an N-rate trial at the Cotton Branch Experiment Station during 2002.

		Mehlich-3 extractable nutrients[z]					
N rate	pH	NO_3-N	P	K	Mg	Ca	B
(lb N/acre)		----------	----------	---------- (lb/acre)	----------	----------	----------
0	6.4	31	105	266	308	2200	1.4
60	6.4	28	104	280	308	2200	1.1
120	6.4	26	107	276	316	2050	1.2
180	6.4	30	110	274	315	2180	1.2

[z] Modified Mehlich-3 extraction (1:10 extraction ratio).

Table 2. The effect of N fertilizer application rate on cotton yield at the Cotton Branch Experiment Station in 2002.

N rate	Seedcotton yield	Lint yield	Lint yield
(lb/acre)	---------- (lb/acre)	----------	(bale/acre)
0	2420	848	1.77
60	2580	902	1.88
120	2530	885	1.85
180	2465	863	1.79
Significance	NS[z]	NS	NS

[z] NS = not significant at P = 0.05 probability level.

Table 3. Effect of N fertilizer application rate on cotton petiole NO_3-N concentration in an N rate trial conducted at the Cotton Branch Experiment Station during 2002.

N rate	Seedcotton yield	Sampling date: July 10	July 17[z]	July 24	July 31	Aug. 7	Aug. 14[y]	Aug. 21	Aug. 28	Sept. 5
(lb N/acre)	(lb/acre)	[Petiole NO_3-N (mg/kg)]								
0	2420	3570	4189	11313	3520	1012	478	727	475	1417
60	2580	6264	6246	18469	8859	3313	862	1343	755	1209
120	2530	7447	8377	20828	12804	7878	3516	4427	1893	1527
180	2465	12535	9713	23138	15172	11005	5987	6171	3300	2260
Lower sufficiency level[x]		5000	>10000	>9000	>7000	>5000	>3000	>2000	>2000	>1000
Significance		**[w]	**	**	**	**	**	**	*	+
MSD (0.05)[v]		2476	2269	3697	3406	2865	1812	2311	1957	923

[z] First bloom on 19 July.

[y] Cut-out occurred on 17 Aug; first boll opened on 9 Sep.

[x] Recommendations for Arkansas published by Snyder et al., 1995.

[w] **, *, + significant at P = 0.01, 0.05, and 0.10 probability level, respectively.

[v] Minimum Significant Difference as determined by Waller-Duncan Test

Yield and Physiological Response of Dryland and Irrigated Cotton to Potassium Fertilization: A Four-Year Summary

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

RESEARCH PROBLEM

Potassium (K) nutrient deficiency costs the cotton (*Gossypium hirsutum* L.) producer in terms of fiber yield and quality. Throughout the growing season, climatic and numerous other factors may regulate the occurrence of and plant response to K deficiency. Sporadic K deficiencies have been noted in the U.S. Cotton Belt as the developing bolls exert a greater demand on plant K resources. Additional information is needed about the use of supplemental foliar-applied K to rectify K deficiencies in field-grown cotton under varying soil K and moisture levels. Thus, our study objective was to evaluate the potential response of cotton growth, yield, and quality to foliar-K application under water-deficit stress and soil-K deficiency.

BACKGROUND INFORMATION

Cotton is a major economic crop with an indeterminate growth habit and a dynamic range of response to management inputs and environment. A review of the literature shows that K is critically needed for maintaining plant-water relations (Kramer and Boyer, 1995), activating enzymes, supporting photosynthetic systems (Kerby and Adams, 1985), and translocating sugars and starch out of leaves (Bednarz and Oosterhuis, 1999).

Modern cotton cultivars fruit in a shorter period of time, mature earlier, and have greater total-K requirements and this has placed an emphasis on understanding plant uptake and utilization of K throughout the growing season (Oosterhuis, 1995). Although K may be taken up in luxury amounts by the cotton plant prior to peak demand, sporadic K deficiencies often occur during the fruiting period when the large developing boll load becomes the dominant sink for available K and concomitantly the rate of root growth decreases. Factors that interfere with the strong source-sink relationship

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of K in cotton will directly influence the efficiency of K use and the potential for high lint yields (Mullins, 1990; Oosterhuis, 1995). Although yield and economic advantages of timely foliar-K applications to supplement soil-applied K have been documented (Oosterhuis, 1999; Weir, 1999), the impact of mid-season water-deficit stress on the efficiency of foliar-K uptake and yield response to foliar-K fertilization needs further investigation.

RESEARCH DESCRIPTION

Cotton growth, K partitioning, and lint yield under varying water levels and K fertility were studied in 1999 in field plots located at Rohwer (Coker and Oosterhuis, 1999), in 2000 at Clarkedale and Rohwer (Coker and Oosterhuis, 2000), in 2001 at Clarkedale (Coker et al., 2002), and at Fayetteville in 2002. This report describes the 2002 study with reference to the previously conducted studies (cited above) with identical treatments. Eight treatment combinations of well-watered (irrigated) or dry-land (non-irrigated) conditions; high- (preplant, soil-applied K) or low-soil K (unfertilized or no preplant K); and with or without foliar K were arranged in a split-split plot design with five or six replications.

In 2002, the cultivar Suregrow 215 BR was planted on a Captina silt loam on the Arkansas Research and Extension Center located in Fayetteville, AR. Each plot consisted of four, 30-ft long rows spaced 39 in. apart. Preplant granular KCl fertilizer was hand broadcast to designated plots (high-soil K) prior to planting at recommended rates based on University of Arkansas fertilizer recommendations for cotton. The average Mehlich 3-extractable soil K was 241 lb K/acre (Table 1). Preplant K fertilizer application rates ranged from 50 to 96 lb K_2O/acre. Foliar KNO_3 was applied (4.4 lb K_2O/acre/week or 10 lb KNO_3/acre) for four consecutive weeks starting one week after first flower with a CO_2 backpack sprayer calibrated to deliver 10 gal/acre. Irrigation events were scheduled in well-watered plots according to the University of Arkansas Irrigation Scheduling Program. At major phenological stages, measurements were made of photosynthesis, canopy temperature, specific leaf weight, ^{13}C discrimination, chlorophyll, adenosine tri-phosphate, soluble carbohydrates, membrane integrity, antioxidant enzymes, and Rubidium translocation in the uppermost fully-expanded leaves. Final lint yield and components of yield were determined from each plot by hand picking a 3.28-ft length from each of the two center rows and counting and weighing the bolls. Lint yield and components of yield comparisons were made using the SAS General Linear Model procedure and PDIFF option within LSMEANS statements.

RESULTS AND DISCUSSION

Leaf Sugars

Effect of foliar-applied K

At three weeks after first flower, glucose, fructose, and sucrose concentrations were lower ($p \leq 0.05$) in leaves from foliar-K treated plots in the low soil K but not the high soil K treatment (Table 1). Under dryland conditions, the concentration of sugars in leaves decreased ($p \leq 0.05$) in response to foliar-applied K.

Effect of soil-applied K.

Glucose and fructose concentrations in leaves were lower ($p \leq 0.1$) in high soil K, irrigated but not rainfed plots at three weeks after first flower. When averaged over the water and foliar-K treatments, leaf glucose and fructose concentrations were lower ($p \leq 0.05$) in high K plots at first flower plus three weeks (Table 2).

Lint Yield

Effect of foliar-applied K

Yield responses to foliar-applied K were noticeably greater at Fayetteville compared to responses observed during previous seasons at Rohwer or Clarkedale (Table 3). In 2002, foliar-applied K increased lint yield ($p \leq 0.05$) by 211 lb/acre when preplant K fertilizer was applied (high-soil K). When preplant K fertilizer was not applied (low-soil K), the lint yield response to foliar-applied K was approximately 90 lb/acre although it was not statistically different than lint yield without foliar-applied K. Thus far, our studies have shown a small lint yield increase to foliar-applied K when preplant K was not applied (low-soil K) as opposed to when preplant-K fertilizer was applied (high-soil K) when averaged across all three-test sites during the past four years.

In 2002, cotton lint yields were significantly greater (p0.05) when foliar-K applications were made to dryland (rainfed or non-irrigated) cotton, but not to irrigated cotton (Table 3). When averaged across all three-test sites, dryland-cotton lint yields have tended to show slightly greater response to foliar-K application under dryland as compared to irrigated-cotton yields.

Effect of soil-applied K

Lint yield response to soil-applied K was significant ($p \leq 0.05$) for irrigated (well-watered) cotton and tended to be positive, although not statistically significant, under dryland conditions in 2002. Across all locations and growing seasons, soil-applied K (high-soil K) increased the mean irrigated cotton lint yield by 5.9% but had no significant effect on dryland-cotton yields in our studies.

Seasonal Growing Conditions at Fayetteville in 2002

Rainfall amounts were below the long-term average for July but closer to the long-term average although unevenly dispersed during August, 2002. Day/night maximum temperatures were moderate throughout the boll development stage compared to previous growing seasons (ie., the late 1990s) at Fayetteville.

PRACTICAL APPLICATION

Studies during the past three years show significant responses to foliar-applied K on soils with pre-plant soil-test K < 250 lb K/acre, which supports our previous findings (Oosterhuis, 1995). Our results also show that the potential for foliar-K feeding to increase cotton lint yield of dryland (non-irrigated) cotton is similar to if not better than that observed for irrigated cotton. Physiologically, this was evidenced in part by lower concentrations of glucose, fructose, and sucrose in leaves in response to foliar-applied K under water-stressed as compared to well-watered conditions during peak boll development. Therefore, the addition of foliar-applied K can help to alleviate mid-season K-deficiency stress in cotton under water-stressed conditions.

Soil-applied K fertilizer was beneficial to cotton-lint yields produced under irrigated but not necessarily under dryland conditions in plots where the preplant soil-test K values ranged from medium to high (> 250 lb K/acre, Mehlich 3 soil K). Hence, the use of appropriate preplant, soil-applied K fertilizer rates may be particularly important to maximize cotton yields under irrigated conditions. In contrast, foliar-applied K, which can stimulate root uptake of soil K, can be beneficial to cotton-lint yield under dryland or irrigated conditions depending on preplant soil-test K values.

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Table 1. Response of sugar concentration at three weeks after first flower in uppermost leaves of field-grown cotton to foliar-applied K averaged over the water and soil K treatments. Fayetteville, 2002.

Treatment	Glucose	Fructose	Sucrose
		(µg/cm²)	
Averaged over water			
High soil K, no foliar K	37.49	43.28	92.43
High soil K, with foliar K	43.25	50.06	103.52
Low soil K, no foliar K	69.3	76.65	134.94
Low soil K, with foliar K	35.96[z]	42.48[z]	98.34[z]
Soil K X foliar K	–[y]	–[y]	–[y]
Averaged over soil K			
Well-watered, no foliar K	33.77	39.09	83.67
Well-watered, with foliar K	35.16	41.32	90.08
Dryland, no foliar K	73.03	80.84	143.70
Dryland, with foliar K	44.05[z]	51.22[z]	111.79[z]
Water X foliar K	--[y]	--[y]	--[y]

[z] Significant at $p \leq 0.05$ for the paired treatments.
[y] Significant at $p \leq 0.05$ for treatment interaction.

Table 2. Response of sugar concentration in uppermost leaves of field-grown cotton at three weeks after first flower to soil-applied K averaged over the water and foliar-applied K treatments. Fayetteville, 2002.

Treatment	Glucose	Fructose	Sucrose
	----------	($\mu g/cm^2$) ----------	
Averaged over foliar K[z]			
Well-watered, high soil K	27.71	33.20	77.16
Well-watered, low soil K	41.21[y]	47.22[y]	96.59
Dryland, high soil K	53.03	60.14	118.79
Dryland, low soil K	64.05	71.92	136.69
Averaged over water and foliar K			
High soil K	40.37	46.67	97.98
Low soil K	52.63[x]	59.57[x]	116.64

[z] No significant (p 0.05) interactions observed between main effects.
[y] Significant at p 0.1 for the paired treatments.
[x] Significant at p 0.05 for the paired treatments.

Table 3. Yield response of field-grown cotton over four seasons to foliar K and preplant soil-applied K averaged over water, soil K, and foliar K treatments, respectively. Rohwer, 1999 and 2000; Clarkedale 2000 and 2001; and Fayetteville, 2002.

	Lint yield						
	Rohwer		Clarkedale		Fayetteville		
Treatment	1999	2000	2000	2001	2002	Mean	Change
	(lb/acre)						[lb/acre (%)]
Avg. over water[z]							
High soil K, no foliar K	1135	1123	948	1359	1286	1170	
High soil K, with foliar K	1133	1116	956	1342	1497[y]	1209	+39 (3.3%)
Low soil K, no foliar K	1113	1088	887	1287	1239	1123	
Low soil K, with foliar K	1153	1074	985y	1359	1331	1180	+57 (5.1%)
Avg. over soil K[z]							
Well watered, no foliar K	1366	1452	1241	1434	1354	1369	
Well watered, with foliar K	1394	1448	1292	1446	1416	1399	+30 (2.2%)
Dryland, no foliar K	882	758	593	1212	1171	923	
Dryland, with foliar K	894	742	649	1255	1412[y]	990	+67 (7.3%)
Avg. over water and soil K							
No foliar K	1126	1105	917	1323	1262	1147	
With foliar K	1143	1094	970	1350	1414[y]	1194	+47 (4.1%)
Avg. over foliar K							
Dryland, high soil K	847	724	640	1228	1336	955	
Dryland, low soil K	929	776	602	1239	1247	957	-2 (0.2%)
Well watered, high soil K	1421	1514	1264	1473	1447	1424	
Well watered, low soil K	1338	1386[y]	1269	1407	1323[x]	1345	+79 (5.9%)
Water X soil K	[w]	[w]	–	–	–		
Avg. over water and foliar K							
High soil K	1134	1119	952	1350	1391	1189	
Low soil K	1133	1081	936	1323	1285x	1152	+3 7(3.2%)
Preplant soil K level (lb/acre)							
Well watered	264	334	249	263	241	270	
Dryland	253	336	249	289	241	274	

[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 $p \leq 0.10$ for the paired treatments.
[w] Significant at $p \leq 0.05$ for treatment interaction ("–" = no interaction).

Cotton Response to Potassium and Phosphorus Fertilization in a Silt Loam[1]

Morteza Mozaffari, Michelle A. Henslee, Nathan A. Slaton, Edwin Evans, J.Scott McConnell, and Claude Kennedy[2]

RESEARCH PROBLEM

Potassium (K) and phosphorus (P) are two macronutrients required for cotton production (*Gossypium hirsutum* L.). Cotton yield or quality can be impacted if sufficient amounts of either nutrient are not available for plant uptake. Two field experiments were conducted to evaluate the effect of K and P fertilization on cotton yield and petiole concentrations of K and P.

BACKGROUND INFORMATION

Potassium plays a pivotal role in lint development and P is essential for energy transfer within the cotton plant. A one ton crop of cotton removes 63 lb P_2O_5/acre and 126 lb K_2O/acre (Jones, 2002). Insufficient quantities of either nutrient can adversely affect cotton yield or quality. Similar to N, petiole K concentration is used as a diagnostic tool to assist growers with making in-season foliar K application decisions. Cotton production practices have dramatically changed during the past three decades. An example is the introduction of new fast-fruiting cultivars. These cultivars may have different nutritional requirements than the obsolete cultivars that were originally used to develop our current fertilizer and petiole K monitoring recommendations. In order to provide Arkansas growers with up-to-date technical information, new field experiments are needed to evaluate the effect of K and P fertilizer rates on cotton yield and nutrient concentrations in the petiole.

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RESEARCH DESCRIPTION

Two separate, replicated field experiments were conducted at the University of Arkansas Cotton Branch Experiment Station (CBES) in Marianna, AR, during the 2002 growing season to evaluate the effect of K and P fertilization on cotton yield and petiole K and P concentrations, respectively. The soil at the experimental site is mapped as Loring silt loam. Prior to planting, two composite soil samples were collected from the top 6 inches of each plot; each composite sample consisted of eight 1-inch diameter samples from the eight cotton rows. Soil samples were extracted with Mehlich-3 solution (1:10 ratio) and concentration of elements in the soil extract was measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Nitrate, pH, and EC were measured by standard University of Arkansas soil testing procedures and results were tabulated (Tables 1 and 2). Cotton (Stoneville 4892) was planted in 38-inch row spacings on 21 May using recommended conventional tillage practices for both experiments.

Individual K fertility plots were 90 ft long and 25 ft wide and P plots were 200 ft long and 25 ft wide. Potassium fertilizer was applied at 0, 30, 60, and 120 lb K_2O/acre as muriate of potash (KCl) and P was applied at 0, 30, 60, and 90 lb of P_2O_5/acre as triple super phosphate. Both fertilizers were mechanically incorporated into the soil prior to planting. All experimental plots received a blanket application of 60 lb N/acre as NH_4NO_3 at the pinhead square stage. The design of both experiments was a randomized complete block with four replications of each treatment. Cotton petiole samples were collected for 10 consecutive weeks starting on 1 July and ending on 5 September. The first two weeks, 24 petioles from the fifth node from the top were randomly collected from each plot. The final eight weeks, 16 petioles from the fifth node from the top were randomly collected from each plot. Cotton petioles were dried overnight at 70°C and ground to pass a 1-mm seive. A 0.075-g sub-sample was also mixed with 21 mL of 2% acetic acid, shaken for 10 minutes, and filtered. Petiole concentrations of K, P, and S were determined by ICP-AES. At maturity, seedcotton yield was measured from the center four rows of each plot with a 4-row cotton picker equipped with an AgLeader™ cotton yield monitor. Analysis of variance was used to evaluate the effect of K or P fertilizer rates on cotton yield and petiole nutrient concentrations with significant treatment means separated by the Waller-Duncan test.

RESULTS AND DISCUSSION

K Fertilization

Seedcotton yield ranged from 1685 to 1846 lb/acre (calculated lint yield 590 to 684 lb/acre) and was not significantly affected by K fertilizer rate (Table 3). This was somewhat unexpected since according to current recommendations a yield response to K fertilizer is anticipated when preplant soil-test K concentrations are <200 lb K/acre. Petiole K concentrations increased as K fertilizer application rate increased for the first

seven sample times but were not affected at the final two sample dates (Table 4). Within each sample time, petiole K started to decline one week after the first bloom (July 22) and consistently decreased throughout the rest of the growing season (Table 4). This is consistent with the general trend of K utilization by growing cotton plants. Petiole K was consistently below the lower sufficiency range (listed in Table 4) for all treatments amended with <120 lb K_2O/acre. This suggests that on this soil the current K sufficiency ranges, established with older cultivars, may not be accurate for prescribing in-season K fertilizer applications or that perhaps the subsoil contains a significant amount of plant available K.

P Fertilization

Seedcotton yield ranged from 2412 to 2717 lb/acre (calculated lint yield range 824 to 951 lb/acre) and was not significantly affected by P fertilizer application rate (Table 5). This was not unexpected since preplant soil-test P was high enough (Table 2) that only a small amount (10 lb P_2O_5/acre) of P fertilizer was recommended by University of Arkansas cotton fertilization guidelines. This indicates that the current upper limit of soil-test P for cotton appears to be appropriate or could possibly be lowered. Petiole-P concentrations were not affected by P fertilizer application rate and there was no consistent trend in concentration changes for petiole P during the season (Table 6).

PRACTICAL APPLICATION

Potassium fertilizer application failed to increase cotton yields on a Loring silt loam with preplant soil-test K ranging from 192 to 199 lb K/acre. However, petiole K concentration increased as K fertilizer rate increased. In this experiment the current lower sufficiency range for petiole K was not an accurate assessment of the need for K fertilization since cotton yield did not respond to K fertilization. Sufficiency ranges may need to be recalibrated for petiole monitoring to be an effective diagnostic tool for prescribing in-season foliar K application. No yield response to P fertilization was observed when preplant Mehlich-3 extractable (1:10 ratio) soil-test P ranged from 72 to 76 lb/acre. This soil-test P is equivalent to approximately 50 lb/acre in current recommendation where 1:7 soil:solution ratio is used. The current upper levels of soil-test P for cotton appears to be appropriate for identifying soils that are not responsive to fertilizer application. However, to prevent excessive P buildup in Arkansas soils additional soil-test calibration data are needed.

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Table 1. Selected chemical properties before fertilizer application of the top 15 cm of soil used for a K-fertilization study conducted at the Cotton Branch Experiment Station during 2002.

		Mehlich-3 extractable nutrients[z]					
N rate	pH	NO_3-N	P	K	Mg	Ca	B
(lb N/acre)		(lb/acre)					
0	6.4	26	75	194	419	2626	0.9
30	6.3	38	73	199	419	2714	1.0
60	6.5	34	73	194	417	2681	3.4
120	6.3	28	74	192	424	2798	0.9

[z] Modified Mehlich-3 extraction (1:10 extraction ratio).

Table 2. Selected chemical properties before fertilizer application of the top 15 cm of soil used for a P-fertilization study conducted at the Cotton Branch Experiment Station during 2002.

		Mehlich-3 extractable nutrients[z]					
N rate	pH	NO_3-N	P	K	Mg	Ca	B
(lb N/acre)		(lb/acre)					
0	6.7	14	76	255	271	1736	0.6
30	6.6	13	72	244	153	1601	0.5
60	6.7	13	72	235	250	1646	0.6
120	6.7	12	72	240	248	1612	0.8

[z] Modified Mehlich-3 extraction (1:10 extraction ratio).

Table 3. The effect of K fertilizer application rate on cotton yield at the Cotton Branch Experiment Station in 2002.

N rate	Seedcotton yield	Lint yield	Lint yield
(lb/acre)	------------------- (lb/acre)	----------------	(bale/acre)
0	1685	590	1.21
30	1954	684	1.46
60	1846	646	1.34
120	1839	644	1.33
Significance	NS[z]	NS	NS

[z] NS = not significant at P = 0.05 probability level.

Table 4. Effect of K fertilizer rate on cotton petiole K concentration at the Cotton Branch Experiment Station during 2002.

	Seedcotton	Sampling date								
K rate	yield	July 8	July 15[z]	July 22	July 29	Aug. 5	Aug. 12[y]	Aug. 19	Aug. 26	Sept. 3
(lb K_2O/acre)	(lb/acre)	------------------	------------------	------------------	------------------	[Petiole K (%)]	------------------	------------------	------------------	------------------
0	1685	2.5	1.8	3.2	3.0	1.7	1.2	1.2	1.0	1.0
30	1954	2.8	2.1	3.8	3.4	2.1	1.6	1.5	1.5	0.9
60	1846	3.2	2.5	4.1	3.6	2.4	2.0	2.0	1.5	1.3
120	1839	4.1	3.1	4.6	4.3	2.9	2.4	2.3	1.2	1.2
Lower sufficiency level[x]		4.0	4.0	4.0	3.5	3.0	2.5	2.0	1.7	1.3
Significance		**[v]	**	*	+	**	**	**	NS[w]	NS
MSD (0.05)[u]		0.4	0.4	0.8	1.2	0.3	0.5	0.6	NS	NS

[z] First bloom on 19 July.

[y] Cut-out occurred on 17 August; first open boll on 9 September.

[x] Published by Snyder et al., 1995.

[w] NS = not significant.

[v] **, *, + significant at P = 0.01, 0.05, and 0.10 probability level, respectively.

[u] Minimum Significant Difference as determined by Waller-Duncan test.

Table 5. The effect of K fertilizer application rate on cotton yield at the Cotton Branch Experiment Station in 2002.

N rate	Seedcotton yield	Lint yield	Lint yield
(lb/acre)	---------- (lb/acre) ----------		(bale/acre)
0	2414	844	1.75
30	2593	908	1.88
60	2354	824	1.71
120	2717	951	1.98
Significance	NS[z]	NS	NS

[z] NS = not significant at P = 0.05 probability level.

Table 6. Effect of P fertilizer rate on cotton petiole P concentration at the Cotton Branch Experiment Station during 2002.

	Seedcotton	Sampling date								
P rate	yield	July 8	July 15[z]	July 22	July 29	Aug. 5	Aug. 12[y]	Aug. 19	Aug. 26	Sept. 3
(lb P_2O_5/acre)	(lb/acre)	---------- [P (mg/kg)] ----------								
0	1685	2.5	1.8	3.2	3.0	1.7	1.2	1.2	1.0	1.0
0	2412	1068	916	2030	2157	1734	999	1599	1822	1876
30	2593	1063	898	2038	2340	1766	992	1622	1629	1759
60	2354	1014	904	1997	2428	1691	1034	1536	2236	2123
90	2717	1266	937	2199	2558	1616	931	1580	1787	2054
Significance		NS[x]	NS	NS	NS	NS	NS	NS	NS	NS

[z] First bloom on 19 July.

[y] Cut-out occurred on 17 August with first open boll on 9 Sept.

[x] NS = not significant at P = 0.05 probability level.

Effect of Soil- and Foliar-Applied Boron on the Yield and Physiology of Cotton under Two Nitrogen Regimes

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

RESEARCH PROBLEM

Current boron (B) recommendations are based largely on research conducted nearly 30 years ago and little is known of the physiological effect that B has on the cotton plant. For this reason a series of field studies were conducted to determine the agronomic and physiological implications of B fertilization. It was hypothesized that improved B nutrition will increase boll weight and boll number, and total lint yields. To test this hypothesis the following objectives were designed. The main objective was to determine how B fertilization impacted boll retention, boll development, and overall lint yield. A secondary research objective was to determine the effect that B had on certain physiological aspects of field grown cotton.

BACKGROUND INFORMATION

Boron has long been known as an essential micronutrient element required for optimal growth and development of cotton (*Gossypium hirsutum* L.) plants. Boron has also been shown to play an important role in the physiology of cotton (Zhao and Oosterhuis, 2002, 2003). Current production recommendations in Arkansas call for initial preplant soil applications of 1.0 to 2.0 lb B/acre or 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). Boron deficiency is common in highly leached and acidic sandy soils of cotton growing regions in the world. Boron is important in pollen germination and pollen tube growth for successful fruit formation. Therefore, B deficiency during flowering and fruiting may significantly reduce boll retention, resulting in low yield and poor fiber quality. However, little is known about the effect of B deficiency during the early growth of cotton prior to squaring on subsequent growth and physiology of the plant.

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RESEARCH DESCRIPTION

Field studies were planted during early to mid-May each year (2000-2002) at Clarkedale in northeast Arkansas in a Dundee silt loam to determine what effect B fertility had on lint yields. Additionally, in 2002 specific leaf weight and chlorophyll content were evaluated to determine the effect of B fertility on the physiology of cotton. Each year the study was planted in a split-plot design with five replications and six treatments. All plots were furrow irrigated as needed. Treatments included a control with no soil or foliar-applied B; foliar B applied at a rate of 0.2 lb B/acre at FF, FF + 2 weeks, and also at FF+4 weeks; and soil-applied B at a rate of 1.0 lb/B acre applied at PHS. Each of the three B treatments were evaluated under high N (100 lb N/acre) and low N (50 lb/acre) conditions. At final harvest, a subsample of two meters per plot was collected to evaluate yield components for purposes of explaining yield development.

RESULTS AND DISCUSSION

Lint Yields

Soil- or foliar-B treatments had no significant affects on lint yields irrespective of soil N level (Table 1). Also, there were no significant differences in yield for the N treatments when averaged over B treatments. This lack of significant differences is likely due to high initial N and B levels in the soil at time of planting each year.

Yield Components

There was no significant interaction ($P<0.05$) between B and N treatments for increasing the number of bolls or average weight of bolls collected from a two-meter row length at harvest (Table 2). These yield components also failed to show a significant effect at the individual B or N level. Averaged over B, the high-N treatment resulted in the highest numerical boll number but had the lowest average boll weight.

Specific Leaf Weight (SLW) and Chlorophyll

There was no significant effect at the B level for changing the specific leaf weight of cotton leaves when averaged over N levels; however when averaged over B levels, the low-N leaves had significantly greater specific leaf weights (Table 3). Chlorophyll content was highly significant ($P<0.001$) at the N-level with high-N leaves having higher chlorophyll values. There was no significant difference at the B level with respect to chlorophyll content. However, there was a significant interaction between B and N levels for changing the chlorophyll content of cotton leaves (Table 3).

PRACTICAL APPLICATION

Results from this three-year yield study indicated that soil- or foliar-applied fertilizer B may not have been necessary on the Dundee soil for obtaining high cotton yields irrespective of N status. The number of bolls per acre and average boll weight were also very similar between B treatments. In terms of physiology, there were no differences between B treatments for altering chlorophyll content or specific leaf weight. However, plants grown in low-N soil levels had thicker leaves with lower chlorophyll content and there was a significant interaction between B and nitrogen in regard to chlorophyll content. These results indicate that B as well as N levels in the plant are very critical for maintaining plant physiological processes; however the routine application of additional B may not be necessary for maximizing yield in Arkansas. This needs to be confirmed on other cotton soils. These non-significant differences in lint yield should be interpreted with respect to initial soil-B levels which were above the recommended levels for optimum fertility.

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Table 1. Effect of soil- and foliar-applied B under two nitrogen regimes on the lint yield of cotton in Clarkedale, AR, from 2000 to 2002.

	Lint yield			
Treatment	2000	2001	2002	3-year average
	(lb/acre)			
High N-control	1348	965	829	1047
High N-soil B	1462	921	834	1072
High N-foliar B	1302	911	835	1016
Low N-control	1296	998	809	1034
Low N-soil B	1352	961	775	1029
Low N-foliar B	1392	902	808	1034
LSD (0.05)	NS[z]	NS	NS	NS

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

Table 2. Effect of soil- and foliar-applied B under two nitrogen regimes on yield components of cotton measured at final harvest during the 2002 growing season at Clarkedale, AR.

Treatment	Boll number	Average boll weight
	(no./acre)	(g/boll)
High N-control[z]	146,400 a	3.86 a
High N-soil B	162,900 a	3.84 a
High N-foliar B	146,900 a	3.73 a
Low N-control	146,800 a	4.08 a
Low N-soil B	143,800 a	3.66 a
Low N-foliar B[z]	156,100 a	3.89 a

[z] There was not a significant difference at the B level or at the N level at $P<0.05$.

Table 3. Effect of soil- and foliar-applied B under two nitrogen regimes on the specific leaf weight and chlorophyll content of cotton measured three weeks after first flower during the 2002 growing season at Clarkedale, AR.

Treatment	Chlorophyll content[z]	Specific leaf weight
	(SPAD units)	(g/m^2)
High N-control	45.6 a[y]	63.0 b
High N-soil B	46.1 a[y]	61.6 b
High N-foliar B	45.6 a[y]	62.8 b
Low N-control	39.8 b	64.7 a[y]
Low N-soil B	35.6 b	64.0 a[y]
Low N-foliar B	40.2 b	64.1 a[y]

[z] There was a significant interaction between B and N levels for chlorophyll content at $P<0.03$.
[y] There were significant differences at the N level for chlorophyll and specific leaf weight at $P<0.05$.

Field Test of a New Cotton Petiole Monitoring Technique

Derrick M. Oosterhuis, Dennis L. Coker, and Donald E. Plunkett[1]

RESEARCH PROBLEM

Potassium (K) deficiencies in cotton (*Gossypium* hirsutum L.) are frequently observed in fields during the mid- to later-parts of the growing season. Previous research has shown that the boll load was a major driving force influencing petiole nutrient levels (Oosterhuis and Bondada, 2001) and that petioles lower in the canopy, closer to the developing boll load, may be more sensitive to plant nutrient levels (Bednarz and Oosterhuis, 1996). Hence, analysis of the lower-position petioles should more clearly show the development of a pending K deficiency such that timely remedial action can be taken.

BACKGROUND INFORMATION

Symptoms of K deficiency frequently occur in cotton fields when root growth is reduced after flowering and the rapidly developing boll load serves as the dominant sink for available K (Oosterhuis, 1995). Previous research evaluated the petiole sampling program with particular respect to physiological factors influencing plant response to deficiencies (Bednarz and Oosterhuis, 1996; Zhao and Oosterhuis, 1998). In the previous two years, conventional and modified petiole sampling procedures were compared in field tests at ten Cotton Research Verification Program (CRVP) sites on farms in Arkansas (Oosterhuis and Coker, 2001). The results showed that the lower petiole (i.e. eighth main-stem node) did indeed show a drop in K status before the conventionally sampled fourth node from the terminal. 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. Furthermore, because almost half the cotton in the mid-South is dryland, it was important to determine how water stress

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might affect K concentration in petioles. The objective of this study was to observe the effect of soil K level/fertilizer regime, plant water status, 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).

RESEARCH DESCRIPTION

Cotton was grown in field plots at the Arkansas Agricultural Research Center in Fayetteville, AR, during summer 2002. Eight treatment combinations of well-watered or dryland conditions, high-soil K or low-soil K, and with foliar-applied K or without foliar-K were arranged in a split-split plot design with five replications. Each plot consisted of four 30-ft long rows, spaced 39 in. apart. The cotton cultivar Suregrow 215 BR was planted into a moderately well-drained Captina silt loam on 23 May 2002. Preplant granular KCl fertilizer was hand broadcast to high-soil K plots at recommended rates (i.e., 50 to 96 lb K_2O/acre) based on University of Arkansas fertilizer recommendations (Sabbe, 1998). Other fertility inputs, and insect and weed control were managed according to Extension recommendations for cotton grown in Arkansas. Beginning two weeks after pinhead square, 10 to 15 petioles from main-stem nodes 4 and 8 were sampled weekly from the plots without foliar-applied K. Upon collection, the petioles were promptly dried at 60°C, ground to pass a 2 mm screen, and submitted to the Arkansas Soil Test Research Laboratory at Marianna, AR, for nutrient analysis. Final lint yield and components of yield were determined by hand harvesting a 1-m length from each of the two center yield rows and counting the number of bolls. Gin turnout was calculated for each plot by ginning a 120 g subsample of seedcotton.

RESULTS AND DISCUSSION

Rainfall amounts were below the long-term average in July but near average and unevenly dispersed during August, 2002. Day/night maximum temperatures were moderate throughout the boll development stage compared to previous growing seasons at Fayetteville.

Petiole K

Potassium deficiency symptoms were apparent in mid- to upper-canopy leaves beginning at first flower under the high soil-K 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 from three weeks after pinhead square until three weeks after first flower (Fig. 1). These observations were very similar to our earlier observations at Clarkedale in 2001 and Rohwer, AR, in 1999 (data not shown).

Petiole-K concentration in node 4 and 8 petioles differed considerably less under dryland as compared to well-watered conditions throughout the sampling period. However, we did observe a lower K concentration in node 8 as compared to node 4 petioles at one ($p \leq 0.1$) and four weeks ($p \leq 0.05$) after first flower under either level of soil K. Again, these observations were similar to what we saw previously at Clarkedale and Rohwer, AR. According to existing Cooperative Extension recommendations for Arkansas, petiole K concentrations were inadequate for optimal production in all of our primary treatments beginning at first flower.

A significant ($p \leq 0.05$) water x main-stem node interaction for petiole-K concentration was observed beginning three weeks after pinhead square through each sampling date until four weeks after first flower (Table 1). Water deficit appeared to minimize the difference in petiole-K concentration between nodes 4 and 8 beginning at three weeks past the pinhead square stage of growth. Again, these results appeared to be consistent with those from our previous studies on double-petiole sampling. Under water-stressed conditions four weeks after first flower, petiole K concentrations in node 8 petioles were rapidly declining and lower ($p \leq 0.05$) than in node 4 petioles. Overall, the earliest and most clear signal of a pending K deficiency was shown by sampling node 8 (from the terminal) rather than node 4 petioles, particularly under well-watered conditions.

Petiole NO_3-N

Overall, petiole NO_3-N measured in nodes 4 and 8 decreased rapidly between two weeks after pinhead square and first flower and thereafter decreased more gradually or leveled off with the progression of boll development under well-watered or water-stressed conditions (data not shown). Beginning at three weeks after pinhead square, petiole NO_3-N was generally lower ($p \leq 0.05$) in node 8 versus node 4 petioles under either level of soil K, in well-watered conditions. According to Extension recommendations (Snyder et al., 1995), node 8 petiole NO_3-N concentrations were in the deficient range by first flower at either level of soil K under well-watered conditions. Under water-stressed conditions and both levels of soil K, node 4 petiole NO_3-N concentration was lower ($p \leq 0.05$) compared to node 8 at three weeks after pinhead square and first flower. At these early stages, the NO_3-N concentrations shown in fourth-node petioles rather than eighth-node petioles would have been considered near deficient by Extension recommendations. At three and four weeks after first flower, NO_3-N concentration in the node-8 petiole was lower ($p \leq 0.05$) compared to node 4 petiole NO_3-N under dryland conditions and either level of soil K. We observed a water level x main-stem node interaction ($p \leq 0.05$) for petiole NO_3-N at three weeks after pinhead square through four weeks after first flower, except no interaction was observed at three weeks after first flower (Table 1). We observed the same pattern of interactions with the same study the previous season. The repeated observation of this interaction seemed to

confirm that a water deficit can magnify the difference between node 4 and 8 petiole NO_3-N concentration prior to first flower and the effect may last into the early boll development stage.

Petiole P and S

As found in our previous studies of double-petiole sampling at Clarkedale in 2001 and Rohwer in 2000 (data not shown), node 4 versus node 8 petiole P and S concentrations were different in much the same way as petiole K regarding seasonal plant water status and main-stem node position for petiole sampling.

Yield Versus Main-Stem Node K

Lint yield response to soil-applied K was significant ($p \leq 0.05$) for irrigated cotton and tended to be positive, although not statistically significant, under dryland conditions in 2002 (Fig. 2). Under well-watered conditions, node 8 petiole K concentrations gave the earliest indication of a large drain on plant K supply due to the developing boll load and apparent K deficiency in low-K plots.

PRACTICAL APPLICATION

Our results have shown that soil and plant water status can interact with the availability of petiole NO_3-N and K at different main-stem nodal positions (for petiole sampling). Under well-watered conditions, collection of node 8 instead of node 4 petioles will likely result in a more accurate assessment of pending K deficiencies throughout the flowering and boll development stages. Under water-stressed conditions, collection of node 8 petioles for monitoring plant K status appears equally sufficient to collecting node 4 petioles for detection of a pending deficiency. However, node 4 petioles may be better than node 8 for detection of N deficiencies at early flowering but not necessarily throughout the peak boll development stage under water-stressed conditions. Therefore, cotton producers should strongly consider the plant moisture status and apparent boll loads when monitoring nutrient levels in petioles during the flowering and boll development stages. Our studies have shown that sampling node 8 as opposed to node 4 petioles may be the most effective way to monitor and ameliorate yield-limiting K and N deficiencies in the cotton plant.

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Table 1. Effects of water stress (wat), soil K level (sK), and main-stem node position (MSN) on petiole nutrient concentrations in field-grown cotton, Fayetteville, AR, 2002.

Sampling stage	Treatment/interaction	NO_3-N	P	K	S
		------------ Statistical	difference ------------		
PS+2 weeks[z]	MSN	NS[y]	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	NS	NS	NS	NS
	sK × MSN	NS	NS	P≤0.05	P≤0.05
	wat	NS	NS	NS	NS
	sK	NS	NS	P≤0.05	P≤0.05
	wat × sK	NS	NS	NS	NS
PS+3 weeks	MSN	NS	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	P≤0.05	p≤0.1	P≤0.05	p≤0.1
	sK × MSN	NS	NS	NS	NS
	wat	P≤0.05	NS	p≤0.1	P≤0.05
	sK	NS	NS	P≤0.05	NS
	wat × sK	NS	p≤0.1	p≤0.1	NS
FF[x]	MSN	NS	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	P≤0.05	P≤0.05	P≤0.05	P≤0.05
	sK × MSN	NS	NS	NS	NS
	wat	P≤0.05	P≤0.05	P≤0.05	P≤0.05
	sK	NS	NS	NS	NS
	wat × sK	NS	p≤0.1	NS	NS
FF+1 week	MSN	p≤0.1	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	P≤0.05	P≤0.05	P≤0.05	P≤0.05
	sK × MSN	NS	NS	NS	NS
	wat	P≤0.05	P≤0.05	p≤0.1	P≤0.05
	sK	NS	NS	NS	P≤0.05
	wat × sK	NS	p≤0.1	NS	p≤0.1
FF+2 weeks	MSN	NS	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	P≤0.05	P≤0.05	P≤0.05	NS
	sK × MSN	NS	NS	NS	NS
	wat	p≤0.1	P≤0.05	P≤0.05	NS
	sK	NS	NS	NS	NS
	wat × sK	NS	NS	NS	NS
FF+3 weeks	MSN	P≤0.05	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	NS	P≤0.05	P≤0.05	NS
	sK × MSN	NS	NS	NS	NS
	wat	NS	P≤0.05	P≤0.05	p≤0.1
	sK	NS	NS	NS	NS
	wat × sK	NS	NS	NS	NS
FF+4 weeks	MSN	P≤0.05	P≤0.05	P≤0.05	P≤0.05
	wat × MSN	P≤0.05	NS	P≤0.05	NS
	sK × MSN	NS	NS	NS	NS
	wat	p≤0.1	NS	NS	NS
	sK	NS	NS	P≤0.05	NS
	wat × sK	NS	NS	P≤0.05	NS

[z] PS = pinhead square stage.
[y] NS = not statistically significant.
[x] FF = first flower.

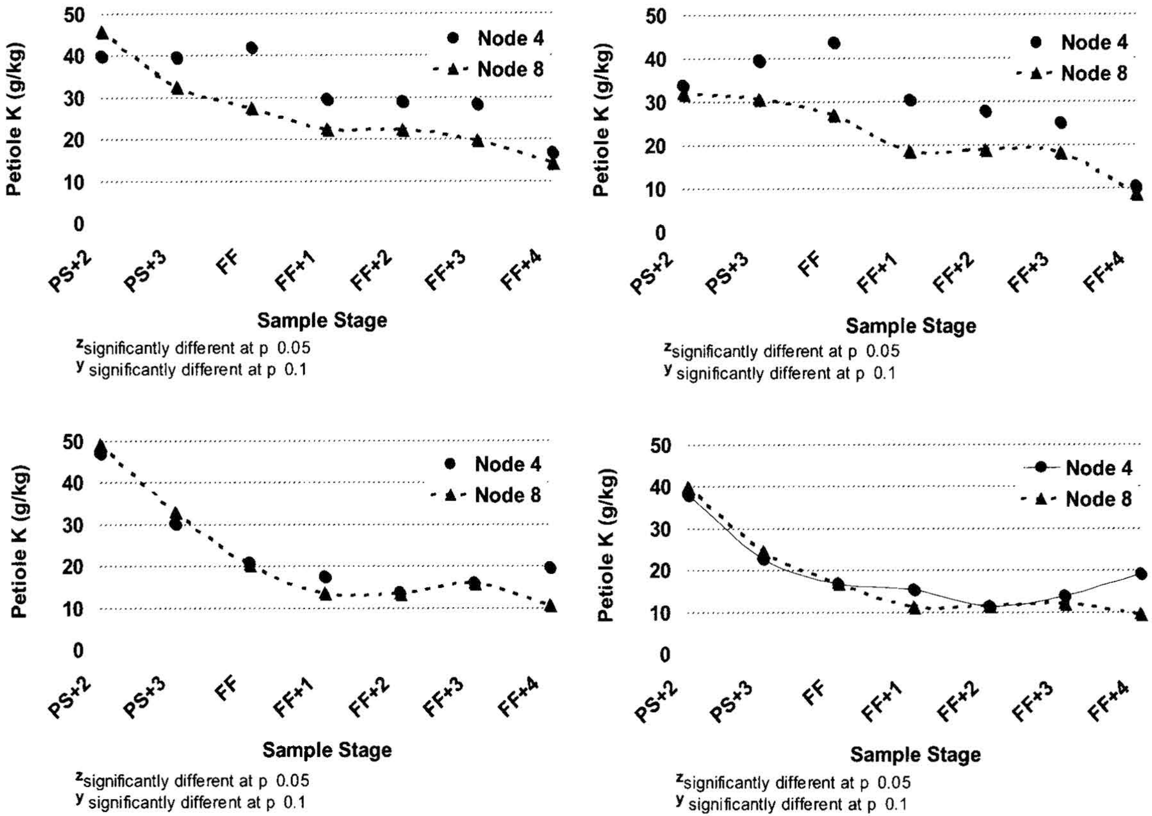

Fig. 1. Petiole KNO_3-N status at main-stem nodes 4 and 8 in cotton grown under well-watered or dryland conditions and high or low soil-K levels. Fayetteville, AR, 2002.

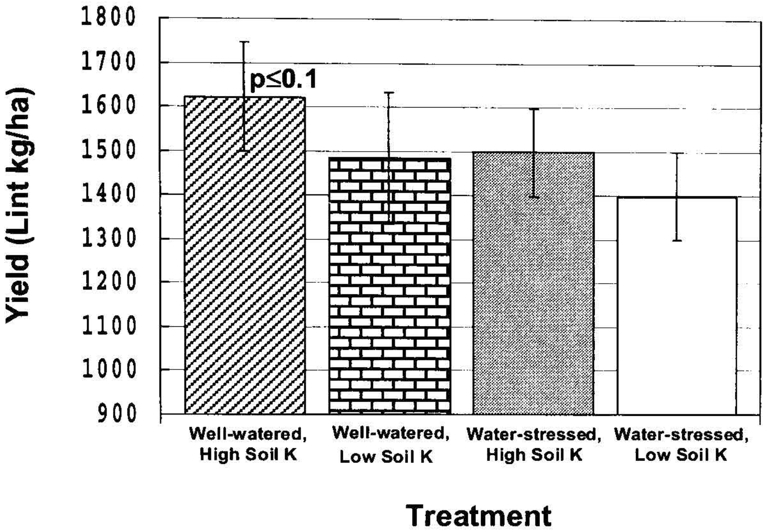

Fig. 2. Effect of soil-applied K on yield under well-watered (WW) and water-stressed (WS) conditions. Fayetteville, Arkansas, 2002. Bars indicate standard error values of the treatment means.

Determining the Optimum Timing for the Final Irrigation on Arkansas Cotton

Earl Vories, Jeremy Greene, Tina G. Teague, William C. Robertson, and Phil Tacker[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 of the whole crop. These studies are part of a multi-state project the overall objective of which is to develop crop-based recommendations for timing the final irrigation on cotton grown in a range of typical field environments. This report describes the studies conducted in Arkansas in 2002.

BACKGROUND INFORMATION

Cotton growers across the Cotton Belt are adopting COTMAN, a COTton MANagement system developed at the University of Arkansas, 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 (Oosterhuis et al., 1999).

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. Currently, research-based decision guides have been

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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 follow the approach taken with other management recommendations

RESEARCH DESCRIPTION

Six irrigation termination studies were conducted in Arkansas during the 2002 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.

Northeast Arkansas

Three studies were conducted in Mississippi County in northeast Arkansas. One study was on the Northeast Research and Extension Center (NEREC) at Keiser, on a field containing areas of Sharkey silty clay and Sharkey-Steele complex soils. Irrigation plots were 4 rows approximately 800 ft long, with 4 buffer rows between plots. 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 were 18 rows approximately 1200 ft long. A third study with four replications was on fields under four similarly located center pivots with the same cultivar and similar (i.e., over a four-day period) planting dates. Irrigation plots were approximately 40 acres in size (one-fourth of a quarter-mile pivot), with each separate pivot functioning as a replication. Excessive rainfall interfered with the treatments for all three studies.

East-central Arkansas

One study was conducted in Lee County in east-central Arkansas on the Cotton Branch Experiment Station (CBS) near Marianna. The experiment with five replications was on a Memphis silt loam. Irrigation plots were 4 rows approximately 800 ft long, with 4 buffer rows between plots. Seedcotton weights were determined from all 4 rows of each plot.

Southeast Arkansas

Two studies were conducted in Desha County in southeast Arkansas on the Steve Stevens Farm near Rohwer. One experiment with four replications was on the east Weaver field on a Hebert silt loam. Irrigation plots were 12 or 16 rows approximately 1200 ft long. Seedcotton weights were determined from the center 4 rows of each plot. The second experiment with four replications was on Barrett field on a Rilla silt loam. Irrigation plots were 16 rows approximately 500 ft long. Seedcotton weights were determined from the center 8 rows of each plot.

RESULTS AND DISCUSSION

Northeast Arkansas

While the NEREC field reached NAWF=5 on 77 DAP, 3 days earlier than the 80 DAP for the COTMAN TDC (Table 1), the other two fields took much longer (approximately 100 days). The differences were probably due to the differences in planting date. The NEREC field was planted more than two weeks after the other two fields and did not experience as much cool weather early in the season. However, frequent rains interfered with the treatments and none of the studies were harvested.

East-central Arkansas

The CBS field reached NAWF=5 on 76 DAP (6 August), 4 days earlier than the 80 DAP for the COTMAN TDC (Table 1). The difference was probably due to the relatively late planting date (22 May) and thus warmer temperatures, and was not an indicator of a stressed crop. The crop received many of the rains that interfered with the studies in northeast Arkansas and no treatments near NAWF=5 could be applied. However, after the rain of 17 August it was dry enough for three treatments. The 17 August rainfall was treated as the final "effective" irrigation for the earliest treatment (Table 2). A significant yield increase was observed for one additional irrigation on 22 August (16 days and 343 DD60 after NAWF=5) but not for a second (Table 3).

Southeast Arkansas

Even though the planting dates differed by nine days, the fields reached NAWF=5 only one day apart, 27 July (89 DAP) and 26 July (97 DAP), for Stevens east Weaver and Stevens Barrett, respectively (Table 1). The longer time for Stevens Barrett resulted from early-season stress that delayed fruiting. The similar yields for the two fields (Table 3) suggest that the crop recovered from the early stress. A 1.25-inch rain occurred on 14 August, one day after an irrigation at east Weaver. Therefore, 14 August was considered the "effective" irrigation date and all calculations were based on

that date. Final irrigations ranged from 14 August (18 days or 400 DD60 after NAWF=5 at east Weaver) to 5 September (40 days or 862 DD60 after NAWF=5 at east Weaver) (Table 2). Yield was not significantly affected by termination date at either location (Table 3).

PRACTICAL APPLICATION

Only one of the six studies showed significant differences in cotton yield with later irrigation; however, rainfall affected the studies in southeast Arkansas and prevented completion of the northeast Arkansas studies. Where yield difference was significant, no differences were observed later than 16 days or 343 DD60 after NAWF=5. Similar coordinated studies were conducted in Louisiana, Mississippi, Texas, and Missouri in 2002 and studies at these locations will be continued in 2003. 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, Chuck Capps, Bob Glover, and Dale Wells.

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Table 1. Cultivar and significant dates for each site from the 2002 cotton irrigation termination studies.

Location	Cultivar	Planting date	NAWF=5 Date	NAWF=5 DAP	Harvest
NEREC	SG 747	16 May	1 Aug	77	--
Wildy 89	DP 451 B/RR	24 Apr	3 Aug	101	--
Wildy pivot[z]	SG 215 BG/RR	30 Apr	6 Aug	98	--
CBS	PM 1218 BG/RR	22 May	6 Aug	76	8 Oct
Stevens E Weaver	ST 4892 BR	29 Apr	27 Jul	89	2 Nov
Stevens Barrett	DP 451 B/RR	20 Apr	26 Jul	97	30 Sep

[z] Several fields under four center pivots with common cultivar and planting date.

Table 2. Timing of the final irrigation in the 2002 cotton irrigation termination studies.

Treatment	Final irrigation Date	Days after planting	Days after NAWF=5	DD60 after NAWF=5
CBS				
1	17 Aug[z]	87	11	228
2	22 Aug	92	16	343
3	29 Aug	99	23	480
Stevens E Weaver				
1	14 Aug[y]	107	18	400
2	22 Aug	115	26	569
3	28 Aug	121	32	688
4	5 Sep	129	40	862
Stevens Barrett				
1	14 Aug	116	19	424
2	21 Sep	123	26	568
3	28 Sep	130	33	710
4	4 Sep	137	40	845

[z] Date represents last of several days with rain, used as "effective" irrigation date.
[y] Date changed by one day to account for rain on day following irrigation.

Table 3. Lint yield, assuming 35% gin turnout, from the 2002 cotton irrigation termination studies.

Treatment	Lint yield
	(lb/acre)
CBS	
1	1150
2	1234
3	1281
LSD (0.05)	61
Stevens E Weaver	
1	1097
2	1105
3	1096
4	1117
LSD (0.05)	NS[z]
Stevens Barrett	
1	1087
2	1088
3	1066
4	1085
LSD (0.05)	NS

[z] NS = not significant.

Comparing the Last Effective Boll Populations in UNR 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) indicates physiological cutout (Oosterhuis et al., 1999) may need to be changed for ultra-narrow-row (UNR) cotton. This study is part of a multi-state project the overall objective of which is to determine the main-stem node number of the last effective boll population in UNR cotton as grown in a range of typical field environments, compared to wide-row cotton in those environments. This report describes the study conducted in northeast Arkansas in 2002.

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., regarding 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 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 signifi-

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cantly to yield. However, Gwathmey et al. (1999) reported that the current COTMAN cutout reference (i.e., 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. 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 and Glover, 2002). 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, other studies have indicated that growth curves and cutout for low nitrogen and mepiquat chloride-treated cotton differ from the TDC (Oosterhuis et al., 1999, 2001). In addition, 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 nonirrigated cotton (*Gossypium hirsutum* L. cv. PM 1218 BG/RR) in 2002 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 49,000 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 105,000 plants/acre. Planting date was 21 May, with imidicloprid- (Gaucho) treated seed. Nitrogen was aerially applied at 125 lb N/acre as urea on both treatments on 25 June.

At first flower, 16 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 11 August. The tagged bolls were hand picked and the seedcotton was air-dried before weighing. Plots were machine harvested on 17 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 AND DISCUSSION

White flowers were first observed in CONV on 12 July, 52 days after planting (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 21 May for planting, after temperatures were warmer than typical for cotton planted earlier in the growing season. White flowers were first observed in UNR on 17 July, 57 DAP. The five-day delay in flowering was probably due to the flat planting for UNR.

A total of 754 flower tags were recovered, with 451 from CONV plots and 303 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 NAWF value (Table 1). Regression analysis indicated a NAWF at first flower of 6.9 for the CONV plots and 4.7 for UNR. The value for UNR (4.7) is below the value normally associated with physiological cutout (5) and demonstrates the need for this research. In fact, only 29 of the 303 tags (<10%) recovered from UNR plots had NAWF 5, versus 47% for CONV. The rate of decline (slope) was not significantly different between treatments. The effective flowering period (period from first flower to NAWF=5) was 12 days for CONV, much less than the 20 days associated with the COTMAN TDC. However, drought stress probably affected the days to NAWF=5 and possibly the NAWF at first flower. Of the 754 flower tags recovered, 437 were associated with whole bolls, with 278 and 159 from CONV and UNR plots, respectively. Boll size was only significantly different for NAWF=4, with larger bolls for CONV (data not included).

Lint yields were not significantly different between UNR and CONV, with 555 and 519 lb/acre for UNR and CONV, respectively. Three-year average values of 33% and 29% for CONV and UNR, respectively, reported by Vories et al. (2001) were used for gin turnout 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 = 2, 3, and 4; while more was associated with CONV from NAWF = 5, 6, and 7. The contribution of other bolls, primarily second sympodial-position bolls, was not significantly different (33% and 25% for CONV and UNR, respectively).

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). However, 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 7, CONV had more flowers per acre. Peak flower numbers were associated with NAWF = 2 and 5 for UNR and CONV, respectively. There was significantly higher retention of flowers with UNR for NAWF = 3 and 4 (Fig. 3).

PRACTICAL APPLICATION

Yield distribution oF the plants was different between UNR and CONV, with 48% of UNR yield associated with NAWF = 3 and 4; 38% of CONV yield was associated with NAWF=5 and 6, and 33% 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.

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Table 1. Nodes above white flower data from tagged flowers from ultra-narrow-row cotton study at the University of Arkansas Northeast Research and Extension Center at Keiser in 2002.

	NAWF equation[y]		First flower[x]		NAWF=5[x]	Eff. flowering
Treatment[z]	Slope	Intercept	DAP	NAWF	DAP	period[w]
						(days)
CONV	-0.163	15.4	52	6.9	64	12
UNR	-0.158	14.0	59	4.9	–[v]	–[v]
LSD (0.05)[u]	NS[t]	NS				
TDC[s]	-0.2125	22	60	9.25	80	20

[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 @ first flower and DAP @ NAWF=5 calculated from NAWF equation.
[w] Effective flowering period = days from first flower to NAWF=5.
[v] Peak value < 5, so NAWF=5 and effective flowering period undefined.
[u] Fisher's least significant difference for comparing treatment means at alpha=0.05.
[t] NS = nonsignificant effect.
[s] TDC = COTMAN Target Development Curve.

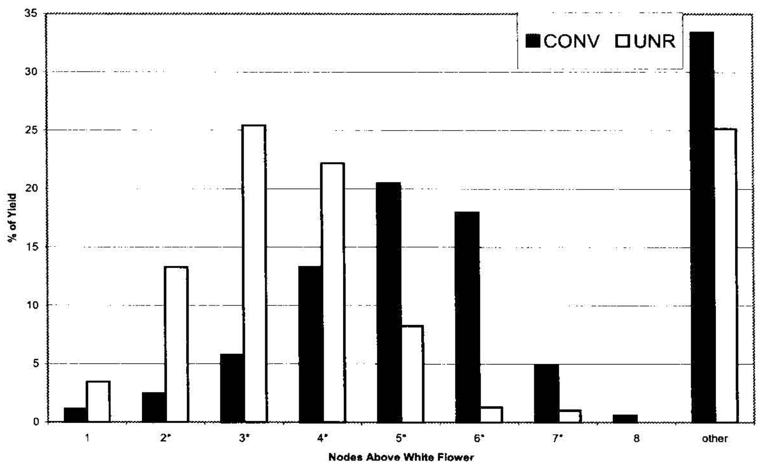

Fig. 1. Distribution of yield by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2002. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. "Other" bolls were collected from somewhere other than first sympodial fruiting position. Nodes with "*" represent a significant difference between treatments at alpha = 0.05.

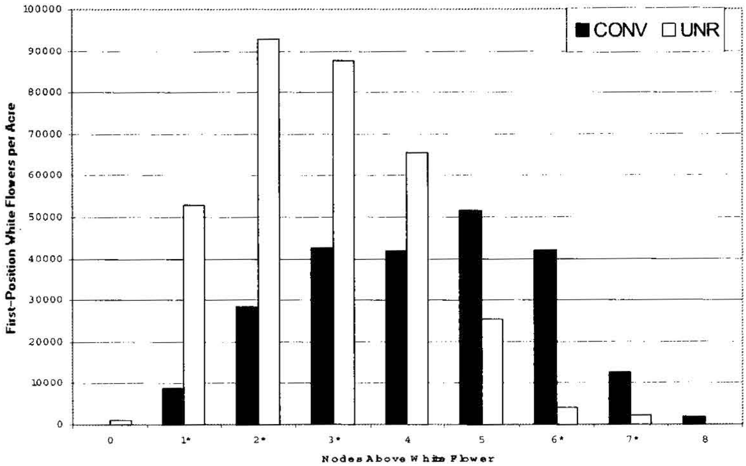

Fig. 2. First-position white flowers per acre by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2002. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. Nodes with "*" represent a significant difference between treatments at alpha = 0.05.

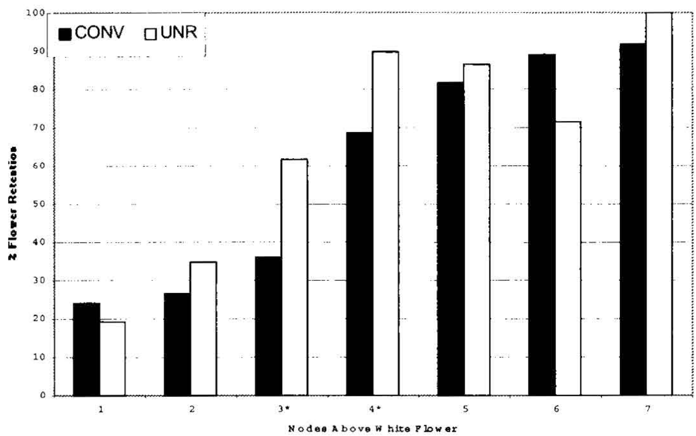

Fig. 3. First-position white flower retention by nodes above white flower from ultra-narrow-row cotton study at the Northeast Research and Extension Center at Keiser in 2002. CONV produced in 38-inch rows and UNR produced in 7.5-inch rows. Nodes with "*" represent a significant difference between treatments at alpha = 0.05.

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 often 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 over 1,000,000 acres in Arkansas in 2001, with almost 65% of those acres irrigated (Arkansas Agricultural Statistics Service, 2002). 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 cultivars and Texas High Plains conditions. Concerns that the curve led to 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 agricultural engineer (Vories), a cotton physiologist (Oosterhuis), and a cotton breeder

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(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 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 cultivars (SG 105; PSC 355; NuCOTN 33 B) were the split-plot treatments. The study was planted on 23 May. Daily evapotranspiration was estimated using the system of Cahoon et al. (1990) adapted for subsurface drip irrigation. The drip irrigation system began daily applications on 1 July. 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 12 July. COTMAN (Danforth and O'Leary, 1998) data were collected throughout the growing season and sequential hand harvests were conducted during the boll-opening period. Lint yields were estimated assuming a 35% gin turnout.

RESULTS AND DISCUSSION

Rainfall during the early part of the growing season was plentiful, with over 3 inches from planting through 10 June (data not shown). From that point until 12 August there were approximately 3 additional inches. However, between 12 August and 24 August approximately 6 inches of rain were recorded. The crop developed at an accelerated pace, probably due to the relatively late planting and warm temperature during vegetative growth. Nodes above white flower (NAWF) peaked <7 on all plots, well below the apex (9.25) of the COTMAN target development curve (TDC). Days to NAWF=5 were significantly affected by the water treatments and by cultivar (Table 1). As expected, NI was the first treatment to reach NAWF=5 and Hi was the last, though the difference between Hi and Lo was not significant. The days to mean maturity based on sequential hand harvests followed the same trend, although the differences among the irrigation treatments were not significant.

The differences in days to NAWF = 5 were not reflected in yield differences (Table 2). In fact, irrigation treatment was not significant for lint yield, lint percent, or fiber quality and no irrigation treatment by cultivar interactions were observed. Cultivar effects were significant for lint percent, micronaire, and length. Larger differences

among the irrigation treatments were expected and were observed in other NEREC cotton studies. The differences in water status of the plots, at least between irrigated and nonirrigated, were fairly large, as indicated by the estimated soil water deficits (Fig. 1) and supported by the soil moisture tension readings from the Watermark sensors (Fig. 2), and were reflected in the days to NAWF = 5 results (Table 1). The study will continue in 2003.

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, although the difference between the two irrigated treatments was not significant. Days to mean maturity followed the same trend; however, lint yield was not significantly affected by irrigation treatment or cultivar. None of the fiber quality parameters had a significant irrigation treatment effect, though lint percent, micronaire, and length had significant cultivar effects.

ACKNOWLEDGMENTS

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Table 1. Crop maturity parameters for the three irrigation treatments and three cultivars in the 2002 drip irrigation study.

Irrigation treatment	Parameter value — Cultivar: SG 105	PSC 355	NuCOTN 33 B	Mean[z]
	NAWF = 5 (DAP)			
NI	63	64	67	65 b
Lo	66	69	71	69 a
Hi	67	71	71	70 a
Mean[z]	65 b	68 a	70 a	
	Mean maturity date (DAP)			
NI	123	119	123	122 a
Lo	123	123	127	124 a
Hi	124	123	126	124 a
Mean[z]	123 b	122 b	125 a	

[z] Means in the same column (irrigation treatment) or row (cultivar) followed by the same letter were not significantly different. No irrigation by cultivar interactions were observed.

Table 2. Crop yield and quality for the three irrigation treatments and three cultivars in the 2002 drip irrigation study.

Irrigation treatment	Parameter value — Cultivar: SG 105	PSC 355	NuCOTN 33 B	Mean[z]
		Lint yield (lb/acre)		
NI	1210	1380	1441	1344 a
Lo	1415	1306	1323	1348 a
Hi	1325	1418	1249	1331 a
Mean[z]	1317 a	1368 a	1338 a	
		Lint percent		
NI	40.2	38.9	37.7	38.9 a
Lo	39.5	38.8	36.4	38.3 a
Hi	39.3	39.2	37.4	38.7 a
Mean[z]	39.7 a	39.0 a	37.2 b	
		Micronaire		
NI	4.55	4.90	4.12	4.72 a
Lo	4.45	4.80	4.05	4.43 a
Hi	4.82	5.20	4.15	4.52 a
Mean[z]	4.61 b	4.97 a	4.11 c	
		Length (in.)		
NI	1.14	1.14	1.16	1.14 a
Lo	1.17	1.14	1.16	1.16 a
Hi	1.14	1.12	1.15	1.15 a
Mean[z]	1.15 a	1.13 b	1.16 a	
		Strength (g/tex)		
NI	29.2	28.8	29.2	29.4 a
Lo	30.9	29.0	29.5	29.8 a
Hi	29.7	29.1	29.6	29.1 a
Mean[z]	29.9 a	29.0 a	29.4 a	

[z] Means in the same column (irrigation treatment) or row (cultivar) followed by the same letter were not significantly different. No irrigation by cultivar interactions were observed.

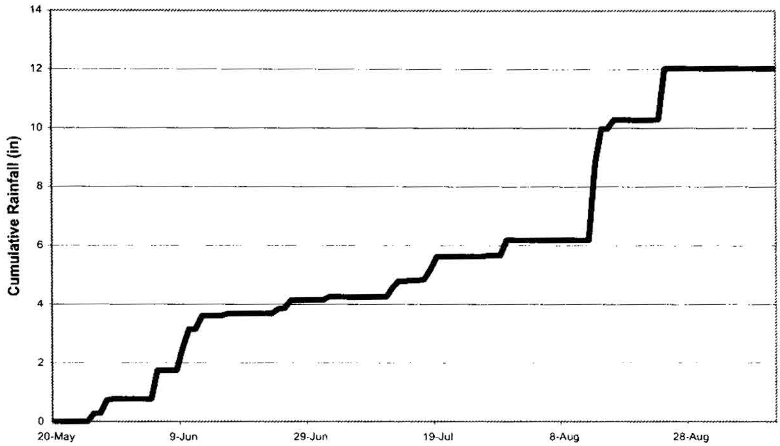

Fig. 1. Estimated soil water deficits for the three irrigation treatments from the Arkansas Irrigation Scheduler in the 2002 cotton drip irrigation study.

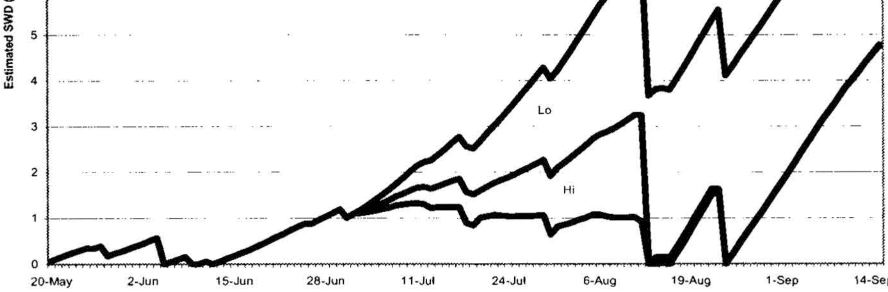

Fig. 2. Soil moisture tension from Watermark sensors for the three irrigation treatments in the 2002 cotton drip irrigation study.

Estimating the Cost of Delaying Irrigation for Cotton on Clay Soil

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

RESEARCH PROBLEM

Yields of irrigated cotton in Arkansas for the past 18 years have leveled off, averaging 838 lb lint/acre. Cotton producers often know that they need to irrigate sooner than they do but have no idea of the cost of delaying irrigation. The risks associated with irrigating are well known to them, especially for furrow irrigation on a clayey soil where the soil will not dry out for several days. Cultivation, pesticide application, and fertilization may have to be delayed for several days after irrigation until the soil dries sufficiently to support traffic without severe rutting or soil compaction. An estimate of the costs associated with waiting to irrigate would allow a more informed decision to be made on what to do first.

BACKGROUND INFORMATION

Data from the National Agricultural Statistics Service (2002) suggest that yields of irrigated cotton in Arkansas for the past 18 years (1984 through 2001) have leveled off, averaging 838 lb lint/acre (Fig. 1). While there has been a consistent increase (average of 214 lb lint/acre during that period) above dryland yields, many producers feel that the variability in irrigated cotton yield is unacceptably high. An example of that variability is in the three years 1992 through 1994. In 1992, average irrigated yields were third highest of the eighteen years (919 lb lint/acre); followed in 1993 by the lowest average irrigated yields of the period (657 lb lint/acre); followed in 1994 by the highest average irrigated yields of the period (951 lb lint/acre; Fig. 1). Since stabilizing yields is often given as a principal reason for investing in irrigation, and an average of 66% of the Arkansas crop was irrigated over the last five years (1997-2001; NASS,

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2002), variability in irrigated yields is a major concern. While some improvement could come through the development of new cultivars, such a shift could take years. Short-term answers will probably have to come through improved management.

Water requirement for cotton varies throughout the season, with low use during the vegetative period and rapidly increasing needs during reproductive growth. The water requirement decreases late in the year as the first bolls mature and air temperatures cool. Current University of Arkansas Cooperative Extension Service (CES) recommendations are to begin monitoring the moisture status of the crop at planting (e.g., tensiometers, water balance calculations) and maintain well-watered conditions until bolls begin to open. Due to factors such as cultivation, fertilization and preparing other crops on the farm, the first irrigation in cotton is often applied later than recommended. Of course, the effect of such a delay will depend greatly on the weather conditions. Periods of drought are less likely early in the season, so rainfall will often prevent excessive stress from developing when an early irrigation is missed. Later in the season, the plants use water at a faster rate and the likelihood of drought is greater.

RESEARCH DESCRIPTION

To investigate the effects of delaying irrigation on cotton, a study was conducted at the Northeast Research and Extension Center at Keiser. The cultivar 'PM 1218 BG/RR' was planted on 21 May 2002 at approximately 5 seeds/ft in 38-in. rows on a Sharkey silty clay (Chromic Epiaquerts) precision graded to approximately 0.2% slope. Nitrogen was applied in a single pre-flower application at a rate of 125 lb N/acre, and no other fertilizers were required. CES recommendations were followed for weed and insect control. All plots were four 38-in. rows by approximately 600 ft long, with all four rows harvested for yield determination. A four-row border area was left between each pair of plots. There were three furrow-irrigated treatments and a nonirrigated check (NI) (Table 1). A well-watered treatment (WW) was irrigated at a 2-in. estimated soil water deficit (SWD) based on the Arkansas Irrigation Scheduler (Cahoon et al., 1990). Irrigations for two "delay" treatments were initiated on the date of the second irrigation (Delay1) or third irrigation (Delay2) of the WW treatment and then irrigated at a 2-in. estimated SWD. Irrigations were ceased when open bolls were observed, according to CES recommendations.

Nodes above white flower (NAWF) were counted weekly from 10 plants per plot beginning soon after all plots were flowering and continuing until the average NAWF for all plots was less than 5, indicating physiological cutout. Seedcotton was harvested on 17 October with a Case IH 1822 two-row cotton picker and seedcotton weights for each plot were determined with an instrumented boll buggy. An approximately 1-lb sample of seedcotton from each plot was ginned on a 10-saw laboratory gin without lint cleaners to determine gin turnout for lint yield calculations.

Costs for the inputs and operations were estimated with the Mississippi State Budget Generator (Spurlock and Laughlin, 1992). All inputs and thus all costs other

than irrigation were the same for all treatments. Therefore, only the costs related to the different irrigation treatments were considered. For this analysis, the nonirrigated field had the same degree of precision grading as the irrigated fields and had water available; therefore, there were no differences in land and well preparation costs between the treatments and only the variable costs were considered.

Because so much cropland is rented rather than farmed by the owner, it was necessary to include the impact of rent payments. While in practice there are a seemingly infinite number of rental arrangements, this analysis assumed a 25% crop share rent for all treatments, with the farmer paying all costs of production. Furrow irrigation with disposable poly-tubing was used, with all costs based on Bryant et al. (2001). A price of $0.52/lb lint, the USDA farm program loan rate in effect, was assumed and fiber quality was not considered. The study was designed as a randomized complete block with four replications. Fisher's least significant difference (LSD) was used to compare treatment means whenever significant (p values $\leq$ 0.05) treatment effects were observed.

RESULTS AND DISCUSSION

Uniform emergence was observed, resulting in a stand of 3.7 plants/ft (50,900 plants/acre). Heat unit data for the study period appeared fairly typical; however, August was a relatively wet month (data not included). In fact, a 1.7-in. rain followed one day after the final irrigation (23 August), negating most of the effect of the irrigation. Such an untimely rainfall is a constant risk in the mid-South region and underscores the importance of adequate surface drainage.

Due to the relatively late planting and the corresponding warm temperatures, the crop developed at an accelerated rate. While the COTMAN (Danforth and O'Leary, 1998) target development curve (TDC) has first flower at 60 days after planting (DAP), flowers were observed at 52 DAP. Similarly, the COTMAN TDC has an effective flowering period (time between first flower and NAWF=5) of 20 days; however, only the WW treatment ever exceeded NAWF=5, a value normally associated with physiological cutout (Bourland et al., 1992).

Highest yields were observed for the well watered treatment (WW, Table 2). Yields for the delayed-irrigation treatments (Delay1, Delay2) were not significantly different than for NI. Vories and Glover (2000) reported their highest yield for a treatment matching the Delay1 treatment in this study. While they suggested compensation from later bolls may have affected yields in their study, the late planting in both years of this study made any yield compensation unlikely. Since a constant price without premiums or discounts was used, the response for total revenue mirrored the response for yield (Table 2). Even though the differences were not always significant, the trend was for lower yields and lower returns with each delay in initiating irrigation.

PRACTICAL APPLICATION

The cost of delaying irrigation initiation by one irrigation was $106/acre. The cost of delaying irrigation initiation by two irrigations was $121/acre. Although the difference was not statistically significant, delaying initiation of irrigation resulted in returns being insufficient to pay the cost of the irrigations (i.e., higher returns for NI than either Delay treatment). Continuing the study in additional environments will help to better identify conditions when timeliness of the initial irrigation is most critical.

ACKNOWLEDGMENTS

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Table 1. Irrigation treatments in the cotton irrigation study at NEREC, Keiser, Arkansas.

Treatment[z]	Date of first irrigation	Date of final irrigation	Total irrigations
WW	8 July	23 August	4
Delay1	26 July	23 August	3
Delay2	5 August	23 August	2
NI	none	none	0

[z] Treatments were: well watered (WW), which was irrigated according to CES recommendations; Delay1 missed the first irrigation of WW; Delay2 missed the first and second irrigations of WW; and no irrigation (NI).

Table 2. Yield and economic comparisons for cotton irrigation study at NEREC, Keiser, Arkansas.

						Under a 25%/75% share rent[u]		
Treatment[z]	Lint yield[y]	Total revenue[x]	TVC[w]	Returns over TVC	Cost of delaying irrigation[v]	Total revenue[x]	Returns over TVC	Cost of delaying irrigation[v]
	(lb/acre)							
WW	746 a	$388 a	$22	$366 a		$291 a	$269 a	--
Delay1	535 b	$278 b	$18	$260 b	$106 a	$208 b	$190 b	$78 a
Delay2	497 b	$258 b	$14	$244 b	$121 a	$194 b	$180 b	$89 a
NI	522 b	$271 b	$0	$271 b	$94 a	$203 b	$203 b	$65 a

[z] Treatments were: well watered (WW), which was irrigated according to CES recommendations; Delay1 missed the first irrigation of WW; Delay2 missed the first and second irrigations of WW; and no irrigation (NI).

[y] Values within a column followed by the same letter not significantly different at alpha=0.05 level.

[x] Total revenue = lint yield times $0.52 per pound.

[w] TVC is the total variable cost associated with the irrigations and is equal to $5.75 per acre for poly-tubing plus $4.14 per irrigation.

[v] Includes nonirrigated treatment; WW not included in analyses of cost of delaying irrigation.

[u] The tenant receives 75% of the lint yield and pays all of the TVC of irrigation.

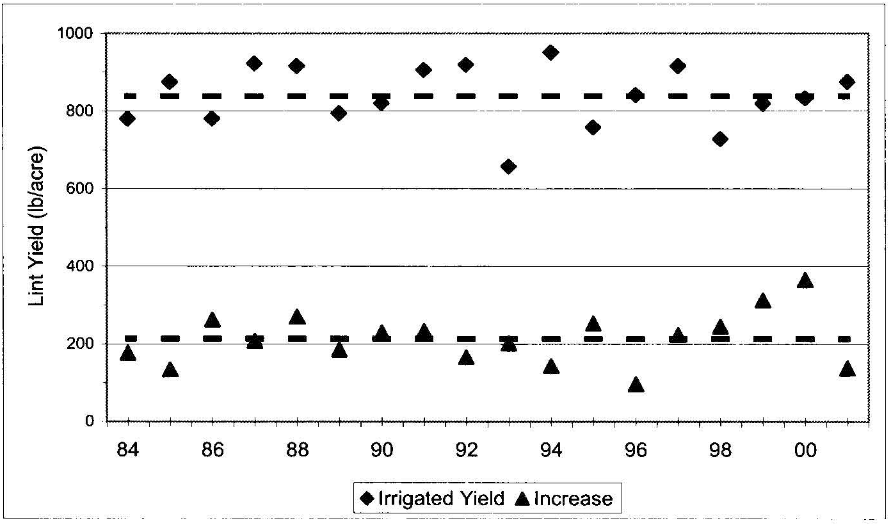

Fig. 1. Arkansas state-averaged irrigated cotton yields and the associated increases above dryland yields for the years 1984 through 2001 (NASS, 2002).

Characterization of Cotton Gene Expression Related to Trehalose and Proline Metabolism in Response To Water-Deficit Stress

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

RESEARCH PROBLEM

Stress resulting from cellular water-deficit is the most common challenge encountered by plants, and can result from a wide array of situations including drought, chilling and freezing, and saline soils. Through time, plants have evolved a complex mechanism of overlapping responses to water-deficit stress. The physiological changes that manifest as a result of water-deficit stress originate at the gene expression level. However, it is unclear if many of the morphological, physiological, and molecular responses induced by water-deficit stress actually enhance tolerance. One exception is osmotic adjustment, a process that is highly conserved in most organisms, and transgenic studies with model crops demonstrate that this phenomenon improves water-deficit stress tolerance.

BACKGROUND INFORMATION

Two solutes potentially contributing to osmotic adjustment that have recently received much attention in regards to water-deficit stress tolerance are the disaccharide, trehalose, and the amino acid, proline. The goal of these studies was to elucidate patterns of expression of genes directly involved in the metabolism of these osmotica. While proline is well-established as a compatible solute in higher plants including cotton, the occurrence of trehalose in most higher plants has only recently been documented. Expression of putative genes responsible for the synthesis of trehalose, trehalose-6-phosphate synthase (TPS) (Nepomuceno et al., 2002), and trehalose-6-phosphate phosphatase (TPP) are differentially expressed in response to water-deficit stress in cotton (*Gossypium hirsutum* L.). Neither the accumulation of trehalose nor the expression of trehalase, the enzyme that catabolizes trehalose, have previously been

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shown in cotton. Expression of genes related to proline metabolism is well-documented in model crops, but such studies are lacking in cotton. The present study sought to determine expression in cotton of the genes responsible for the metabolism of proline and trehalose.

RESEARCH DESCRIPTION

The Australian cultivar Siokra L-23, known for its high level of water-deficit stress tolerance (Nepomuceno et al., 1998), was grown in 2-L pots of Sunshine Mix under controlled conditions and subjected to slow stress induction (18 to 21 days) by withholding water to the point of moderate wilt. Plants were harvested at the point of maximum stress, when they were approximately six weeks old. A modified hot-borate method was used for the extraction of RNA, and northern analysis was used to determine expression of the various genes. Probes used in the northern analyses were cDNA clones of the respective genes from cotton or from other model plant species such as *Arabidopsis* or tomato.

RESULTS AND DISCUSSION

All three genes for trehalose metabolism (TPS, TPP, and trehalase) were present and regulated by water-deficit stress. One band (~1.5 kb) was obtained for TPS that was up-regulated under water-deficit stress conditions (Fig. 1). At least two genes for TPP (~2 and 3 kb) were present in cotton, the heavier of which was constitutively expressed while the lower molecular weight gene was induced by water-deficit stress. Three bands were present for trehalase (~1, 2, and 4 kb). The lowest molecular weight gene was noticeably up-regulated while the 2 kb band was slightly up-regulated by water-deficit stressed conditions. Expression of the largest gene apparently was not responsive to water deficit. Although two of the trehalase genes were up-regulated under water-deficit stressed conditions, they appeared to have a low level of constitutive expression in the well-watered plants. Since trehalose does not accumulate in cotton, the presence and role of these enzymes in response to water-deficit stress can only be conjectural at this point.

Among the genes responsible for proline metabolism, slight up-regulation was observed in some of the genes for Δ1-pyrroline-5-carboxylate reductase (P5CR) and Δ1-pyrroline-5-carboxylate synthetase (P5CS). These two enzymes are responsible for the synthesis of proline. On the other hand, the gene for proline dehydrogenase (PDH), the enzyme that degrades proline, was down-regulated. Only one gene product was detected for P5CR (~2.5 kb), with the stressed plants showing a very slight degree of up-regulation. Three gene products were obtained for P5CS (~1, 1.5, and 2.5 kb), which is responsible for the rate-limiting step in proline formation. While the differences between band intensity between water regimes were not dramatic, the two larger genes

(~1.5 and 2.5 kb) appeared to be slightly down-regulated in the water-deficit stressed plants, while the smaller gene (~1 kb) was slightly up-regulated in this treatment. Water-deficit stress resulted in a notable down-regulation of PDH, with only one band being present for this gene (1.5 kb). These studies revealed that proline metabolism of cotton in response to water-deficit stress followed patterns similar to those exhibited in other plants. Namely, genes coding for enzymes involved in proline synthesis are slightly up-regulated while the gene coding for the proline-degrading enzyme is down-regulated in response to water-deficit stress. Logically this suggests that proline accumulates by increased synthesis, but especially by decreased degradation.

PRACTICAL APPLICATION

The responses to water-deficit stress are far-reaching and often overlapping. If plant production under adverse conditions is to be improved, underlying genetic mechanisms that improve resistance to stress must be understood so that these can be selected in breeding programs. Gene expression studies provide information on potentially useful systems of adaptation at the most basic molecular level. Results from the current study contribute to the field of knowledge of the effect of water-deficit stress on cotton gene expression related to compatible osmolyte synthesis, a component of osmotic adjustment. The observed expression of a putative trehalase gene as a complement to genes for enzymes involved in trehalose synthesis raises significant questions concerning the role of this disaccharide in resistance to water-deficit stress.

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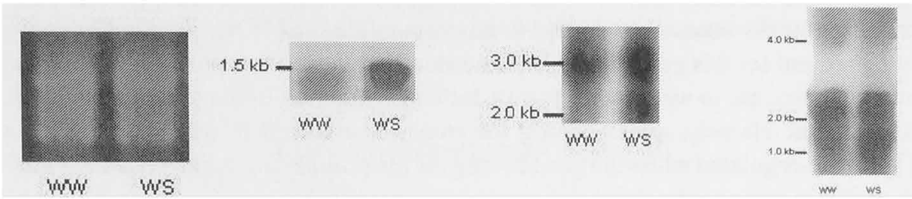

Fig. 1. Results of northern analysis in Siokra L-23 under well-watered (WW) and water-deficit stressed (WS) conditions for genes involved in trehalose metabolism. Left to Right: 1) EtBr stained membrane prior to hybridization; hybridization with cDNA probe corresponding to 2) TPS, 3) TPP, and 4) Trehalase.

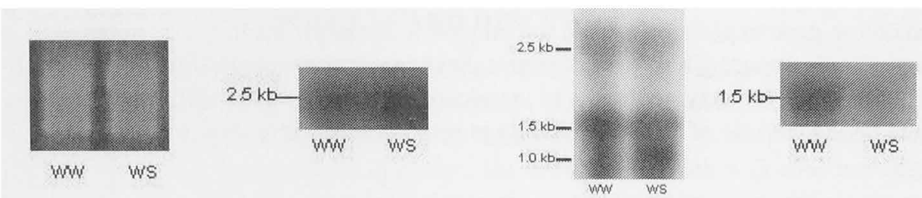

Fig. 2. Results of northern analysis in Siokra L-23 under well-watered (WW) and water-deficit stressed (WS) conditions for genes involved in proline metabolism. Left to right: 1) EtBr stained membrane prior to hybridization; hybridization with cDNA probe corresponding to 2) P5CS, 3) P5CR, and 4) PDH.

Legend: WW = well-watered, WS = water-deficit stressed, TPS = trehalose -6-phosphate synthetase, TPP = trehalose-6-phosphate phosphatase, P5CR = 1-pyrroline-5-carboxylate reductase, P5CS = 1-pyrroline-5-carboxylate synthetase, PDH = proline dehydrogenase.

Effect of Extreme Night Temperatures on Boll Growth and Yield

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

RESEARCH PROBLEM

Cotton yields in Arkansas increased steadily during the eighties but has leveled off or even declined slightly in recent years (Lewis et al., 2000). Of even more concern, however is the large year-to-year fluctuation in yield and lack of stable yields. For example, the 1994 crop was a record high yield, whereas the 1993 and 1995 seasons were extremely disappointing with unusually low yields despite the promise of a high-yielding crop at mid-season (Oosterhuis, 1996). This variability has been associated with partitioning changes in modern genotypes and also with environmental stress, particularly drought and high temperatures. A strong correlation has been shown to exist between high temperatures during boll development and low yields in the mid-South (Oosterhuis, 1994). However, the effects of high night temperatures on boll growth and yield are not well understood. This study was designed to investigate and quantify the effect of extreme night temperatures on boll growth and yield.

BACKGROUND INFORMATION

The ideal temperature range for growing cotton is 68 to 86°F (Reddy et al., 1991). However, temperatures in the US Cotton belt during the boll development period are usually well in excess of the optimum range. Furthermore, cotton metabolism decreases dramatically at high day termperatures (Burke et al., 1988). Limited data are available on the effects of elevated day and night temperatures on cotton yield, possibly because of the difficulty in conducting the research in the field under different temperatures. A comparative study of yields and temperatures between Arkansas and Greece showed that 8°C cooler night temperatures during boll development with similar maximum day temperatures in Greece (Fig. 1) were largely responsible for the higher yields obtained in Greece with similar cultivars and production practices (Oosterhuis, 2002). However,

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information is lacking on plant response to elevated *night* temperatures and effects on boll development and yield. Warm *night* temperatures increase respiration with an additional loss in carbohydrates, possibly resulting in insufficient carbohydrate produced to satisfy all the plant's needs. This will be reflected in increased boll shedding, smaller boll size, and decreased lint percent. This situation was particularly evident in full season cultivars and in late-planted cotton. Furthermore, periods of low rainfall often coincide with these spells of hot weather and further exacerbate the detrimental effects of high temperatures. An additional problem that compounds the high temperature stresses during boll development is that root growth in Arkansas, due to poor early-season development in cool, wet conditions, may not always be adequate to meet the demands during peak boll development.

Understanding the impact of high temperatures on boll growth and yield would permit us to formulate strategies, such as using irrigation to cool the crop at critical times, using earlier-maturing cultivars to avoid the highest temperatures, breeding for temperature tolerance, using crop monitoring and plant growth regulators to ensure early maturity, or possibly using new osmolyte sprays to improve temperature tolerance.

RESEARCH DESCRIPTION

A field study was planted at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, AR on 25 May 2002 on a Captina silt loam (Typic fragiudult). The cotton (*Gossypium hirsutum* L.) cultivar Suregrow 215 BR was planted at a row spacing of 0.9 m in plots 5 x 2.7 m. Treatments consisted of: (1) a control with no temperatures amendment, (2) cool night temperatures, and (3) hot night temperatures imposed. Temperature shelters were constructed from PVC tubes to support a plastic covering over the two middle rows of the canopy in each plot in order to maintain the imposed temperature treatments. Night temperatures were altered with factory space heaters or air conditioners that blew hot or cool air, respectively, down the two middle rows of each plot for four hours from 8:00 P.M. until midnight for a period of one week starting three weeks after first flower. A plastic covering was placed over each plot at the same time that the temperature treatments began every day and was removed the following day at sunrise. Two temperature Watchdog sensors (Model 100, Spectrum Tech. Inc., IL) were located one meter from the beginning and end of each plot and recorded temperatures every 15 min.

White flowers were tagged (50/plot) during the first, second, and third week after flowering and the temperature treatments were imposed during the third week in order to have three different stages of boll development exposed to the temperature treatments. Half of the bolls were sampled after the week of temperature treatment, and the remaining bolls were harvested at full maturity. Photosynthesis and respiration were measured on three leaves per plot using the uppermost fully expanded main-stem leaf (fourth node from the terminal) with a LI-COR 6200 (LICOR Environmental Services,

Lincoln, NE) during and after the week of temperature treatments. Dry matter, leaf area, nutrient concentration, and epicuticular wax content were recorded on the same leaf as photosynthesis.

RESULTS AND DISCUSSION

Effect on Photosynthesis, Respiration, and Plant Biomass

Raising or lowering the night temperatures had no significant effect ($P \leq 0.05$) on photosynthesis or respiration when measured during or after the week of temperature treatment (Table 1). Furthermore, there were no significant differences during the night or the following day. The lack of effect on respiration was unexpected due to the sensitivity of this process to temperature. According to Warner et al. (1995) diurnal carbon metabolism in cotton plants respond to night and day temperatures, with a subsequent affect on photosynthetic metabolism the following day. There was also no significant effect from the altered night temperature treatments on leaf area, wax content, and plant dry matter (Table 2) although the cooler night temperature treatment had numerically higher values of dry matter and leaf epicuticular wax content.

Effect on Boll Development

Although fiber weight per seed is a fundamental component of yield (Lewis et al., 2000), this parameter was not significantly reduced ($P \leq 0.05$) by the seven-day period of altered night temperature treatment when applied to bolls 1, 2, or 3 weeks of age. In accordance with our hypothesis we expected a decrease in fiber weight from the elevated night temperature. Possibly the week of elevated or lowered night temperature may not have been sufficient for a lasting effect due to subsequent compensation during the remainder of the boll development period.

Total Boll Weight and Fiber Yield at Harvest

There was no significant ($P \leq 0.05$) effect from *raised* or *lowered* night temperatures on final boll weight or fiber weight per seed (Figs. 2 and 3). However, there was a numerical trend for elevated night temperature to decrease fiber and boll weight, which, although not statistically significant, would support our hypothesis of high night temperatures being detrimental to developing boll weight. Decreased boll weight would presumably be related to a shortage of carbohydrates for boll growth. High temperatures would be further compounded when coupled with periods of water shortage as invariably occurs in the Mississippi Delta during boll development in July and early August.

PRACTICAL APPLICATION

There was lack of statistical significance between temperature treatment for affects on boll growth, although there was a numerical indication that elevated temperatures decreased fiber weight per seed. Probably the short period (1 week) of night temperature imposition allowed sufficient time afterwards until boll maturity for compensation. Future research will include some modifications to the experimental protocol including a longer (2-week) period of time and extra covering on the sides of the plots for a more uniform temperature effect in the canopy. Carbohydrate analysis will be made on leaf tissue and bolls before, during, and after the temperature treatments.

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Table 1. Effect of raised or lowered night temperature on photosynthesis and respiration during and after the 7-day night-temperature treatments.

	Photosynthesis		Respiration			
	During	After	During treatments		After treatments	
Treatments	week of trt.	week of trt.	Day	Night	Day	Night
	(μmolCO²/m²/s)					
Control	30.96 a[z]	31.10 a	-5.26 a	-3.29 a	-5.72 a	-3.00 a
Cool	31.30 a	32.23 a	-5.47 a	-2.46 a	-5.48 a	-4.47 a
Heat	30.78 a	30.54 a	-5.03 a	-2.37 a	-5.05 a	-2.28 a

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

Table 2. Effect of raised or lowered night temperature on biomass analysis one day after the 7-day night-temperature treatment.

		Dry matter			
Treatments	Leaf area	Leaf	Petiole	SLW[z]	Leaf wax
	(cm^2)	----------- (g) -----------		----------- (mg/m^2) ---------	
Control	559.84 a[y]	5.33 a	1.63 a	86.86 a	319.67 a
Cool	617.52 a	5.60 a	1.88 a	90.38 a	300.33 a
Heat	645.18 a	5.57 a	1.77 a	94.05 a	225.33 a

[z] Specific Leaf Weight of the fourth leaf sample.
[y] Numbers followed by the same letter within a column are not significantly different (P≤0.05).

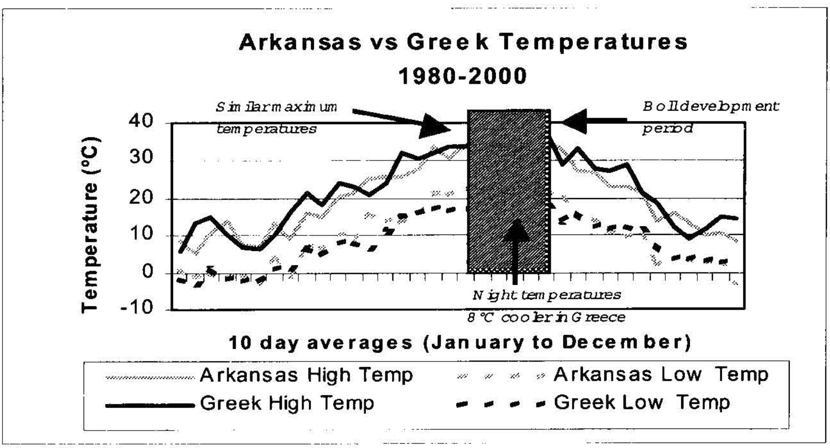

Fig.1. Maximum and minimum temperature during the cotton season in Arkansas and Greece (from Oosterhuis, 2002).

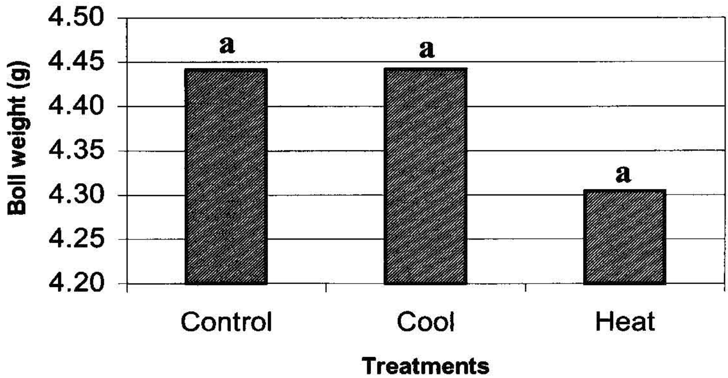

Fig. 2. Effect of 70-day night-temperature treatments on boll weight average from 2-m boll samples at harvest, Arkansas, 2002. Columns with the same letter are not significantly different (P≤0.05).

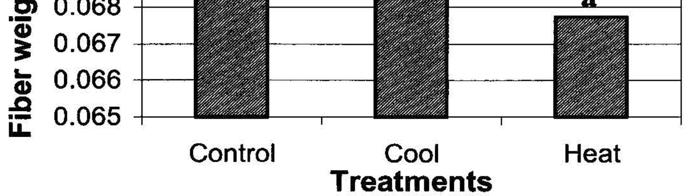

Fig. 3. Effect of 7-day night-temperature treatments on weight of fiber per seed from 2-m boll samples at harvest, Arkansas, 2002. Columns with the same letter are not significantly different (P≤0.05).

Yield Component Comparison of Modern Versus Obsolete Cultivars for Explaining Yield Stagnation and Variability

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

RESEARCH PROBLEM

The U.S. Cotton industry has faced very difficult times in recent years due to problems with year-to-year variability in yield. According to Helms (2000), there is clearly a significant problem with the lack of uniformity in current yields. Recent literature and hypotheses indicate that the yield variability is mostly related to extreme environmental conditions (i.e., particularly high temperatures and drought) as well as a peak in genetic improvements in yield (Meredith, 1995). It is speculated that modern cultivars partition dry matter and energy pools differently within the boll and at the seed level than obsolete cultivars making them potentially more sensitive to environmental stress. It is assumed that modern cultivars produce smaller bolls with smaller seeds but more seeds per boll than obsolete cultivars. Under adequate growing conditions this allows for more seeds per unit area and the potential for more fiber per unit area, i.e., higher yields. However, under poor environmental conditions, i.e., drought and high temperatures, the modern cultivars are unable to tolerate the added carbohydrate stress and fail to fill seed and produce fiber necessary for optimal yield. Given the potential differences between partitioning aspects of modern and obsolete cultivars, the main objective of this study was to evaluate boll and yield components of these cultivars in relation to water-deficit stress to gain insight into the sensitivity of yield development.

BACKGROUND INFORMATION

Cotton yields in Arkansas as well as much of the U.S. increased steadily during the 1980s, but in the 1990s there has been a leveling off and lately a decrease in yields (Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the extreme year-to-year variability. Three out of five seasons from 1995 to 1999 were extremely disappointing with unusually low yields (Oosterhuis, 1999). The 1998 and 1999 crop

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yields were the poorest in recent history and much of this was related to extreme weather conditions and less on insect pressure. Generally, each year the cotton crop appears to have good yield potential at mid-season, but this potential is not always achieved at harvest due to combinations of moisture stress and high temperatures during the boll development period. Besides environmental conditions, changes in breeding objectives over the past few decades may also be an underlying reason for yield variability. Increased yield variability may be the result of differential partitioning of metabolites between fiber and seed of modern and obsolete cultivars as a result of environmental stress during early boll development.

RESEARCH DESCRIPTION

A field study was designed at Clarkedale in northeast Arkansas on a Dundee silt loam in 2001 and 2002 to determine if water-deficit stress differentially impacted lint yields or the components of yield of modern versus obsolete cultivars. The study contained water and cultivar as the two factors tested. Water was the whole-plot factor and consisted of either well-watered or water-deficit conditions. The sub-plot factor was cultivar and consisted of eight cultivars (four modern and four obsolete). The modern cultivars evaluated were ST 474, SG 747, DP 33B, and Acala Maxxa and the obsolete cultivars evaluated were ST 213, DP 16, REX, and SJ2. Each of these eight cultivars was subjected to both water treatments and was replicated six times. At final harvest, a two-meter subsample of seedcotton was collected from each 4-row plot in order to evaluate boll and yield components. Boll and yield components included average boll weight, boll number per unit area, seeds per boll, seeds weight, seeds per unit area, and weight of fiber per seed. Following the subsample for yield components, lint yields were determined from mechanically harvesting the center two rows of each 4-row plot.

RESULTS AND DISCUSSION

Since there were no significant interactions between water treatments and cultivars, all data will be presented by looking at the main effects, i.e. modern cultivars versus obsolete cultivars averaged over water treatments, and well-watered versus water-deficit averaged over cultivars.

Lint Yields

Yield results from the 2002 field study indicated no significant differences ($P<0.05$) in lint yield between modern and obsolete cultivars when averaged over water treatments (Table 1), or differences between water treatments averaged over cultivars (Table 2). At the cultivar level, the modern cultivars numerically yielded higher than the obsolete cultivars (Table 1), which was expected given optimal rainfall during the crucial first three to four weeks of boll development. Modern cultivars produce smaller bolls with

smaller seeds but more seeds per boll, i.e. more seeds per acre, than do obsolete cultivars. Thus, under adequate growing conditions (adequate rainfall) this allows for modern cultivars to produce more fiber per unit area (higher yields). However, under poor environmental conditions (i.e. drought and high temperatures) it is believed that the modern cultivars would be unable to tolerate the added carbohydrate stress and fail to fill seed and produce fiber necessary for optimal yield. The yield data from the 2002 season support data from the past season, in which rainfall during boll development was adequate, resulting in higher yields by the modern cultivars (Brown et al., 2001).

Boll and Yield Components

When averaged over water treatments in 2002, boll component values indicated that the numerical increase in yield by the modern cultivars was due to significant ($P<0.05$) improvements in gin turnout and fiber per seed (Table 1). As expected, boll weight and seed weight were significantly higher for the obsolete cultivars compared to the modern cultivars (Table 1). In terms of yield components, there were no differences between modern and obsolete cultivars for changing boll number or seed number per acre at the cultivar level when averaged over water treatments. There were no differences in yield or boll components at the water treatment level averaged over cultivars, which was expected due to the similarity between well-watered and water-deficit plots given adequate rainfall during boll development. Boll and yield component data were very similar to the data from the 2001 season in which the weather patterns were also optimal during boll development (Brown et al., 2001).

PRACTICAL APPLICATION

It is speculated that the reason for the stagnant yields and year-to-year yield variability is a combination of poor environmental conditions during boll development coupled with changes in the way that modern cultivars partition energy and carbohydrate pools between seed and fiber. Therefore, we urgently need to understand why cotton yields are so variable from year to year and how this variability differentially affects contrasting genotypes as measured through yield components. By accomplishing this goal it may be possible to formulate management strategies before yields are adversely affected. This study will be repeated at two locations in 2003.

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Table 1. Genotypic effect on yield, boll components, and yield components averaged over water treatments.

Treatment	Yield	Boll weight	Gin turnout	Seed weight	Bolls	Seeds	Fiber/seed
	(lb lint/acre)	(g/boll)	(%)	(g/100 seed)	---------- (#/acre)	-----------	(mg/mg)
Modern	656	3.59	36.8*	8.94	219,000	8,220,000	0.59*[z]
Obsolete	622	3.95*	34.7	9.94*	192,000	7,890,000	0.52

[z] Treatment means followed by an * are significantly different at P<0.05.

Table 2. Environmental effect on yield and components of yield averaged over cultivars.

Treatment	Yield	Boll weight	Gin turnout	Seed weight	Bolls	Seeds	Fiber/seed
	(lb lint/acre)	(g/boll)	(%)	(g/100 seed)	---------- (#/acre)	-----------	(mg/mg)
Well-watered	637	3.69	35.9	9.46	209,000	8,370,000	0.56
Water-stressed	641	3.86	35.6	9.41	202,000	7,740,000	0.55

A Physiological Comparison of Modern Versus Obsolete Cultivars Under Water-Deficit Stress

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

RESEARCH PROBLEM

There is a significant problem with the lack of uniformity in current yields. Recent literature and hypotheses indicate that the yield variability is mostly related to extreme environmental conditions but may also be influenced by a peak in genetic improvements for yield (Meredith, 1995). Comparative growth, dry matter partitioning, and yield of modern and obsolete cultivars have been studied (Meredith and Well, 1989); however little reference is made to the physiological differences between modern and obsolete cultivars. Therefore, the main objective of this study was to compare the physiological responses of modern versus obsolete cultivars to water-deficit stress conditions. This information may give additional insight into the development of cotton yields and help to formulate an explanation of why yields have become increasingly variable from year to year over the past few decades.

BACKGROUND INFORMATION

Cotton yields in the Mississippi Delta increased steadily during the 1980s, but in the 1990s there has been a leveling off and lately a decrease in yields (Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the extreme year-to-year variability. Generally, each year the cotton crop appears to have good yield potential at mid-season, but this potential is not always achieved at harvest due to combinations of moisture stress and high temperatures during the critical first three to five weeks of flowering and boll development. Besides environmental conditions, changes in breeding objectives over the past few decades may also be an underlying reason for yield variability. It has been speculated that increased yield variability may be the result of differential partitioning of carbohydrate and energy pools between fiber and seed of modern and obsolete cultivars as a result of environmental stress during early boll development.

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RESEARCH DESCRIPTION

A field study was designed at Clarkedale in northeast Arkansas in 2002 on a Dundee silt loam to determine if water-deficit stress differentially impacted plant physiological parameters of modern versus obsolete cultivars. The study contained water and cultivar as the two factors tested. Water was the whole-plot factor and consisted of either well-watered or water-deficit conditions. The sub-plot factor was cultivar and consistED of eight cultivars (four modern and four obsolete). The modern cultivars evaluated were ST 474, SG 747, DP 33B, and Acala Maxxa, and the obsolete cultivars used were ST 213, DP 16, REX, and SJ2. Each of these eight cultivars was subjected to both water treatments and was replicated six times. Physiological measurements included leaf photosynthesis measured with a LICOR 6200 portable photosynthesis system; canopy temperature measured with a handheld infrared thermometer; chlorophyll content taken with a SPAD meter; specific leaf weight (an indication of leaf thickness); and leaf nonstructural carbohydrates. Measurements were taken at select times during boll development.

RESULTS AND DISCUSSION

Photosynthesis and Canopy Temperature

There were no statistical differences ($P<0.05$) between modern and obsolete cultivars for increasing net leaf photosynthesis or reducing leaf temperature at either water level when measured three weeks after first flower (FF3) (Fig. 1). Photosynthesis and canopy temperature are more commonly associated with water relations than genetics and since there was no significant water-deficit stress present in the field at the time of sampling, it was believed that differences were not expected.

Nonstructural Carbohydrates

There were no statistical differences ($P<0.05$) between modern and obsolete cultivars when averaged over water treatments, or differences between water levels averaged over modern and obsolete cultivars for accumulating sugars measured at FF3 (Fig. 2). When averaged over cultivars, glucose and sucrose levels were numerically higher under well-watered conditions compared to water-deficit conditions. Furthermore, when averaged over water treatments the obsolete cultivars had slightly higher values for glucose, sucrose, and fructose (Fig. 2).

Specific Leaf Weight (SLW)

There were no differences at either the cultivar or the water treatment level for altering SLW at the first flower plus two week stage (FF2). However, by four weeks after first flower (FF4), obsolete cultivars had a significantly lower SLW than did modern cultivars under both water levels (Fig. 3).

Chlorophyll Content

Chlorophyll content was significantly higher for modern cultivars than for obsolete cultivars under both water treatment levels at each sample time during the season (Fig. 4). Chlorophyll content was also numerically higher at the FF4 stage compared to the FF2 stage.

PRACTICAL APPLICATION

Preliminary research has shown some physiological differences between modern and obsolete cultivars. However, to provide an improved understanding of yield variability problems experienced in recent years (i.e. from a physiological perspective), a moderate stress during boll development is needed. To accomplish this goal, growth chamber studies need to be performed in order to control environmental conditions and create adequate stress conditions for comparing the physiological response of contrasting genotypes. Determining subtle physiological differences between modern and obsolete cultivars could lead the way to an improved understanding of yield development. This in turn could spur counteractive management strategies to stabilize factors affecting yield before yields are adversely affected.

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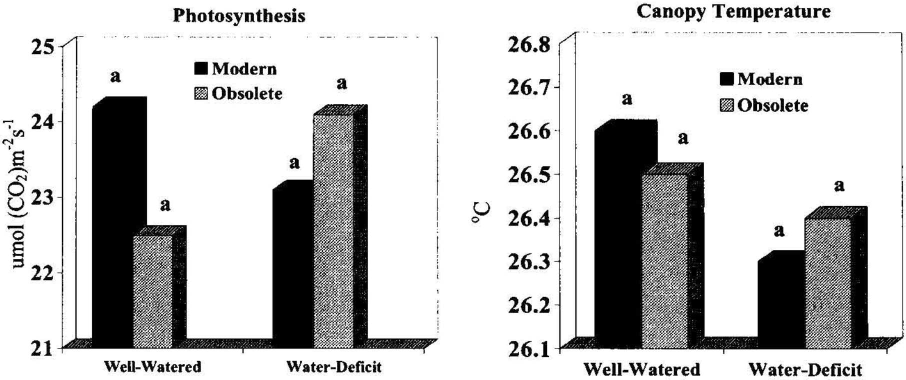

Fig. 1. Photosynthesis and canopy temperature of modern and obsolete cultivars measured at three weeks after first flower.

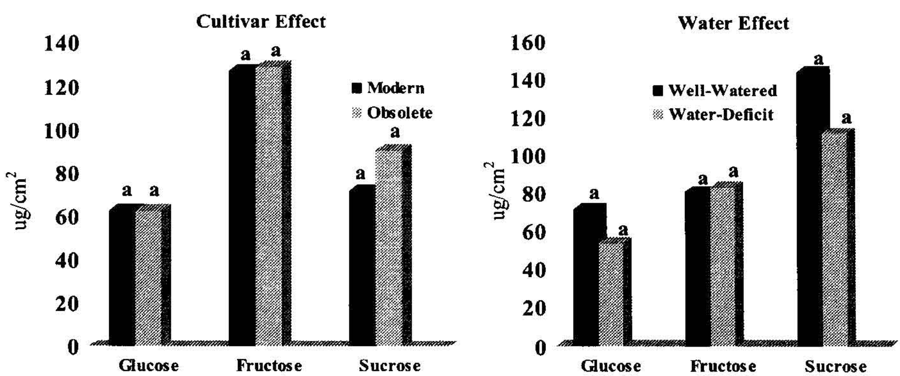

Fig. 2. Sugar concentrations of modern and obsolete cultivars averaged over cultivar and water treatment levels measured at three weeks after first flower.

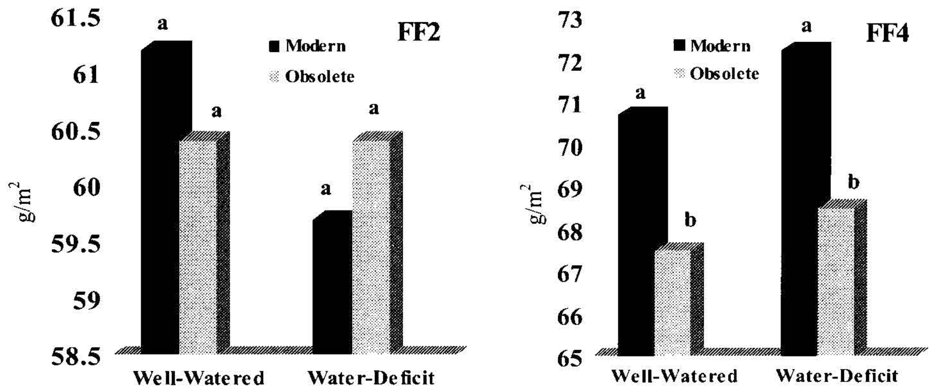

Fig. 3. Specific leaf weight comparisons of modern versus obsolete cultivars measured two and four weeks after first flower (FF).

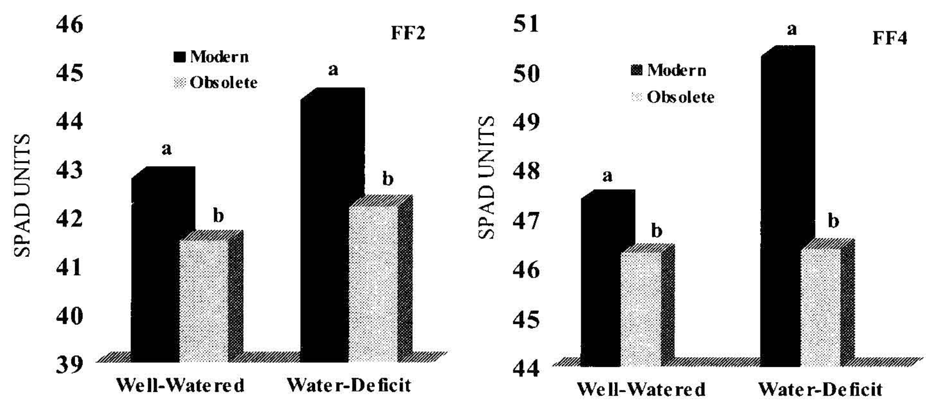

Fig. 4. Chlorophyll content of modern versus obsolete cultivars measured at two and four weeks after first flower (FF).

Cotton Response to Foliar-Applied Messenger® Under Conditions of Water-Deficit Stress and Potassium Deficiency

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

RESEARCH PROBLEM

Messenger® is a new class of crop protectants containing the harpin protein which activates a plants natural defense mechanisms by inducing system acquired resistance, thus providing resistance to a broad range of diseases and pests. Messenger® has also been credited with improving plant growth mechanisms resulting in improved yield and quality. Yield improvement with Messenger applications has been reported in more than 40 crops, including cotton (French, 2001). However, in cotton (*Gossypium hirsutum* L.) the results have been variable with yield increases in Florida (Wright, 2000) but not in Georgia (Brown et al., 2001), Mississippi (Phelps and McCarty, 2001), or Arkansas (Meek et al., 2001; Meek and Oosterhuis, 2002). It was hypothesized that Messenger may work better when plants are exposed to environmental stress. Thus, the objective of this field study was to evaluate the effect of foliar-applied Messenger on the physiology and yield of cotton grown under water-deficit and soil K deficiency.

BACKGROUND INFORMATION

Sporadic K deficiencies have typically been noted in Arkansas cotton as the developing bolls exert a greater demand on plant K resources (become dominant sinks) and the rate of root growth decreases (Oosterhuis, 1995). In addition, water deficit has often been reported to be the most limiting factor in crop production, and Coker et al., (2002) has shown a relationship between water-deficit stress and K deficiency on cotton yield. We hypothesized that Messenger®, a biorational product containing the harpin protein, may alleviate the effects of a pending K deficiency and water-deficit stress in cotton by inducing the plant's natural defense mechanism. Growth chamber

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studies in Arkansas resulted in significantly more squares and main-stem nodes at first-flower (FF) in when compared to untreated control plants, indicating that Messenger™ enhanced cotton development (Meek et al., 2001). The purpose of our studies was to evaluate the physiological, biochemical, and developmental responses of cotton to Messenger™ under water and potassium deficit.

RESEARCH DESCRIPTION

Cotton was grown in field plots at the Arkansas Agricultural Research Center in Fayetteville during summer 2002. Four treatment combinations of well-watered (irrigated) or water-stressed (dryland) conditions and high-soil K or low-soil K were arranged in a split-plot design with five replications. Each plot consisted of four 30-ft long rows, spaced 39 in. apart. The cotton cultivar Suregrow 215 BR was planted into a moderately well-drained Captina silt loam on 23 May 2002. Preplant granular KCl fertilizer was hand-broadcast to high-soil K plots at recommended rates (i.e. 50 to 96 lb K_2O/acre) based on University of Arkansas fertilizer recommendations (Sabbe, 1998). Messenger was foliar-applied to a designated guard row of each plot at 2.2 oz/acre in 10 gallons deionized water two weeks after pinhead square. Other fertility inputs, as well as insect and weed control, were managed according to Extension Service recommendations for cotton grown in Arkansas. At one week after first flower, 10 petioles and leaves from main-stem node 4 were sampled from Messenger and control treatments and submitted to the Arkansas Soil Test Research Laboratory at Marianna, AR, for nutrient analysis. Leaf area was determined the day of collection using a LICOR 6100 leaf area instrument and leaf dry-weight determination by drying at 60°C. Photosynthesis measurements were collected near solar noon at three weeks after first flower using a LICOR 6200 portable IRGA. Final lint yield and components of yield were determined by hand harvesting seedcotton from two 1-m lengths from each guard row and a 1-m length from each of the two center yield rows and counting the number of bolls. Gin turnout was calculated for each plot by ginning approximately 200 g of subsampled seedcotton (G&H Associates, Tillar, AR).

RESULTS AND DISCUSSION

Petiole NO_3-N, P, K, and S Concentrations

Averaged over water treatments, foliar-applied Messenger increased ($p \leq 0.1$) the concentration of P, K, and S in fourth-node petioles at one week after first flower under low-soil K (Table 1). One foliar application of Messenger also increased the S ($p \leq 0.05$) concentration in petioles at one week after first flower under high-soil K. Averaged over soil K, foliar-applied Messenger increased ($p \leq 0.1$) petiole P and S concentrations under well-watered conditions, and increased ($p \leq 0.05$) petiole S under water-stressed

conditions. Averaged over water and soil K, petiole P, K, and S concentrations responded to foliar-applied Messenger ($p \leq 0.1$, $p \leq 0.1$, and $p \leq 0.05$, respectively).

Soil K level did not appear to noticeably affect the concentration of nutrients in petioles except S (Table 1). The level of S was higher ($p \leq 0.05$) in petioles from low-soil K plots as compared to high-K plots under well-watered conditions; however, the inverse relationship occurred under dryland conditions [significant ($p \leq 0.05$) water by soil K interaction]. Petiole NO_3 concentrations tended to be lower and petiole P, K, and S were significantly lower ($p \leq 0.05$, $p \leq 0.1$, and $p \leq 0.05$, respectively) due to water-deficit stress at one week after first flower (data not shown).

Specific Leaf Weight

When averaged over water, specific leaf weight (calculated from leaf area and dry matter) showed a response ($p \leq 0.1$) to foliar-applied Messenger under the high-soil K level and a trend for increase under the low-soil K level at one week after first flower (Fig. 1). Under well-watered conditions (averaged over both levels of soil K), foliar-applied Messenger increased specific leaf weight ($p \leq 0.05$); whereas, under water-stressed conditions, specific leaf weight was not significantly different due to foliar-applied Messenger (Fig. 2). At one week after first flower, specific leaf weight was greater ($p \leq 0.05$) under water-stressed as compared to well-watered conditions (data not shown). At the same sampling, we did not observe differences in specific leaf weight due to soil K level regardless of plant water status.

Leaf Gas Exchange

Three weeks after first flower, foliar-applied Messenger had a significant effect ($p \leq 0.05$) on leaf stomatal conductance under high - but not low-soil K, and well-watered conditions (data not shown). Stomatal conductance in leaves was also greater ($p \leq 0.05$ and $p \leq 0.1$) in response to foliar-applied Messenger under high- and low-soil K averaged over the water treatments at three weeks after first flower; however these differences did not translate into greater ($p \leq 0.05$) photosynthesis (Table 2). Although the Messenger treatment increased stomatal conductance ($p \leq 0.1$) and intercellular CO_2 ($p \leq 0.1$) under the dryland condition and stomatal conductance ($p \leq 0.05$) under the well-watered condition, photosynthesis was lower ($p \leq 0.1$) in response to foliar-applied Messenger under the well-watered or water-stressed condition at three weeks after first flower. We did not observe a response in leaf photosynthesis, intercellular CO_2, and stomatal conductance due to soil-K level under well-watered or water-stressed conditions at three weeks after first flower (data not shown). However, photosynthesis and stomatal conductance were lower ($p \leq 0.05$ and $p \leq 0.1$, respectively) due to water stress at three weeks after first flower.

Lint Yield

Generally, the number of harvested bolls tended to be greater from "control" plots whereas lint mass per boll tended to be greater from plots that received one application of foliar Messenger (Table 3). Averaged over the water treatments, lint yield did not respond significantly to foliar-applied Messenger at either level of soil K. Likewise, there were no differences in lint yield due to foliar-applied Messenger under well-watered or water-stressed conditions when averaged over the soil-K levels.

PRACTICAL APPLICATION

Foliar-applied Messenger can increase the concentration of P, K, and S in petioles during the boll development stage. Accumulation of critically needed nutrients within the above-ground plant organs could be beneficial, particularly for crops growing under climatic stress. Our results have shown that Messenger can increase specific leaf weight which could offer physiological advantages during the boll filling period. In this study, leaf photosynthesis failed to respond to foliar-applied Messenger under adequate or deficient K and well-watered or dryland conditions, which seemed to correlate closely to the lack of significant treatment differences observed with lint yield at final harvest. Future studies utilizing the same treatments should be conducted in areas with a higher known pest pressure to fairly evaluate the protective benefits attributed to the harpin protein in previous studies.

ACKNOWLEDGMENTS

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Table 1. Effect of Messenger on nutrient concentrations in fourth-node petioles collected one week after first flower (FF1) from cotton cultivar Suregrow 215 BR grown with and without preplant soil-applied potassium under well-watered and dryland conditions. Fayetteville, 2002.

Treatment	Petiole nutrients at FF1			
	NO_3-N	P	K	S
	(µg g^{-1})	(µg g^{-1})	(µg g^{-1})	(µg g^{-1})
Averaged over water				
High-soil K, no foliar Messenger	2989	1651	23.6	1065
High-soil K, with foliar Messenger	3008	1945	26.2	1318[z]
Low-soil K, no foliar Messenger	3086	1851	22.9	1203
Low-soil K, with foliar Messenger	4195	2204[y]	28.6[y]	1368[y]
Averaged over soil K				
Well-watered, no foliar Messenger	4128	2131	30.0	1362
Well-watered, with foliar Messenger	3966	2518[y]	33.9	1555[y]
Dryland, no foliar Messenger	1947	1371	16.5	906
Dryland, with foliar Messenger	3236	1631	20.9	1130[z]
Averaged over water and soil K				
No foliar Messenger	3038	1751	23.3	1134
With foliar Messenger	3601	2074[y]	27.4[y]	1343[z]

[z] Significant at $p \leq 0.05$ for the paired treatments.

[y] Significant at $p \leq 0.1$ for the paired treatments.

Table 2. Effect of Messenger on leaf gas exchange in fourth-node leaves at three weeks after first flower (FF3) from cotton grown with and without preplant soil-applied potassium under well-watered and dryland conditions. Fayetteville, 2002.

	Leaf gas exchange at FF3		
Treatment	Photosynthesis	Intercellular CO_2	Stomatal conductance
	(μmol $CO_2/m^2/s$)	(ppm)	(cm/s)
Averaged over water			
High-soil K, no foliar Messenger	30.7	296	3.34
High-soil K, with foliar Messenger	28.8[z]	293	3.87[y]
Low-soil K, no foliar Messenger	29.5	287	3.33
Low-soil K, with foliar Messenger	28.1[z]	310[y]	3.62[z]
Soil K x foliar Messenger	-	[x]	-
Averaged over soil K[w]			
Well-watered, no foliar Messenger	31.2	293	3.44
Well-watered, with foliar Messenger	29.4[z]	295	3.96[y]
Dryland, no foliar Messenger	29.1	290	3.23
Dryland, with foliar Messenger	27.5[z]	308[z]	3.53[z]
Averaged over water and soil K			
No foliar Messenger	30.1	292	3.33
With foliar Messenger	28.4[y]	302	3.74[y]

[z] Significant at $p \leq 0.1$ for the paired treatments.
[y] Significant at $p \leq 0.05$ for the paired treatments.
[x] Significant at $p \leq 0.1$ for treatment interaction ("-" = no interaction).
[w] No significant ($p \leq 0.1$) interactions observed between main effects.

Table 3. Lint yield response of cotton to foliar-applied Messenger at 12 days after pinhead square with and without preplant soil-applied potassium under well-watered and dryland conditions. Fayetteville, 2002.

Treatment	Number of bolls	Lint/boll	Yield
	(#/m^2)	(mg/boll)	(kg/ha)
Averaged over water			
High-soil K, no foliar Messenger	93	1523	1399
High-soil K, with foliar Messenger	84	1561	1283
Low-soil K, no foliar Messenger	104	1314	1322
Low-soil K, with foliar Messenger	94	1457	1351
Averaged over soil-K			
Well-watered, no foliar Messenger	100	1486	1454
Well-watered, with foliar Messenger	100	1463	1432
Dryland, no foliar Messenger	97	1351	1267
Dryland, with foliar Messenger	78[z]	1555[z]	1202
Averaged over water and soil K			
No foliar Messenger	98	1419	1360
With foliar Messenger	89[y]	1509	1317

[z] Significant at p≤0.05 for the paired treatments.

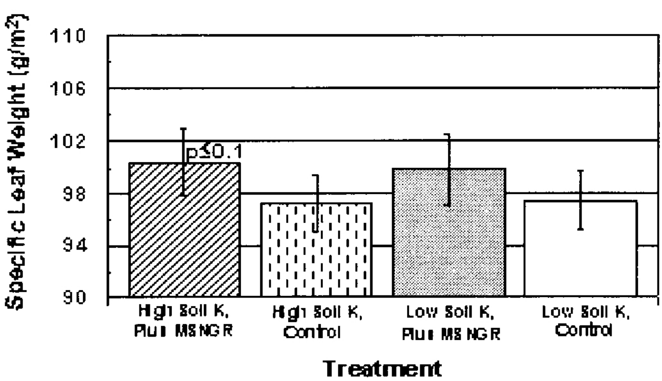

Fig. 1. Effect of foliar-applied Messenger averaged over the water treatment on specific leaf weight under high- versus the low-soil K levels, Fayetteville, AR, 2002. Bars indicate standard error values of the treatment means.

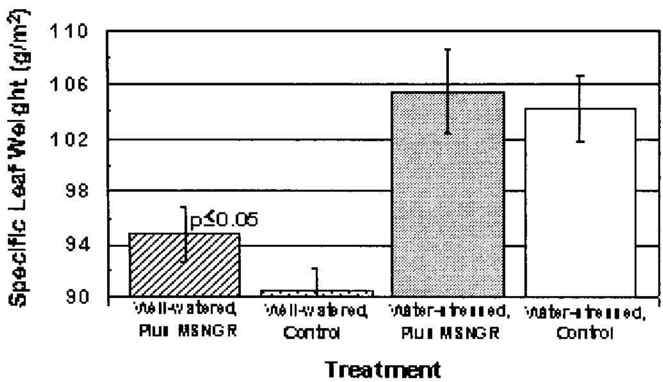

Fig. 2. Effect of foliar-applied Messenger averaged over the soil-K treatments on specific leaf weight under well-watered versus water-stressed conditions. Fayetteville, AR, 2002. Bars indicate standard error values of the treatment means.

Evaluation of Messenger™ in Cotton

William C. Robertson and Brian Weatherford[1]

New products that work in other commodities or on cotton under very controlled situations are brought to the cotton market on a consistent basis. Messenger™ is a new product from Eden Bioscience (Seattle, WA) which is reported to increase yields in various crops. A set of field studies was conducted to investigate the benefits of Messenger on cotton.

BACKGROUND INFORMATION

Messenger is similar chemically to a protein that is produced by the bacterial plant pathogen causing fireblight in pears and apples. This protein, called 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 an incompatible pathogen. When harpin is applied to plants, the protein activates several different natural plant genes that are involved in plant growth and pest resistance. The objective of these studies was to evaluate the effect of Messenger on boll development with regard to hardlock and boll rot occurrence, and lint yield.

RESEARCH DESCRIPTION

Messenger was evaluated in 2000 and 2001 in replicated small-plot studies at a rate of 2.23 oz/acre per application with three to five sequential applications season-long in a root-knot nematode-infested field (Table 1). Messenger was evaluated in 2002 in replicated small plot studies at a rate of 2.25 oz/acre per application in various single application timings to three sequential applications season-long in a non-nematode-infested field (Table 2). Studies were harvested with plot pickers and lint fraction was determined from ginning hand harvested samples on a laboratory gin.

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RESULTS

2000 – 2001 Studies

Significant yield differences were not observed with sequential Messenger treatments. Lint yields differed by only 72 pounds from 2000 to 2001. Only one treatment resulted in a numerical yield improvement over that of the untreated control (Fig. 1).

2002 Study

Observations of bolls in the field showed that percent open bolls did not differ between treatments in boll samples (sample size 300 to 400 bolls; data not shown). The number of green, hardlock, and/or rotten bolls in the above-mentioned sample did not differ statistically.

Messenger had no significant effect on cotton yields. The three sequential-application treatments did not enhance lint yields (Fig. 2). Each of the three treatments containing two sequential applications of Messenger yielded slightly less numerically than did the control (Fig. 3). Although yields did not differ statistically, lint yields were improved numerically over that of the untreated control at the 2-leaf, pinhead square, and early bloom timings (Fig. 4).

PRACTICAL APPLICATION

Boll assessment measurements did not reveal differences associated with Messenger treatments. Sequential applications of Messenger did not appear to impact yield in a positive manner over that of the untreated control. Single applications appear to have greater potential for improving yield and providing a return on investment. The single application at the 2-leaf stage yielded 134 lb lint/acre over that of the untreated control. More research is needed to better understand the role that Messenger has in cotton improvement before it can be added to university extension recommendations.

Table 1. Messenger application timings in 2000-2001 field studies.

Treatment	2-lf[z]	PHS	PHS + 2 wk	EB	EB + 3 wk
1					
2	X	X	X	X	X
3	X	X	X		
4	X	X		X	
5	X	X	X	X	
6		X		X	X
7		X	X	X	X
8	X			X	X

[z] 2-lf = 2-leaf stage, PHS = pinhead square, and EB = early bloom.

Table 2. Messenger application timings in 2002 field studies.

Treatment	2-lf[z]	PHS	PHS + 2 wk	EB	EB + 3 wk
1					
2		X		X	X
3	X			X	
4		X			X
5				X	X
6	X				
7		X			
8			X		
9				X	
10					X

[z] 2-lf = 2-leaf stage, PHS = pinhead square, and EB = early bloom.

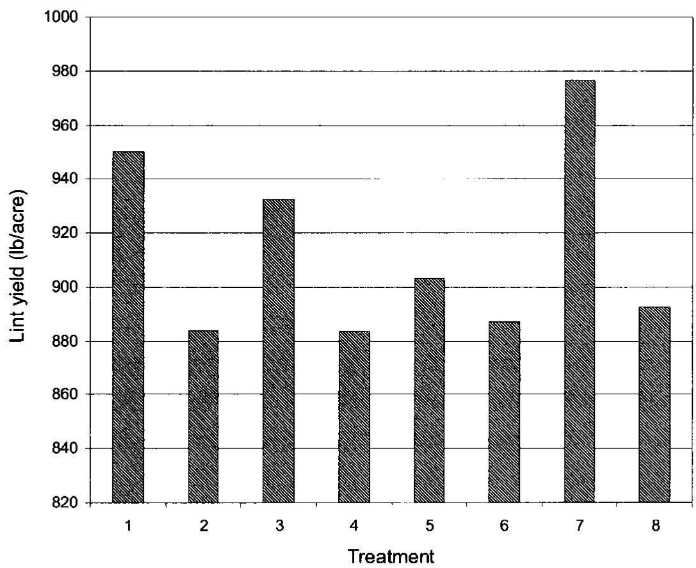

Fig. 1. Lint yield results from 2000-2001 Messenger field studies. Treatments are given in Table 1. There were no significant differences (P=0.05) between treatments.

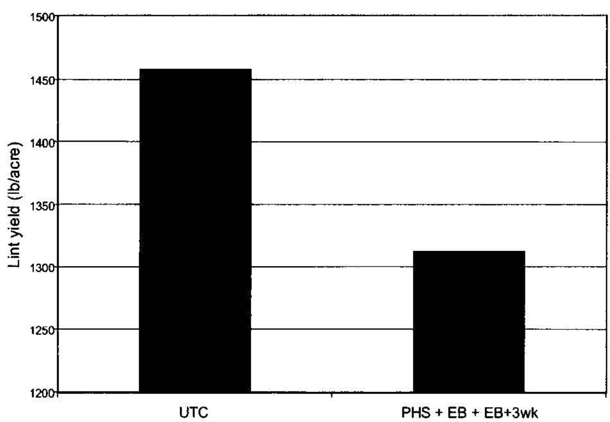

Fig. 2. Lint yield of Messenger-treated cotton in a three-time sequential program compared to an untreated control (2002). There were no significant differences (P=0.05) between treatments.

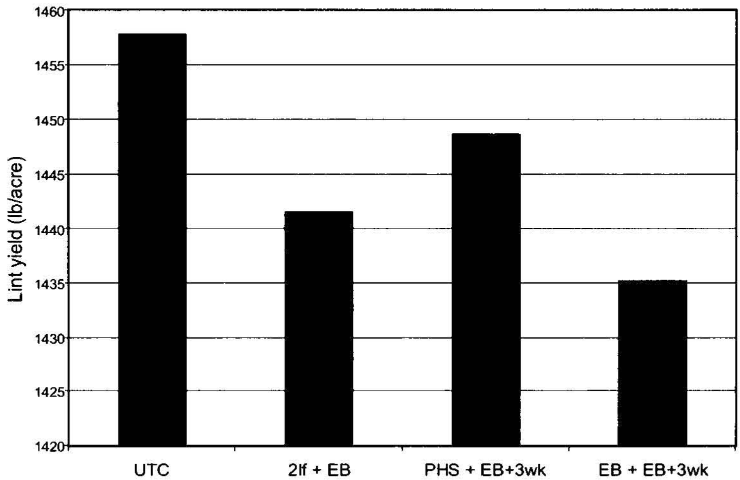

Fig. 3. Lint yield of Messenger-treated cotton in a two-time sequential program compared to an untreated control (2002). There were no significant differences (P=0.05) between treatments.

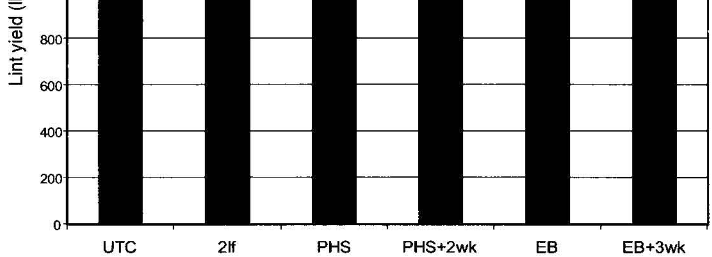

Fig. 4. Lint yield of Messenger-treated cotton in a single application program compared to an untreated control (2002). There were no significant differences (P=0.05) between treatments.

Evaluation of Plant Growth Regulators on the Yield and Fiber Quality of Cotton

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

RESEARCH PROBLEM

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

BACKGROUND INFORMATION

Field evaluation of available PGRs has been routinely conducted at the University of Arkansas for many years (e.g., Urwiler et al., 1989; Oosterhuis and Janes, 1994; Oosterhuis et al., 1996). Research has been directed towards (a) determining the effect of PGRs on growth and yield (Oosterhuis and Zhao, 1998); (b) investigating the physiological effects and underlying mechanisms of PGRs (Guo et al., 1994); and (c) studying the effects of PGRs under stress conditions, i.e. drought, flooding or shade (Zhao and Oosterhuis, 1997, 1998). These studies improve our understanding of how PGRs work and assist with recommendations regarding the use of PGRs in current cotton production systems in Arkansas. The current studies were designed to evaluate PGR-IV Plus, NP321, and Promote 125 as these three PGRs have shown the most consistent yield enhancement of all PGRs tested over the past 10 years (Oosterhuis et al., 1998).

RESEARCH DESCRIPTION

Three field experiments were planted into a Dubbs-Dundee silt loam soil at the Delta Branch Station in Clarkedale, Arkansas, on 16 May 2002 using the cotton cultivar

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Paymaster 1218 *Bt*/RR. Treatments, rates, and timing of each treatment are presented in Table 1. Foliar spray applications were made with a CO_2 backpack sprayer calibrated to deliver 10 gallons solution/acre. The experimental design was a randomized complete block with six replications. Fertilizer, weed, and insect control measures were conducted according to Extension Service recommendations. Plots were furrow irrigated as needed throughout the growing season. Physiological measurements were also made to investigate the mode of action of these PGRs but the results will not be reported here.

RESULTS AND DISCUSSION

Generally, there was little or no yield response to added PGRs in the three field experiments conducted in 2002. This may have been related to good mid-season growing conditions, i.e. high square retention and excellent boll set and boll filling, such that the developing yield potential may not have responded therefore to yield-enhancer PGR applications.

PGR-IV Plus had no significant effect on boll weight or yield (Table 2). However, there was a distinct trend for a numerical increase in yield with PGR-IV Plus applications, with the biggest increase (+114 lb lint/acre) from the three applications at PHS, FF and FF+2 weeks, and the least yield response (-94 lb lint/acre) from the single 1.0 oz/acre application at pinhead square.

Foliar application of NP321 resulted in a numerical yield increase in all treatments, averaging 63 lb lint/acre above the control (Table 3), although only one treatment (i.e., NP321 at 5.0 oz/acre at PHS and FF) was significantly different ($P \leq 0.05$) from the untreated control. The main effect of NP321 appeared to be an increase in boll weight, i.e. +0.2 g/boll (+5.16%) across all NP321 treatments compared to the untreated control (Table 3). Micronaire in all NP321 treatments was equal to or higher than the untreated control (Table 3).

The plant growth regulator Promote 125 had no significant effect on yield (+35 lb lint/acre), boll weight, or fiber quality (Table 4). The addition of Promote to Messenger™ resulted in a 48 lb lint/acre non-significant increase in yield above the untreated control.

PRACTICAL APPLICATION

The primary objective of this study was to evaluate and compare PGRs under field conditions in Arkansas for their effect on yield and quality of cotton. Results were generally disappointing due to a lack of significant yield increases in most treatments with all three PGRs tested. Overall, compared to the untreated controls, NP321 treatments increased yield by 63 lb lint/acre, PGR-IV Plus averaged an increase of 46 lb lint/acre, and Promote averaged a 35 lb lint/acre increase above the control. The excellent mid-season crop growth and boll development may have negated any significant yield advantages from added yield-enhancing PGRs.

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Table 1. Treatment rates and timing used in the PGR-IV, NP321, and Promote PGR field studies at Clarkedale, Arkansas, in 2002.

Experiment	Treatment[z]	Rate	Spray timing
1.	PGR-IV Plus	Untreated control	---- ----
	PGR-IV Plus	1.0 oz/acre	PHS
	PGR-IV Plus	1.5 oz/acre	PHS
	PGR-IV Plus	1.0 oz/acre	FF
	PGR-IV Plus	1.5 oz/acre	FF
	PGR-IV Plus	1.0 oz/acre	FF+2 weeks
	PGR-IV Plus	1.5 oz/acre	FF+2 weeks
	PGR-IV Plus	1.0 oz/acre	PHS, FF, and FF + 2 weeks
	PGR-IV Plus	1.5 oz/acre	PHS, FF, and FF + 2 weeks
2.	NP321	Untreated control	---- ----
	NP321[y]	2.5 oz/acre	FF
	NP321	5 oz/acre	FF
	NP321	10 oz/acre	FF
	NP321	20 oz/acre	FF
	NP321	2.5 oz/acre	PHS and FF
	NP321	5 oz/acre	PHS and FF
	NP321	10 oz/acre	PHS and FF
	NP321	5 oz/acre	PHS, FF and FF + 2 weeks
	NP321	10 oz/acre	PHS, FF and FF + 2 weeks
3.	Promote	Untreated control	---- ----
	Promote	2.0 oz/acre	FF and FF+2 weeks
	PGR-IV Plus	1.0 oz/acre	FF and FF+2 weeks
	Messenger + Promote[x]	2.25 oz/acre, 2.0 oz/acre	FF and FF+2 weeks

[z] All treatments applied as a foliar spray with a CO_2 backpack sprayer calibrated to deliver 10 gal H_2O/acre.
[y] Adjuvant Penetrator Plus used at 0.5% v/v with all NP321 treatments.
[x] Promote was sprayed at 2.0 oz/acre in combination with Messenger.

Table 2. Effect of foliar-applied PGR-IV Plus at pinhead square (PHS), first flower (FF), and two weeks after first flower (FF+2 weeks) on the boll weight and yield of cotton cultivar Paymaster 1218 Bt/RR. Clarkedale, 2002

Treatment	Boll seedcotton weight	Yield
	(g/boll)	(lb lint/acre)
Control 1	5.13 a[z]	1067 ab
PGR-IV Plus at 1.0 oz/acre at PHS	5.23 a	973 b
PGR-IV Plus at 1.5 oz/acre at PHS	5.22 a	1138 ab
PGR-IV Plus at 1.0 oz/acre at FF	5.06 a	1116 ab
PGR-IV Plus at 1.5 oz/acre at FF	4.95 a	1132 ab
PGR-IV Plus at 1.0 oz/acre at FF+2 weeks	4.92 a	1122 ab
PGR-IV Plus at 1.5 oz/acre at FF+2 weeks	5.13 a	1092 ab
PGR-IV Plus at 1.0 oz/acre at PHS, FF, and FF+2 weeks	4.82 a	1181 a
PGR-IV Plus at 1.5 oz/acre at PHS, FF, and FF+2 weeks	5.12 a	1100 ab

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

Table 3. Effect of NP321 of lint yield, boll weight, and fiber quality of cotton in Arkansas. Clarkedale, AR, 2002.

Treatment	Lint yield	Boll weight	Micronaire
	(lb/acrecre)	(g/boll)	
Control	865 b[z]	3.87 abc	3.68 a
2.5 oz/acre at FF	924 ab	4.01 abc	3.9 a
5.0 oz/acre at FF	922 ab	4.26 ab	3.83 a
10.0 oz/acre at FF	892 ab	3.86 c	3.76 a
20.0 oz/acre at FF	932 ab	4.18 abc	3.68 a
2.5 oz/acre at PHS and FF	946 ab	3.99 abc	3.68 a
5.0 oz/acre at PHS and FF	981 a	4.18 abc	3.85 a
10.0 oz/acre at PHS and FF	926 ab	3.93 bc	3.71 a
5.0 oz/acre at PHS, FF, and FF+2 wk	887 b	3.91 c	3.73 a
10.0 oz/acre at PHS, FF, and FF+2 wk	938 ab	4.31 a	3.86 a

[z] Treatment means followed by the same letter are not significantly different ($P \leq 0.50$).

Table 4. Effect of Promote 125 on lint yield, boll weight, and fiber quality of cotton. Clarkedale, AR, 2002.

Treatment	Lint yield	Boll weight	Micronaire
	(lb/acre)	(g/boll)	
Control	755 a[z]	4.51 a	4.22 a
Promote at 2oz/acre FF & FF+2 weeks	790 a	4.64 a	4.12 a
PGR-IV Plus at 1oz/acre PHS & Promote[y]	706 a	4.48 a	3.90 a
Messenger at 2.25oz/acre PHS & Promote[y]	803 a	4.51 a	4.08 a

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

[y] Promote was sprayed at 2 oz/acre at FF and FF+ 2 weeks in combination with Messenger.

Effects of *Bacillus cereus* on Cotton Growth and Yield and the Develolpment of PGR-IV Plus

Derrick M. Oosterhuis and Joe Hickey[1]

RESEARCH PROBLEM

The use of plant growth regulators (PGRs) in cotton to control growth and enhance yield is a widely used practice. The most commonly used PGR to control vegetative growth is Pix® (mepiquat chloride). Recently, the bacterium *Bacillus cereus* was added to Pix to form Pix Plus, a new and improved version of Pix. Research results have shown that Pix Plus has a small yield advantage over Pix while still costing the same. In subsequent research, *Bacillus cereues* has also been added to PGR IV.

BACKGROUND INFORMATION

There are numerous reports about the use and advantages of mepiquat chloride for controlling plant vegetative growth (e.g. Cothren, 1995). Generally, research has shown that mepiquat chloride controls growth (height) 100% of the time, and results in earlier maturity about 50% of the time and a yield increase about 25% of the time (Oosterhuis et al., 1991).

Pix Plus, formerly MepPlus, is a new PGR first tested in 1994 and registered in 1997 by Microflo (Memphis, TN) and now marketed by BASF (Research Triangle Park, NC). It consists of mepiquat chloride (MC) (4.2%), the bacteria *Bacillus cereus* (0.05%), and inert ingredients (95.75%). *Bacillus cereus* was reported to have tolerance exemption on all crops. Recent studies (Oosterhuis et al., 1998; Parvin and Atkins, 1997) have indicted that Pix Plus had a similar effect on plant height control as MC. In addition, Pix Plus has been reported to increased photosynthesis, leaf starch content, dry matter partitioning (Zhao and Oosterhuis, 2000), and lint yield (Parvin and Atkins, 1997) of field-grown cotton compared with the untreated control and MC treated plants. Subsequent research showed that a combination of BC plus a hormone-based formulation enhanced growth characteristics that influenced final yield. Growth chamber and field evaluations initiated in 1998 evaluated several formulations in either single or split

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[1] Distinguished professor, Crop, Soil, and Environmental Sciences Department, Fayetteville; and professor and technical development representative, Microflo, Taft, TX, respectively.

applications. Favorable results were obtained and additional field trials began in 1999 refining proper rates and timing. Based on initial findings, extensive field trials under the direction of certified crop consultants and university researchers began in 2000. The hypothesis of this study is that the use of a combination of *Bacillus cereus* and mepiquat chloride will lead to increased efficacy of other hormone-based products and improved plant growth and higher yields. The following is a summary of the results of these studies. The objectives were to evaluate the benefits of applying *Bacillus cereus* with: (a) mepiquat chloride on yield and fiber quality; (b) a hormone-based PGR (i.e. PGR-IV Plus) on yield and fiber quality; and (c) a pesticide on yield and fiber quality. In addition, we wanted to determine the optimum rate and timing of BC plus the plant growth regulator PGR-IV Plus.

RESEARCH DESCRIPTION

In 1998, formulation studies of *Bacillus cereus* and PGR-IV were conducted at 17 field locations across the Cotton Belt, in addition to a growth room study in Fayetteville, Arkansas. The optimum rate and timing of PGR-IV Plus was investigated in 1999 at 26 locations. In 2000, a single timing was evaluated at 33 field locations. In 2001 the formulation was optimized in a growth room study, and in 2002 field evaluations were continued. In all field studies, cotton (*Gossypium hirsutum* L.) was planted using current state extension recommendations for optimum cotton yield. Treatments included: (1) an untreated control, (2) Pix Plus as needed for height control, and (3) PGR-IV Plus (i.e., PGR-IV with *Bacillus cereus*). The spray applications were made using aerial application or a backpack sprayer calibrated to deliver 10 gal/acre in consultant field trials and University small plot studies, respectively.

RESULTS AND DISCUSSION

Bacillus cereus and PGR-IV Plus

Bacillus cereus (BC) was originally identified as having PGR effects, i.e., improved partitioning and translocation of carbohydrates to fruits (Zhao and Oosterhuis, 2001). BC was subsequently mixed with mepiquat chloride (MC) at rates of 1x to 4x to improve yield while still providing vegetative control. The 2x rate was generally the best, but at some locations yield response was best at the higher rates. Subsequently, combinations of BC + PGR-IV were tested in 1998-2002 on cotton that had been, or would be, treated with Pix Plus. From these studies, PGR-IV Plus was formulated. The overall results support the hypothesis of additional yield from improved partitioning of carbohydrates to the fruit.

1998 Formulation Study

Five formulations of varying concentrations of PGR-IV with *Bacillus cereus* (PGR-IV Plus) were evaluated at 17 sites in either single or split applications. All formu-

lations, except one, had a higher percentage of locations that ranked in the top three versus Pix Plus (data not shown). Based on these trials, the formulation with the highest percent (76%) of locations ranking in the top three was selected for additional evaluations.

1999 PGR-IV Plus Rate and Timing Trials

Twenty sites across the Cotton Belt were used to evaluate the selected formulation from the 1998 trials. The sites included six from Mississippi, six from South Carolina, six from Texas, four from Louisiana, two from Arkansas, one from Missouri, and one from California. Single and split applications of PGR-IV Plus were made to cotton that had been or would be treated with Pix Plus. Timings included pinhead square (PHS), early bloom (EB), and early bloom + 3 weeks (EB + 3). Split applications of the single applications were also made. Single applications at PHS and EB had the highest yield as compared to the Pix Plus treatment (data not shown). Average yield increase from Pix Plus across 20 sites ranged from 30 to 62 lb lint/acre. Bloom applications were the most consistent across all twenty locations with the PGR-IV Plus treatment ranking in the top three treatments for each experiment at 75% of the locations.

2000 PGR-IV Plus Dry Formulation Evaluation

To insure product efficacy and extend shelf life, a dry formulation containing the same active ingredients was developed. Thirty-three sites under the supervision of independent cotton consultants evaluated this product. Twenty-five consultants in the Tri-State Delta and eight consultants in Texas made single applications of PGR-IV Plus at early bloom at 1 oz/acre or 1.5 oz/acre to cotton that had been or would be treated with Pix Plus. Average yields for the 1.0 oz/acre rate were 1062 lb lint/acre versus 982 lb lint/acre. The average yields for the 1.5 oz/acre rate were 1048 lb lint/acre versus 992 lb lint/acre. The dry formulation of PGR-IV Plus proved to be highly efficacious with regards to both yield and consistency of positive plant yield response. Cotton treated with Pix Plus and subsequently treated with PGR-IV Plus had increased lint yields of 9.2% at the 1.0 oz/acre rate, and 5.9% at the 1.5 oz/acre rate. Consistency was greatly increased with 93.9% of locations exhibiting yield increases with the 1.0 oz/acre rate.

2001 Growth Chamber and Rate Response

Previous growth chamber and rate response studies were evaluated and further testing was initiated. Both growth chamber and field trials have indicated that the *Bacillus cereus* component increases carbohydrate partitioning to the fruiting structures, i.e., squares and bolls (Zhao and Oosterhuis, 2000). Field rate response trials conducted in 2001 again proved that applications of PGR-IV Plus at PHS, EB or EB + 3 weeks have a positive yield effect on cotton that has been treated with Pix Plus or

mepiquat chloride. Percent yield increases by application timing of PGR-IV Plus were as follows: pinhead square, 6.0%; early bloom, 7.2%; and early bloom + 3 weeks, 8.7% versus the more traditional mepiquat-chloride applications.

2002 Field Studies - PGR-IV Plus Alone and in Combination with a Pesticide

Field studies in 2002 showed that PGR-IV Plus out-yielded the control by 70 lb lint/acre (+6.1%) for the 1.0 oz/acre rate and by 83 lb lint/acre (+8.2%) for the 1.5 oz/acre rate (Table 1). These results are in agreement with those from the previous three years. Field studies in 2002 showed that *Bacillus cereus* combined with acephate out-yielded the control by 41 lb lint/acre (+3.4%) at the 0.5 oz/acre rate and by 45 lb lint/acre (+3.7%) at the 0.75 oz/acre rate (Table 2). These results show the positive results from combining *Bacillus cereus* with a pesticide, presumably through improved translocation. These positive yield responses from combining *Bacillus cereus* with mepiquat chloride, PGR-IV, and pesticides will necessitate further field testing with additional emphasis on improving our understanding of the mechanism of these combinations.

Increased Yields from PGR-IV Plus Over the Area Standard

There were positive yield increases each year from PGR-IV Plus applications over the area standard (i.e. whatever rate of mepiquat chloride was used as a standard treatment to control vegetative growth):

- 1999 University and Consultants: average yield increase 46 lb lint/acre.
- 2000 MS Delta Consultants: average yield increase 70 lb lint/acre.
- 2000 TX Consultants: average yield increase 67 lb lint/acre.
- 2002 MS Delta University and Consultants: average yield increase 76 lb lint/acre.

In general, over all five years and 91 locations, an average 69.3 lb lint /acre yield increase was achieved.

Theory Behind the *Bacillus cereus* Hormone Combination

The theory behind the *Bacillus cereus* hormone combination is that maximum plant uptake rates of nutrients and carbohydrate occur during the squaring and early flowering period (Oosterhuis and Hickey, 2003). Therefore enhancement of partitioning and translocation during this period should benefit yield, particularly under stressful conditions. Earlier studies by Zhao and Oosterhuis (2000) showed that the new plant growth regulator Pix Plus, consisting of *Bacilus cereus* and mepiquat chloride, improved translocation of photoassimilates from leaves to fruits and partitioning of dry matter among plant tissues, resulting in improved yields (Fig. 1).

PRACTICAL APPLICATION

An important objective of Plant Growth Regulators (PGRs) is to balance vegetative and reproductive growth as well as improve yields and fiber quality. Various PGRs have been used to achieve these objectives with varying successes. Recently, *Bacillus cereus* was added to mepiquat chloride for additional yield advantage. Addition of *Bacillus cereus* to mepiquat chloride resulted in improved partitioning and carbohydrate translocation to the fruit. Subsequent combinations *of Bacillus cereus* and the hormone PGR-IV (forming PGR-IV Plus) resulted in additional yield increases averaging 69.3 lb lint/acre in field and growth room studies over a four year period at 71 locations across the Cotton Belt (that had received standard Pix Plus applications). Optimum timing of PGR-IV Plus application was achieved with early- to mid-bloom applications. These studies have shown activity of *Bacillus cereus* with growth retardants (mepiquat chloride), growth enhancers (PGR-IV), and insecticides (acephate). Future studies will continue to evaluate *Bacillus cereus* in PGR-IV Plus for growth and yield advantages as well as in combinations with insecticides.

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Table1. Effect of PGR-IV Plus on yield averaged over 20 locations in 2002.

	Lint yield	
Treatment	1.0 oz/acre	1.5 oz/acre
Control	1127	1009
PGR-IV Plus	1196	1092
Difference	70 (+6.1%)	83 (8.2%)

Table 2. Effect of *Bacillus cereus* with Acephate (AcePlus) on yield averaged over 18 locations in 2002.

	Lint yield	
Treatment	0.5 oz/acre	0.75 oz/acre
Orthene	1204	1216
AcePlus	1245	1261
Difference	41 (+3.4%)	45 (+3.7%)

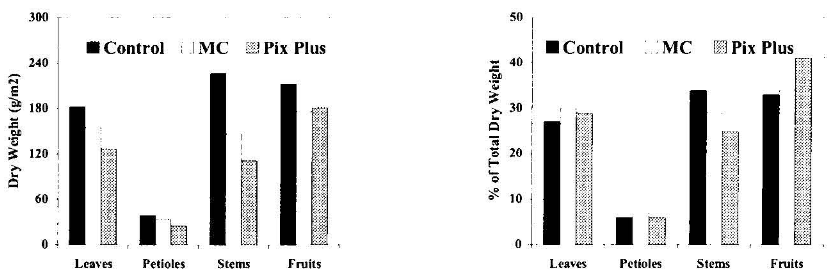

Fig. 1. Effect of mepiquat chloride and Pix Plus on dry matter accumulation (left) and partitioning (right) of field-grown cotton (From Zhao and Oosterhuis, 2000).

Increased Efficacy of Bt Cotton with Chaperone™

Derrick M. Oosterhuis and Robert S. Brown[1]

RESEARCH PROBLEM

Variability of endotoxin expression and/or concentration within transgenic cotton (*Bt*) varieties has been and continues to be a concern of cotton growers, researchers, and breeders. While not a consistent problem, it can cause major economic problems. Transgenic cotton cultivars, to be effective throughout the season, must produce additional levels of proteins that conventional cottons do not. Chaperone™ (formerly Arysta Experimental NP321), a protein transport enhancer, containing nitrophenolates has been shown to increase the efficacy of the endotoxin levels within transgenic cottons, resulting in higher worm mortality and increased yield. The current research was designed to quantify the enhanced protein/endotoxin levels and increased insect mortality in cotton from foliar applications of Chaperone.

BACKGROUND INFORMATION

Chaperone is a new *Protein Transport Enhancer* for transgenic plants, registered by EPA in 2000 and with patent pending. Chaperone is a combination of nitrophenols, namely sodium 5-nitroguaiacolate, sodium o-nitrophenolate, and sodium p-nitrophenolate. Phenolics play a central role in plant metabolism and growth. For example, they are known to increase photosynthetic electron transport, improve/protect membrane integrity, increase enzyme/protein production (e.g. IAA oxidase and glucose 6-phosphate dehydrogenase) (Robinson, 1980), act as a part of lignin biosynthesis, and increase fruit retention. Observations in transgenic cottons have shown that endotoxin levels have occasionally failed to be fully expressed under various conditions, including environmental factors and varietal differences, thus occasionally leading to less efficient insect control and yield losses.

Our hypothesis was that utilization of the phenolic properties of Chaperone in transgenic cotton would aid in alleviating non-expression or under expression of Cry I

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Ac (BOLLGARD™ by Monsanto) or a combination of Cry I Ac with Cry 2 Ab (BOLLGARD II™ by Monsanto), which are currently the genes utilized for expression of the endotoxin protein *Bacillus thuringiensis*. It has been observed that a reduction in the amount of expressed endotoxin occurs as plants mature, leading to a loss of efficacy in the latter stages of the growing season thus increasing the probability of surviving pests which may develop immunity to the endotoxin (Greenplate, 1999; Benbrook and Hansen, 1997). In *Bt* cotton, it is theorized that expression of the Cry I Ac gene drops due to a decline in the concentration of the CAMV35S promoter causing the gene to be "silenced" or affected by other post transcription events (Kennedy and Turner, 1999). The Cry I Ac protein may also be reduced due to increased turnover, sequestration within the plant, or dilution due to growth and aging (Greenplate, 1999). It is understood that Cry I Ac transcription levels are occasionally unstable in both immature and mature *Bt* cotton plants (Daly and Fitt, 1998). Testing to date has indicated an increase in *Bt* expression where Chaperone has been applied, improved worm mortality, and increase yield (Oosterhuis et al., 2003).

RESEARCH DESCRIPTION

Yield Trials

In 2001, yield trials were conducted at 18 locations across the Cotton Belt. Plant samples were taken from nine of these locations for determination of endotoxin levels by Elisa testing at Agdia Laboratories. Treatments consisted of foliar applications of Chaperone applications made at match-head square and at mid-bloom at a rate of 5-10 oz/acre. A randomized complete block design was used. In 2002, yield trials were conducted at 46 locations across the Cotton Belt. Plant samples were taken for endotoxin levels from 10 locations. Treatments consisted of foliar applications of Chaperone at 5-10 oz/acre at match-head square, at mid-bloom, at match-head square and/or mid-bloom, or at MHS, EB, and 2 and 3 weeks after flowering. In 2001, subtending leaves, petioles, and fruiting structures were sampled at 5 and 10 days after Chaperone application by horizon within the plant structure, placed immediately on dry ice and shipped to the Agdia testing facility. Samples consisted of 10 main-stem leaves sampled randomly from the canopy, fourth leaf from the terminal. This was repeated in 2002.

Bollworm MortalityTrials

The cotton (*Gossypium hirsutum* L.) cultivar Paymaster 1218 BtRR was planted March 2002 at the Altheimer Laboratory, University of Arkansas, in 2 L pots containing Sunshine Mix. The growth chamber was set for 12-h photoperiod, with day/night temperatures of 30/25°C and relative humidity of 60 to 80%. Plants were arranged in a completely randomized design with three replications. All pots received half-strength Hoagland's nutrient solution daily to maintain adequate nutrients and water. The Chaperone treatments were applied as a foliar spray at 5, 10, and 20 oz/acre with a CO_2

backpack sprayer calibrated to deliver 10 gallons H_2O/acre. An adjuvant, Penetrator Plus at 0.05% v/v was used. Chaperone treatments were sprayed at the seventh true leaf and the upper expanded main-stem leaf sampled 10 days later. Treatments were sprayed again at the seventh true leaf +10 days and the upper main-stem leaf sampled 5 and 10 days later for the leaf and squares. After each sampling, tissue samples were placed in small ziploc bags and immediately taken to the University of Arkansas Entomology Department for bollworm mortality testing. Bollworm mortality rates were assessed at 24, 48, 72, and 96 hours from the initiation of feeding for samples following first spray application and assessed at 72 and 96 hours following start of feeding for sampling taken after the second spray application.

Field studies were conducted at Clarkdale, Arkansas, using Paymaster 1218 BtRR planted on 6 May 2002. The experimental design was randomized complete block with six replications. Fertilizer, weed, and insect control measures were carried out according to Extension Service recommendations for Arkansas. Plots were furrow irrigated as needed throughout the season. Chaperone treatments were applied as a foliar spray at 5 and 10 oz/acre at early bloom with the adjuvant Penetrator Plus at 0.05% v/v using a CO_2 backpack sprayer delivering 10 gal H_2O/acre. Samples were taken for testing at 72 and 96 hours after application of Chaperone, placed in small ziploc bags, placed on dry ice and immediately taken to the University of Arkansas Entomology Department for bollworm mortality tests.

RESULTS AND DISCUSSION

Yield Studies

Yield data averaged from 24 Midsouth consultant trials showed that NP 321 increased yield by an average of 71 lb lint/acre from a single mid-bloom application at both 5 and 10 oz/acre rates compared to the untreated control (Fig. 1a). However, there was not a rate response as indicated by the similar yield results between the 5 oz/acre and 10 oz/acre treatments. Yield data from 11 university trials showed that Chaperone increased yield from a single mid-bloom application at both 5 and 10 once per acre rates by 92 and 60 lb lint/acre, respectively, compared to the untreated *Bt* control (Fig. 1b). Overall, the 5 oz/acre rate of Chaperone had a greater yield advantage than the 10 oz/acre rate of Chaperone.

Endotoxin Level Studies

A single mid-bloom application of Chaperone increased endotoxin levels compared to the untreated *Bt* control in all three tissues; leaves, petioles, and squares (Fig. 2). Furthermore, as the foliar-applied rate of Chaperone increased, the level of expressed endotoxin was also increased in all three tissues (Fig. 2), with the greatest increase observed in the leaf tissue.

Bollworm Mortality

Neonate bollworm mortality at first flower was increased at both 72 and 96 hours after the initiation of feeding on small *squares* from plants previously treated with NP 321 (Fig. 3a). All three rates of foliar-applied NP 321 showed increased mortality levels of neonate bollworms, with the 5 oz/acre rate of Chaperone showing the highest mortality of neonates feeding on young squares. This result may help to explain the yield advantage that was achieved across test locations when Chaperone was applied at the lower rate of 5 oz/acre. A non-*Bt* treatment was also included in the test that showed less than five percent mortality of neonates. Similarly, bollworm mortality on *leaves* was also significantly increased by Chaperone compared to the untreated *Bt*-control at the seventh true leaf stage (Fig. 3b). The non-*Bt* control showed less than five percent mortality levels of neonate bollworms at all three observation timings.

The percentage increase in bollworm mortality from imposed neonates feeding on cotton *squares* sprayed at MHS is shown in Fig. 4a. At 72 hours after neonate feeding on small squares, there was very little difference among treatments for increasing mortality, whereas by 96 hours after feeding there were noticeable increases in mortality in Chaperone treatments. This increase in mortality after 96 hours also appeared to be rate dependent, with the higher Chaperone rates showing the greatest increases in bollworm mortality. Similarly, bollworm mortality on leaves was also significantly increased compared to the untreated Bt-control (Fig. 4b). At both 72 and 96 hours after feeding there were noticeable increases in mortality in leaves previously treated with Chaperone. This increase in mortality on leaves also appeared to be rate dependent with the higher Chaperone rates showing the greatest increases in bollworm mortality.

It is thought that the Chaperone acts in one or more of several ways: (a) as a form of protective water substitute for cellular membranes during times of water deprivation, and (b) as a protein stabilizer for the desired pesticidal protein and/or as a binder for protein thus facilitating movement via intraplant transport mechanisms. The end result being that transgenic crops treated with Chaperone have been shown to express and move effective proteins into plant tissues in a greater concentration than non-treated plants, thereby enhancing endotoxin levels and bollworm mortality.

PRACTICAL APPLICATION

Applications of NP 321 in 2001-2002 exhibited yield increases in both University and Consultant trials. This was associated with an increase in endotoxin levels for Bt cotton in leaves, petioles, and squares. The increased endotoxin levels resulted in an increase in bollworm mortality as displayed in feeding trials from growth chamber and field studies.

ACKNOWLEDGMENTS

We thank James Lackey and LTA Research for sponsoring this research.

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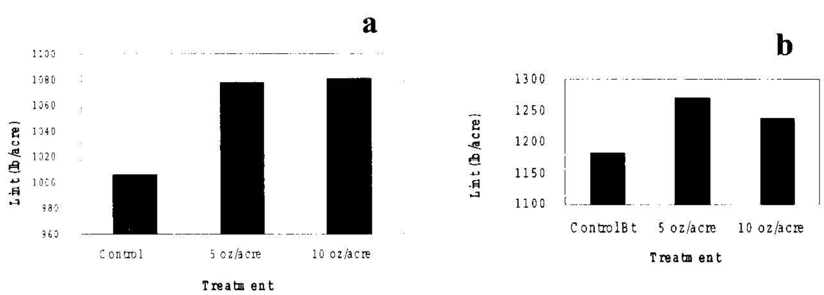

Fig. 1. (a) Mid-South Consultants yield data from 24 locations following Chaperone treatment for 2001-2002. (b) University yield data from 11 locations following Chaperone treatment for 2001-2002.

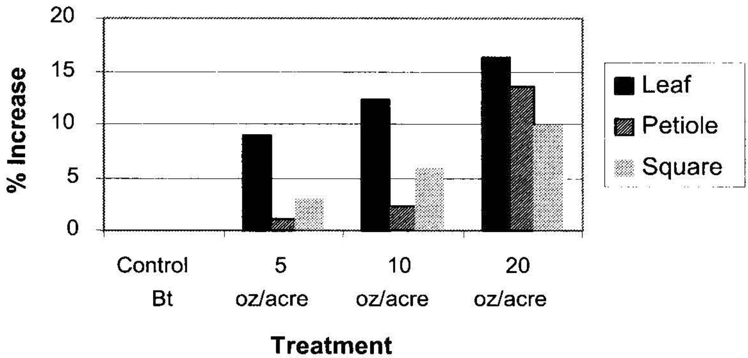

Fig. 2. Percentage increase in plant endotoxin levels in leaves, petioles, and squares following foliar treatment with Chaperone in Bt cotton.

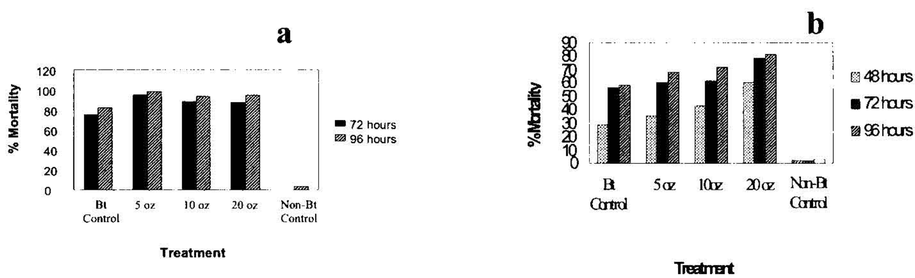

Fig. 3. Mortality levels of neonate bollworms feeding on squares (left) and leaves (right) following Chaperone applications. The study was conducted in 2002 in Fayetteville, AR, in a growth chamber environment.

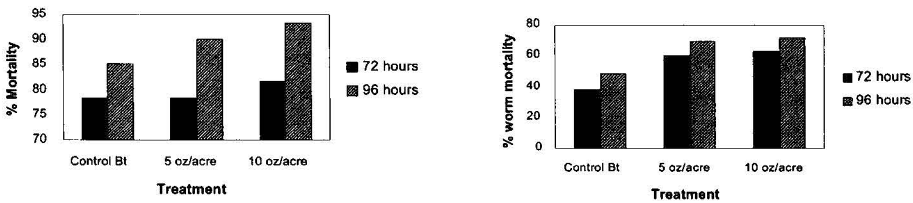

Fig. 4. Mortality levels of neonate bollworms feeding on squares (left) and leaves (right) following Chaperone applications. Samples were obtained from the field trial at Clarkedale, AR, during the summer of 2002.

Susceptibility of Noctuids to *Bt*-Endotoxins in Arkansas

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RESEARCH PROBLEM

Bollgard cotton (*Bt*-cotton) expressing *Cry1Ac* endotoxin is an important pest management tool for Arkansas cotton farmers. The widespread adoption of Bollgard cotton in Arkansas and the US has been associated with less insecticide use and greater control of some major pest species, but potential resistance to *Cry1Ac* and other entodtoxin proteins expressed in the plants is a growing concern, especially potential resistance in bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm, *Heliothis virescens* (F.). With increased adoption of this technology and anticipated commercialization of other transgenic cottons expressing endotoxin proteins, selection for endotoxin-resistant pest populations may become a critical management issue. Variation in the response of different populations of these pests has been reported and apparently varies widely among diversely separated field populations. The objectives of this study were to establish baseline reference data for major noctuid pests of agronomic crops in Arkansas, especially *H. virescens* and *H. zea.* An emphasis was placed on the collection and study of insects from three geographically and ecologically diverse agricultural systems of the state.

BACKGROUND INFORMATION

Bollworm and tobacco budworm vary in their susceptibility to endotoxin proteins (Stone et al., 1989; Gould et al., 1992, 1995; Moar et al., 1995; Burd et al., 2000; Jackson et al., 2001) and the level of resistance may vary widely among geographically diverse populations (Stone and Sims, 1993; Luttrell et al., 1999). Over the past few years, Hardee et al. (2001) monitored the status of bollworm and tobacco budworm resistance to *Bt* cotton in the US. They reported that tolerance of tobacco budworm to *Bt* toxin did not change during the period 1996 to 1998; however, tolerance of bollworm to *Bt* cotton appeared to increase.

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[1] Research specialist, professor, professor, assistant professor, senior graduate assistant, and student helper, respectively, Entomology Department, Fayetteville.

RESEARCH DESCRIPTION

Insects were collected from strategic locations of Arkansas, Missouri, and Mississippi and laboratory colonies were established at the Margaret McClendon Insect Rearing Facility, Department of Entomology, University of Arkansas, Fayetteville. Progenies of these colonies were exposed to Cry1Ac and Cry2Ab endotoxin using a diet-incorporated bioassay technique. Monsanto Company., St Louis, MO and Mycogen Corporation, San Diego, CA supplied the endotoxin. Toxins and freshly prepared diet (Burton, 1969) were poured into 140 ml Nalgene plastic bottles, vortexed, and dispensed (ca. 1 ml/well) into the wells of assay trays. Once the diet was dry, one neonate test insect was placed in each well. The trays were then covered with plastic ventilated covers and incubated at 27°C, 70% relative humidity (RH), and 14:10 h photoperiod, for seven days. There were 48 to 112 larvae used for each concentration and 3 to 8 replications were conducted on different days. Larval mortality was recorded after 7 days.

RESULTS

LC_{50s} of laboratory and field colonies of tobacco budworm exposed to Cry1Ac ranged from 0.22 to 0.43 and 1.20 to 2.78 g of toxin/ml of diet, respectively. Susceptibility of laboratory populations was 5- to 12-fold higher than field populations. Previously, Luttrell et al. (1999) reported a 5-fold level of variation among 11 field populations of tobacco budworm. Susceptibility of bollworm colonies to Cry1Ac varied among laboratory and field colonies. The LC_{50}s for 14 field colonies ranged from 4 to 85 µg of toxin/ml of diet. Based on lack of overlap of fiducial limits, 10 of our field colonies had significantly higher LC_{50}s than both laboratory colonies. In a similar study, Luttrell et al. (1999) reported about 300-fold variation in susceptibility. The LC_{50} for UA laboratory soybean looper colony exposed to Cry1Ac was 5.02 µg/ml. A similar response was observed in the field colony (4.70 µg of toxin/ml of diet) (Table 1).

Susceptibility of tobacco budworm to Cry2Ab did not vary significantly among the field colonies, however, significant variation in susceptibilities of field and laboratory colonies was observed. Field colonies were 2.5- to 40-fold less susceptible than the laboratory colonies. Susceptibility of bollworm to Cry2Ab did not vary among laboratory colonies. LC_{50}s for laboratory colonies ranged from 0.10 to 0.14 percent of diet with toxin. Susceptibilities of the nine colonies varied widely, LC_{50}s ranged from 0.16 to 0.62 percent of diet with toxin. Relative to the laboratory colonies, field colonies were 1.6 to 6.2-fold less susceptible, and most field colonies were significantly less susceptible than the laboratory colonies (Table 2).

PRACTICAL APPLICATION

These data serve as an important benchmark for study of resistance evolution over time. Higher LC_{50}s were associated with collections of large larvae from cotton. We are interested in further examination of these insects and production situations

that allow larvae to survive on *Bt* crops. Additional laboratory work is underway, and we intend to continue the monitoring work in 2003.

ACKNOWLEDGMENTS

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Table 1. Susceptibility of bollworm, tobacco budworm, and soybean looper to liquid MVP II (Cry1Ac) endotoxin in diet-incorporated bioassays.

Colony	Species	Source	LC_{50}	Fiducial limit Lower	Fiducial limit Upper	Slope
			(µl/ml of diet)			
UA Lab	*H. virescens*	Laboratory	0.22	0.15	0.31	0.98
USDA Lab	*H. virescens*	Laboratory	0.43	0.21	0.76	0.87
#6-8	*H. virescens*	Corn	2.78	1.25	25.72	0.75
#27	*H. virescens*	Cotton	1.13	0.75	1.54	1.57
#28	*H. virescens*	Cotton	1.20	0.83	1.73	1.02
UA Lab	*H. zea*	Laboratory	1.04	0.44	2.63	1.20
USDA Lab	*H. zea*	Laboratory	1.75	0.95	3.86	0.50
#9	*H. zea*	Corn	17.80	7.06	164.15	0.58
#11, 13 & 14	*H. zea*	Corn	4.54	0.39	11.77	0.93
#12	*H. zea*	Sweet corn	10.82	7.06	15.76	1.54
#16	*H. zea*	Sorghum	5.59	2.25	9.63	1.31
#17	*H. zea*	*Bt*-corn	18.31	1.0	245.85	1.13
#18	*H. zea*	Corn	29.78	20.19	47.42	1.47
#19	*H. zea*	Sorghum	12.05	8.54	17.58	1.95
#23	*H. zea*	*Bt*-cotton	20.82	10.35	46.83	0.81
#31	*H. zea*	Cotton	27.90	10.47	137.30	1.28
#33	*H. zea*	*Bt*-cotton	85.45	46.70	288.81	1.07
#34	*H. zea*	*Bt*-cotton	46.22	26.76	155.48	1.02
#38	*H. zea*	Corn	36.30	23.14	71.56	1.66
Escapee	*H. zea*		15.93	9.01	30.27	1.27
UA Lab	*P. includens*	Laboratory	5.02	0.91	31.30	2.13
#37	*P. includens*	Soybean	4.70	2.31	11.96	1.57
Lab	*S. frugiperda*	Laboratory	236.41	139.48	624.92	1.21

Table 2. Tolerance of bollworm, tobacco budworm, and soybean looper to Cry2Ab endotoxin in diet-incorporated bioassays (Based on mortality data).

Colony	Species	Source	LC_{50}	Fiducial limit		Slope
				Lower	Upper	
			(% of diet)[z]			
UA Lab	*H. virescens*	Laboratory	0.004	0.00	0.02	0.70
USDA Lab	*H. virescens*	Laboratory	0.002	0.00	0.01	0.72
#6-8	*H. virescens*	Corn	0.08	0.03	0.31	1.11
#27	*H. virescens*	Cotton	0.01	0.00	1.54	1.16
#28	*H. virescens*	Cotton	0.03	0.01	0.08	1.10
UA Lab	*H. zea*	Laboratory	0.14	0.08	0.23	1.49
USDA Lab	*H. zea*	Laboratory	0.10	0.06	0.14	1.16
#9	*H. zea*	Corn	0.59	0.26	3.58	1.69
#11, 13 & 14	*H. zea*	Corn	0.55	0.41	0.69	1.96
#16	*H. zea*	Sorghum	0.45	0.24	0.81	0.91
#17	*H. zea*	*Bt*-corn	0.46	0.35	0.56	2.43
#18	*H. zea*	Corn	0.51	0.33	0.80	1.33
#23	*H. zea*	*Bt*-cotton	0.32	0.23	2.94	2.36
#31	*H. zea*	Cotton	0.16	0.02	0.32	1.49
#34	*H. zea*	*Bt*-cotton	0.92	0.76	1.12	2.41
#38	*H. zea*	Corn	0.62	0.50	0.77	1.95
Escapee	*H. zea*		0.33	0.28	0.38	3.19
UA Lab	*P. includens*	Laboratory	0.03	0.00	0.12	1.42
#37	*P. includens*	Soybean	0.04	0.01	0.08	0.85

[z] Corn leaf powder (source of Cry2Ab) was mixed with diet on a weight-by-weight basis. For example, for 1% of CryAb/ ml of diet, 1µg of corn leaf powder was mixed with 99 ml of diet.

Effects of Trimax™ on the Physiology, Growth, and Yield of Cotton

Derrick M. Oosterhuis and Robert S. Brown[1]

RESEARCH PROBLEM

Trimax is a new insecticide from Bayer CropScience specifically for use on cotton for control of major sucking/piercing insects in cotton. In addition, significant yield enhancement benefits have been observed even in situations without economic insect thresholds. However, information is lacking on how Trimax affects plant growth and thereby enhances yield. The current study was designed to understand plant growth response to foliar application of Trimax with particular emphasis on the physiological and biochemical changes that occur and how these may affect the development of yield.

BACKGROUND INFORMATION

Trimax is an imidacloprid product discovered by Bayer in 1985 and was the first commercially introduced insecticide in the class of chloronicotinyl insecticides. Trimax provides control of the major sucking/piercing insects in cotton (aphids, cotton flea-hopper, banded winged whitefly, plant bugs excluding *Lygus hesperus*, green stink-bug, and southern stinkbug). It also has ovicidal effects on bollworms and budworms. The active ingredient in Trimax is imidacloprid, the only insecticide in the nitroguanidine subclass of chloronicotinyl insecticides with a chloropyridine side chain. This distinguishing side chain is structurally related to compounds like nicotinamde and chloronicotinic acid known as systemic plant resistance inducers. These substances help plants to better tolerate environmental stress during drought, disease, and insect attacks. Field use of Trimax, especially when used in multiple application spray programs beginning early to mid-season, have resulted in enhanced yields (ref: Bayer CropScience Technical Bulletin TRO211, 2002), including in situations where economic insect thresholds have not been reached.

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RESEARCH DESCRIPTION

Growth chamber and field studies were designed to supply information to quantify plant growth response to Trimax. This information should also permit us to determine, or at least formulate, an explanation of how Trimax is affecting the growth and development of the cotton plant and enhancing yield.

Field studies were conducted at the University of Arkansas Delta Branch Experiment Station in Clarkedale, northeast Arkansas, and also at the Main Experiment Station in Fayetteville, northwest Arkansas. Additional studies will be conducted in controlled environment chambers at the Altheimer Laboratory in Fayetteville to further elucidate the mode of action of Trimax. A randomized split-plot design with six replications was used in Clarkedale, and a randomized complete block design with six replications was used in Fayetteville. At Clarkedale, the Trimax treatments were evaluated under both well-watered and water-deficit conditions accounting for the split-plot design. Water deficit was imposed using an irrigation system specially designed to impose well-watered and water-deficit conditions differentially to a randomized field plot system. In Fayetteville, foliar Trimax applications were evaluated only under well-watered conditions.

Treatments consisted of (1) an untreated control, and (2) Trimax at 1.5 oz/acre. The cotton cultivar Stoneville 474 was planted on 16 May 2002 in Clarkedale, and cultivar Suregrow 215 BtRR on 22 May 2002 in Fayetteville, in a Captina silt loam. Trimax was applied with a CO_2 backpack sprayer at three weekly intervals after pinhead square at Clarkedale and once during peak squaring at Fayetteville.

At Clarkedale, measurements were made of (a) plant growth by classical growth analysis, plant mapping, and NAWF; (b) plant physiological response by measuring a range of physiological parameters including nonstructural carbohydrate concentrations, leaf photosynthesis, canopy temperature, specific leaf weight (SLW), and chlorophyll content; (c) plants ability to tolerate stress by measuring antioxidant enzymes; and (d) final lint yield, yield components, and sequential harvest as a measure of yield earliness (sequential harvest data taken by Roger Bowman and Alan Hopkins from Bayer CropScience). Photosynthesis and canopy temperature were recorded using a LICOR 6200 portable photosynthesis system and a handheld infrared thermometer, respectively.

At Fayetteville, measurements were made of (a) final yield and yield components, and (b) enzyme activity from leaf material collected at 3 hour intervals for the first 24 hours and daily for one week beginning immediately following the foliar application of Trimax (data not shown).

RESULTS AND DISCUSSION

Effects of Trimax on Plant Growth

Applications of Trimax during square development appeared to have a stimulatory effect on plant growth, although most of the parameters measured were not sig-

nificantly different ($P<0.05$) from the untreated control (Table 1). Table 1 shows that Trimax stimulated plant growth as demonstrated by a numerical increase in dry matter of plant components. These differences were visually obvious in plant size at first flower but not apparent during boll development and at harvest.

Effects of Trimax on Plant Physiology

Trimax decreased specific leaf weight and increased chlorophyll content but had no effect on leaf photosynthesis or canopy temperature (Table 2). The lack of effect on canopy temperature is to be expected as the crop was not under any appreciable water deficit stress and Trimax was not expected to affect plant-water relations. The increase in chlorophyll was difficult to explain. However, the decrease in specific leaf weight may be related to improved metabolism and translocation of carbohydrates out of the leaf.

Effects of Trimax on Carbohydrates and Antioxidant Enzymes

In order to understand the biochemical changes induced by Trimax on cotton, carbohydrate concentration and the activity of antioxidant enzymes after foliar application of Trimax to cotton leaves were determined. Trimax did not significantly affect carbohydrate concentrations (Table 3). However, there was a significant ($P\leq0.05$) decrease in the level of the antioxidant enzyme glutathione reductase (Table 3). All living organisms produce reactive oxygen species (such as superoxide, hydrogen peroxide, and hydroxyl radicals) as part of normal metabolism particularly under stressful environments. To prevent excessive cellular oxidation from the production of these reactive oxygen metabolites, plants have evolved strategies such as an antioxidant defense system to detoxify the plant and remove these harmful oxygen radicals. It was hypothesized that the apparent growth advantage imposed by Trimax is in part due to the plants experiencing less stress, i.e. as evidenced by less activation of antioxidant enzymes to detoxify the plant of free radicals which are always present due to the numerous environmental stresses that crops face daily. Glutathione is involved in a wide range of metabolic processes (Meister and Anderson, 1983) and its content increases considerably under stressful conditions (Smith et al., 1990). A major function of glutathione is thought to be that of protection against oxidative biotic and abiotic stress, i.e. SO_2, O_3, UV irradiation, drought, extreme temperatures, and attack by other organisms. Our results show a significant decrease in glutathione reductase in Trimax-untreated plants that would support the hypothesis that the untreated plants are exhibiting stress whereas stress was alleviated in Trimax-treated plants.

Effects of Trimax on Lint Yields

Multiple foliar applications of Trimax numerically increased lint yield of field-grown cotton at Clarkedale in northeast Arkansas (Fig. 1A) and significantly increased ($P\leq0.05$) lint yield at Fayetteville in northwest Arkansas (Fig. 1B) where a single appli-

cation of Trimax at 1.5 oz/acre was sprayed. This increase in yield further supports earlier reports of increased yields with multiple applications of Trimax.

Effects of Trimax on Earliness

Trimax-treated plants showed significant earliness as exhibited by a more rapid decline in nodes above white flower (NAWF) (Fig. 2A). NAWF is a standard measure of earliness in the COTMAN crop monitoring program (Danforth and O'Leary, 1999), with a rapid decline to physiological maturity at NAWF=5 indicating earliness. In addition, a larger percentage of the total yield was harvested at the first pick (Fig. 2B). This indicated that a greater proportion of the total number of harvestable bolls matured earlier and was ready for picking before those of the untreated control plants. Early crop maturity is a very important attribute in cotton production for economic and pest control reasons. Also, early maturity is particularly important in the Mississippi Delta where the season length is already limited.

PRACTICAL APPLICATION

Trimax insecticide increased lint yields at both Arkansas test locations when foliar-applied at either single or multiple applications at the 1.5 oz/acre rate. These increases in yield further support earlier reports of increased yields with multiple applications of Trimax. In-season measurements suggest that the increase in lint yield following foliar Trimax application was due in part to more efficient maintenance of physiological and biochemical processes by the cotton plant. However, more research needs to occur to fully validate the effectiveness of Trimax for increasing lint yields, quality, and earliness and to better explain how this yield enhancement is achieved.

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Table 1. Effect of Trimax on plant growth and development measured three weeks after first flower. Clarkedale, AR, 2002.

Treatment	LAI	Dry weights Leaf	Dry weights Fruit	Dry weights Total	Squares
	(m^2/m^2)	(g/m^2)	(g/m^2)	(g/m^2)	($\#/m^2$)
Control	2.9 a[z]	115 a	27.6 a	303 a	193 a
Trimax	3.3 a	132 a	36.6 a	356 a	187 a

[z] Numbers followed by the same letter are not significantly different ($p \leq 0.05$).

Table 2. Effect of Trimax on physiological parameters measured three weeks after first flower. Clarkedale, AR, 2002.

Treatment	Specific leaf weight	Chlorophyll	Photosynthesis	Canopy temperature
	(g/m^2)	(SPAD units)	($\mu mol/m^2/s$)	(C°)
Control	64.1 a[z]	45.7 b	23.3 a	26.7 a
Trimax	56.8 b	51.7 a	24.5 a	26.6 a

[z] Numbers followed by the same letter are not significantly different ($p \leq 0.05$).

Table 3. Effect of Trimax on carbohydrate concentrations and antioxidant enzyme activity measured three weeks after first flower. Clarkedale, AR, 2002.

Treatment	Glucose	Sucrose	Fructose	Glutathione reductase
	($\mu g/cm^2$)	($\mu g/cm^2$)	($\mu g/cm^2$)	(mmol/min)
Control	62.8 a[z]	133.6 a	86.4 a	202.85 a
Trimax	39.3 a	110.4 a	47.1 a	126.56 b

[z] Numbers followed by the same letter are not significantly different ($p \leq 0.05$).

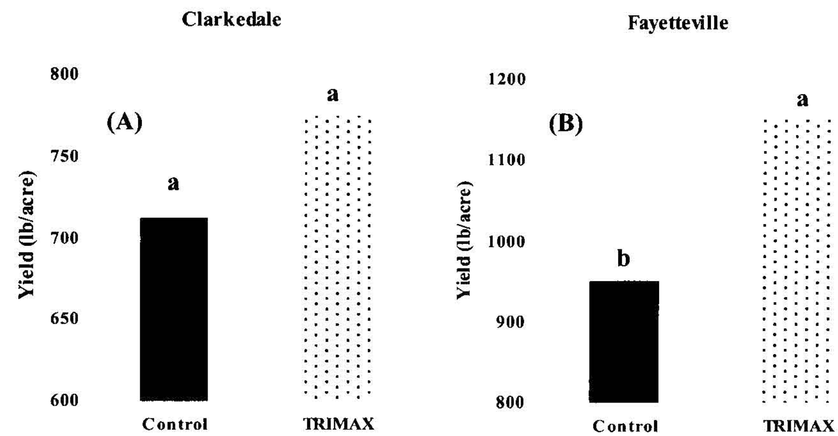

Fig. 1. Effect of Trimax on lint yield at two locations in Arkansas in 2002. Columns superseded by a different letter are significantly different (P<0.05).

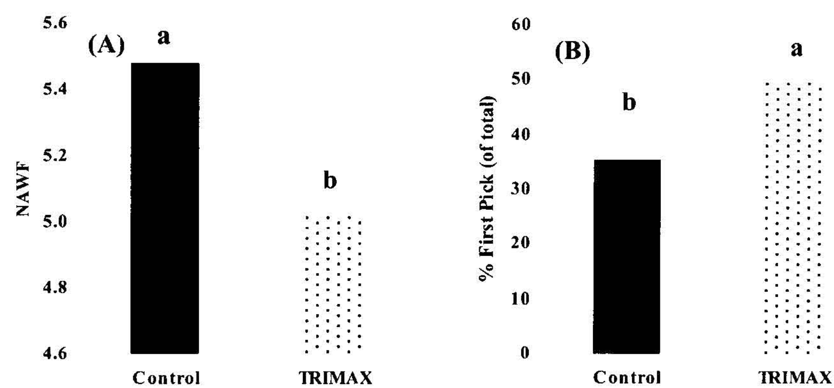

Fig. 2. Effect of Trimax on earliness indicated by NAWF and percent first pick of total yield at Clarkedale, AR. Columns superseded by a different letter are significantly different (P<0.05).

Chitosanase May Enhance Anti-Fungal Defense Responses

Bill Hendrix and James McD. 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 seedlings and established crops. For the Arkansas farmer, these and other fungal pathogens usually 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 crop 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 the cell walls of many fungi. To gain insight on this possibility, a newly-discovered chitosanase gene from *Paenbacillus* sp. 61427 was expressed in tobacco (*Nicotiana tabacum* L cv. Xanthine), and the *in planta* anti-fungal potential of this protein was examined.

BACKGROUND INFORMATION

Chitosanase is an enzyme, similar to chitinase, capable of hydrolyzing the ß-1,4-linkages between N-acetyl-D-glucosamine and D-glucosamine residues in a partially acetylated fungal cell wall polymer. When attacked by pathogenic fungi, many plants exploit this hydrolytic action as a component of a larger post-attack defense response (Agrios, 1997), but these enzymes may also function in pathogenesis-related (PR) signal transduction. Glucosamine oligomers, released from fungal cell walls after hydrolysis with a chitinase or a chitosanase, are elicitors of plant defense responses such as stomatal closure (Lee et al., 1999) and cell wall lignification (Vander et al., 1998; Moerschbacher et al.,1988). The responses elicited by these molecules depend on the length and degree of acetylation of the oligomers released (Vander et al., 1998). More specifically, long oligomers or intact fungal cell walls will cause little or no reaction.

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However, oligomers that are relatively short (e.g., products of chitosanase hydrolysis) are active elicitors.

Many plant species have been transformed with chitinases in an effort to improve plant fungal resistance (Punja, 2001). These studies revealed great variability in the antifungal efficacy among chitinases from different sources. To date, however, there has been only one report of plant transformation with a chitosanase gene (El Quakfaoui et al., 1995), and no reports describing its *in planta* anti-fungal potential.

RESEARCH DESCRIPTION

The *Paenibacillus* sp. 61724 chitosanase gene was cloned and modified for plant expression (Hendrix et al., 2001). The modified gene and a gene conferring antibiotic resistance as a selectable marker were delivered to tobacco leaf disks via *Agrobacterium tumefaciens*-mediated transformation. To select the transformed cells, the leaf disks were subjected to kanamycin selection under tissue culture conditions. Over a period of 5 to 6 wks, transformed cells developed into callus from which plantlets were regenerated. The putative GMO's were then tested for transgene integration via Southern blot, transcription via Northern blot, and translation via a leaf-disk lysoplate assay. Additionally, the antifungal efficacy of the recombinant chitosanase at physiological concentrations was measured by challenging *Rhizoctonia solani* cultures with recombinant protein exuded from transgenic leaf disks.

Confirmed transformants accumulating active, extracellular chitosanase were selected and used for seed production or screened for enhanced defense responses to a *R. solani* cell wall preparation. The cell wall preparation was applied exogenously or through cut petioles and time-course production of hydrogen peroxide, phenylalanine ammonia lyase (PAL), and peroxidase (POD) was measured.

RESULTS

Six lines, confirmed transformed both by Southern and Northern blot, produced high levels of the recombinant chitosanase. Four lines were allowed to set seed, and two lines were used for the defense gene induction experiments. At 2 h and 24 h after application, PAL and POD activity increased in the transgenic lines but was unchanged in the wild-type control (WT). Similarly, hydrogen peroxide production increased at 2 h and 24 h in the transgenic lines, but no increase was observed in the WT until the 24 h measurement. These results suggest the chitosanase producing lines may be able to activate defense mechanisms faster than is possible in WT plants. This enhanced response along with an attacking fungus slowed by cell wall degradation may translate into increased plant fungal resistance.

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. The prevailing theory attributes most of the increased fungal resistance seen in plants transformed with fungal cell wall degrading enzymes to fungal growth inhibition as a result of the enzyme action, but recent reports speculate endogenous defense gene activation may also play an important role. In this study, the preliminary results support the theory that chitosanase decreases the time required for induction of endogenous defense systems. If the transgene is confirmed to enhance fungal resistance in the model tobacco plants, cotton will be genetically engineered with the chitosanase gene.

ACKNOWLEDGMENTS

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Cotton Aphid (Homoptera:aphididae) Treatment Threshold Incorporating Natural Enemies in Arkansas Cotton

Hugh E. Conway, Donald C. Steinkraus, and Timothy J. Kring[1]

RESEARCH PROBLEM

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. The objective of this study was to design management methods that incorporate the action of biological control agents in establishing a threshold for the cotton aphid, *Aphis gossypii.*

BACKGROUND INFORMATION

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.

RESEARCH DESCRIPTION

A 12-acre field at the Delta Branch Station in Clarkedale, AR, was subdivided into 16 plots, each ~ 0.75 acre in size (56 rows x 63 m). The experiment consisted of four treatments: (1) untreated control, (2) fungicide treated, (3) conventional threshold, and (4) experimental threshold; with four replicates in a Latin square design. 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" 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

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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 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 25 June 1999, 28 June and 3 July 2000, and 7 and 12 July 2001 (Fig. 1). The experimental treatment threshold was reached on 25 June 1999, 3 July 2000, and 19 July 2001 (Fig.1). An application of 0.22 L/ha of imidacloprid (Provado® 1.6F Bayer Corporation, Kansas City, MO) 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 June 1999, 6 July 2000, and 27 July 2001 (Fig. 1).

Aphid densities declined over the three years of the study; in the untreated plots, aphids/leaf peaked at ~140 in 1999, ~75 in 2000, and ~30 in 2001 (Fig. 1). Similarly in treated plots, aphids/leaf increased to ~50 in 1999, ~35 in 2000, and ~30 in 2001 (Fig. 1).

The coccinellids (adult and larvae) were the dominant aphid predators present in the cotton field each year (Fig. 2). 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, ~4 in 2000, and ~0.6 in 2001 (Fig. 3). Larvae/row-m in the treated plots peaked at ~3 in 1999, ~1.5 in 2000, and ~ 0.5 in 2001 (Fig. 3). 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, ~2.7 in 2000, and ~0.5 in 2001 (Fig. 4). Adult coccinellids/row-m in treated plots peaked at ~1 in 1999, ~2 in 2000, and ~0.5 in 2001 (Fig. 4). 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. 4).

In 1999, cotton lint yield was significantly higher in plots using the experimental threshold ($P<0.05$, LSD) in comparison to untreated plots (Fig 5). 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 year. 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.

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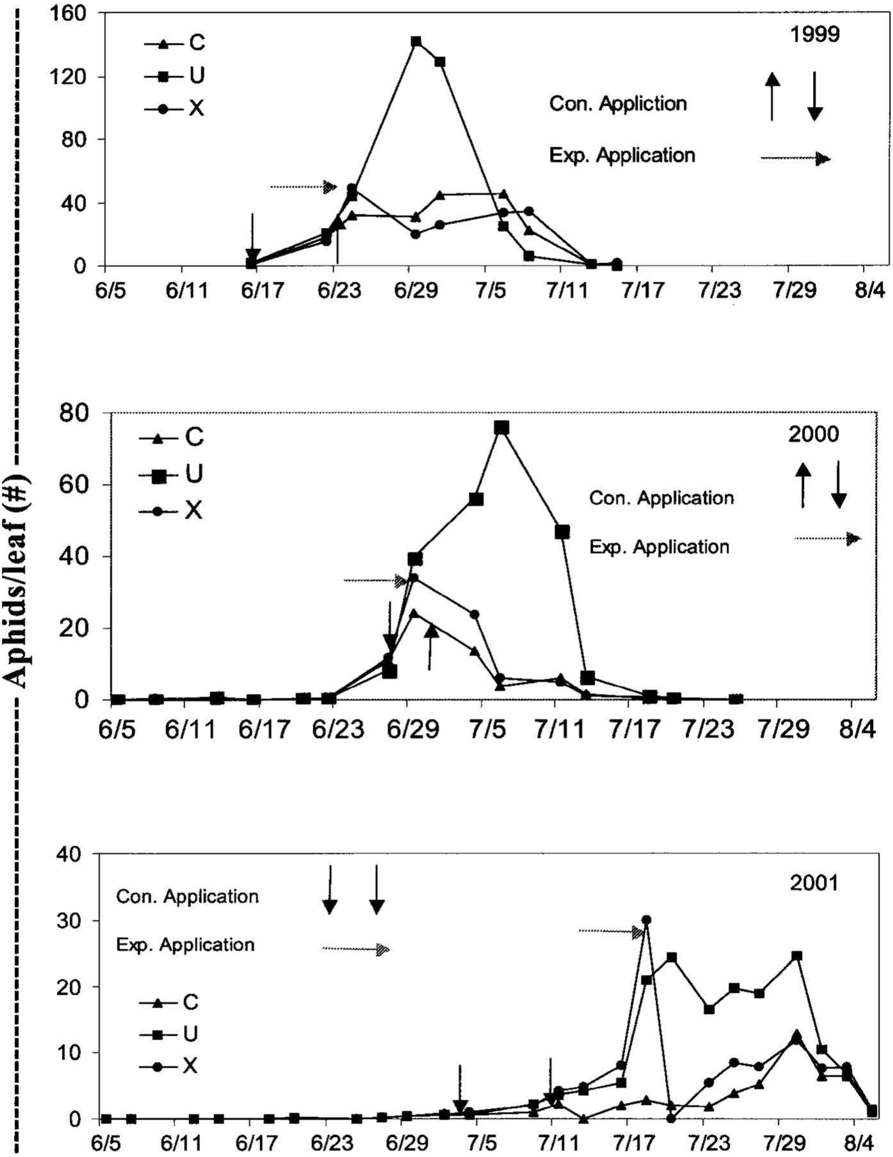

Fig. 1. Aphids per leaf at University of Arkansas Delta Research Station in Clarkedale, AR. 'C' indicates conventional treatment, 'U' indicates untreated, 'X' indicates experimental treatment. Imidacloprid application is indicated by arrows.

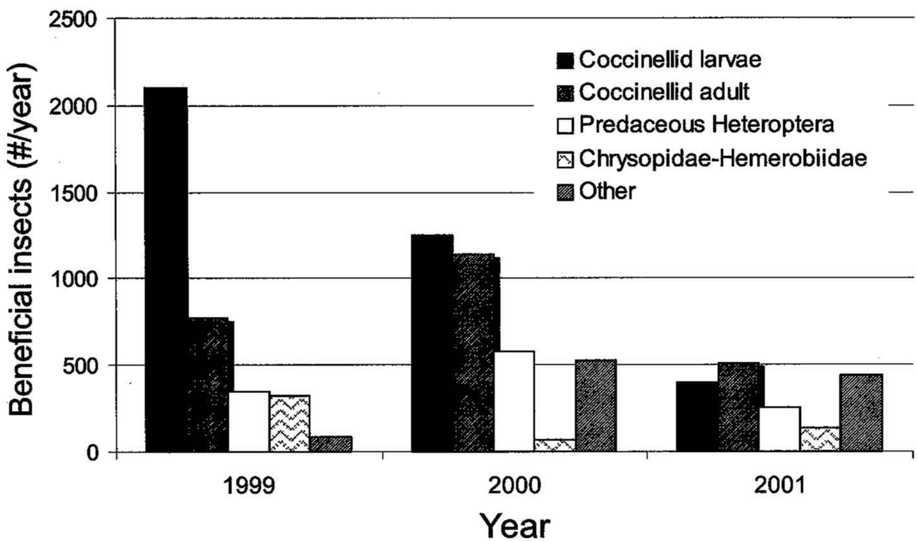

Fig. 2. Comparison of beneficial insects captured per year from test plots at the Delta Research Station, Clarkedale, AR, 1999-2001.

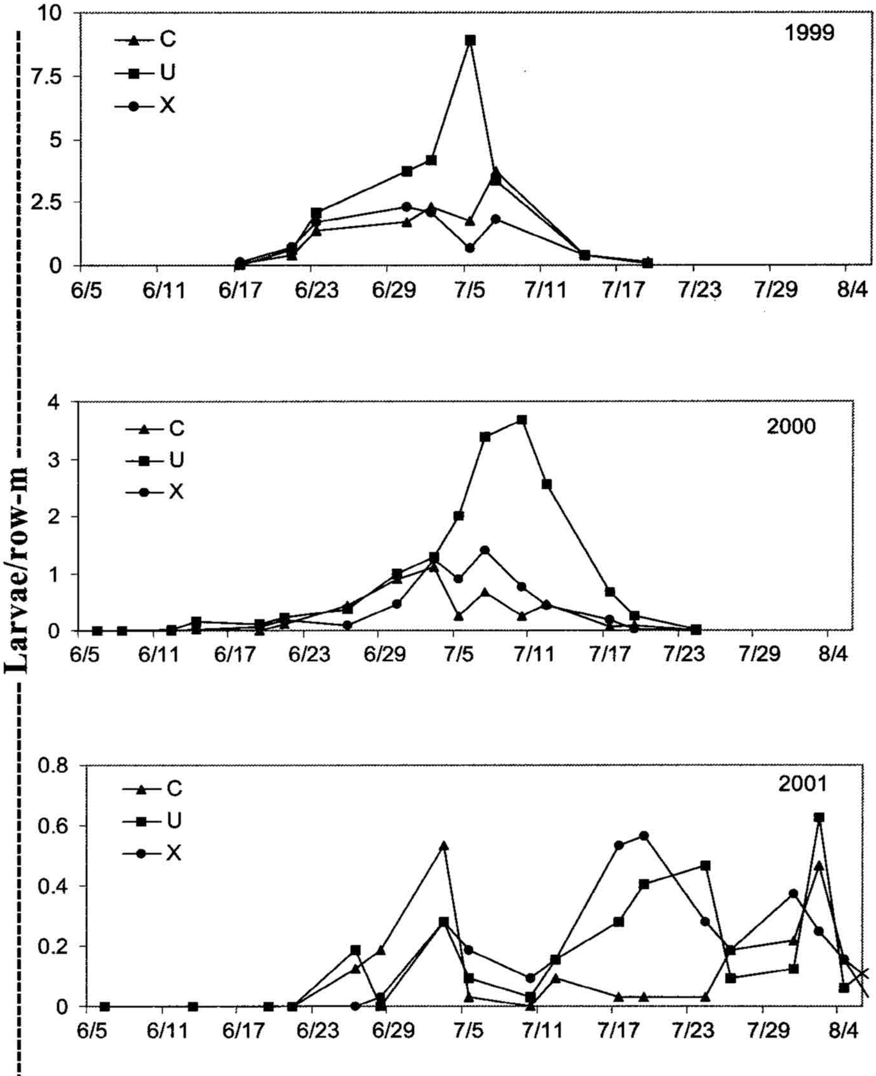

Fig. 3. Larval coccinellids per row-meter at the University of Arkansas Delta Research Station in Clarkedale, AR. 'C' is conventional treatment, 'U' is untreated, and 'X' is experimental treatment.

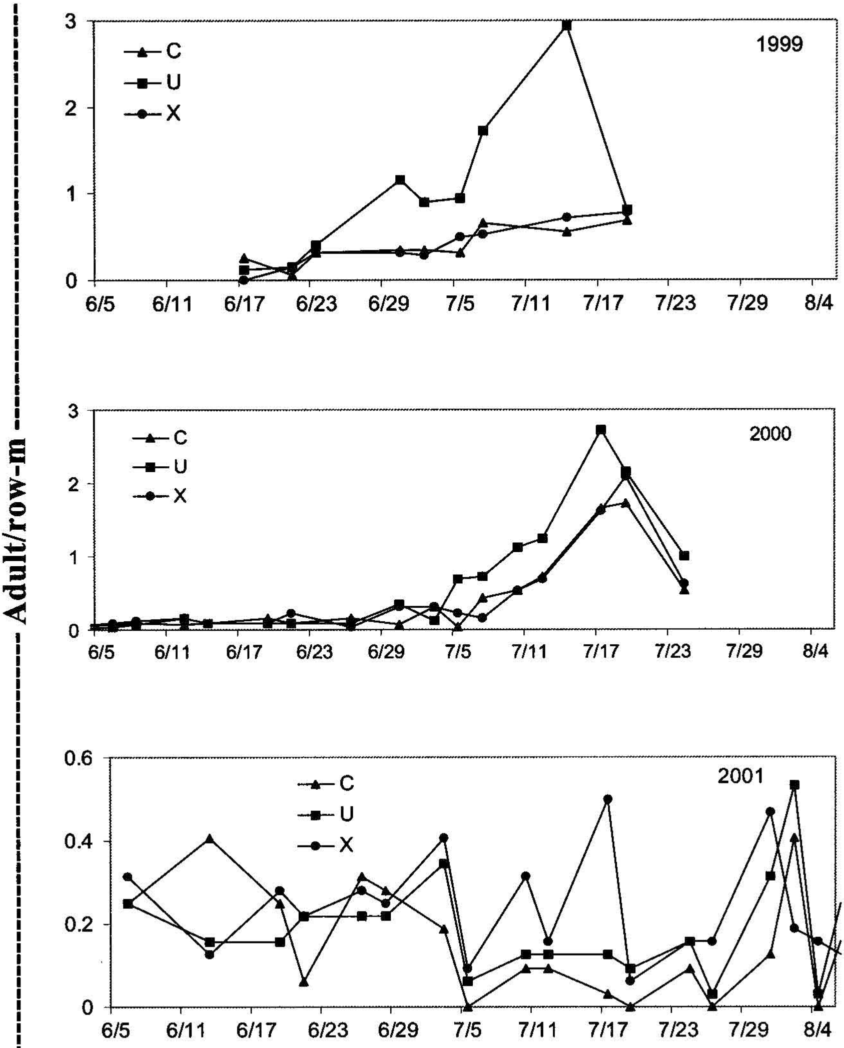

Fig. 4. Adult coccinellids per row-meter at the University of Arkansas Delta Research Station in Clarkedale, AR. 'C' is conventional treatment, 'U' is untreated, and 'X' is experimental treatment.

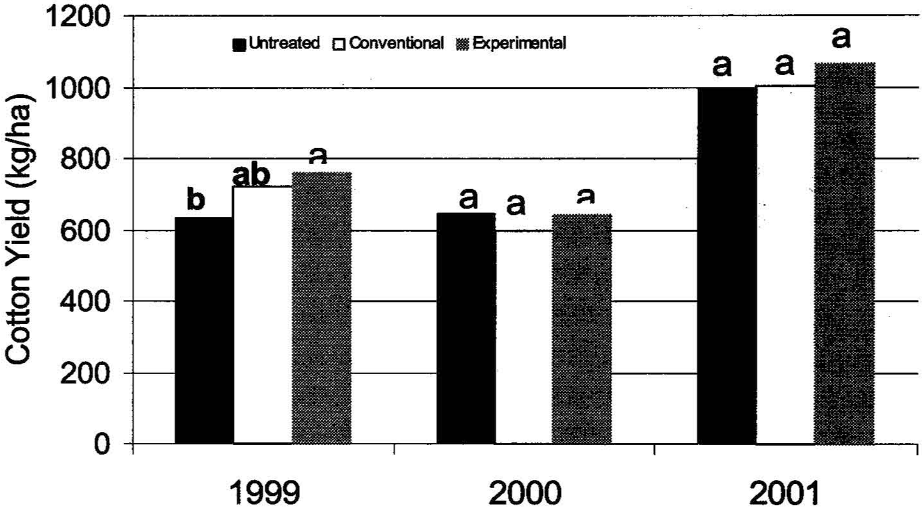

Fig. 5. Cotton lint yield results from test plots at the Delta Research Station, Clarkedale, AR, 1999-2001.

A Decade of the Cotton Aphid Fungus Sampling Service

Donald C. Steinkraus, Gabriele Boys, and Gus M. Lorenz, III[1]

RESEARCH PROBLEM

Cotton aphids, *Aphis gossypii*, are perennial pests of cotton. Aphids are expensive and frequently difficult to control using insecticides. In 1989 Arkansas scientists discovered a natural fungus, *Neozygites fresenii*, that reduces cotton aphid populations below the economic theshold across a wide swath of U.S. cotton sometime each June or July. Methods were developed to predict the occurrence of this fungus to enable cotton growers to avoid treating cotton aphids when fungal epizootics were imminent. The research problem in this case is: How can we incorporate a natural enemy into aphid managment decisions in order to reduce input costs for growers? In 1993 with the help of Cotton Incorporated funding we began an extension-based service to predict aphid declines due to the fungus. Over the years the service has expanded and now includes includes participants in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, and South Carolina. The service provides extension agents, consultants, researchers, and growers with precise information on the prevalence of the aphid fungus within their fields and counties. When the fungus is active, insecticide application for cotton aphids is generally not warranted with resultant monetary savings for producers. The service completed its 10th year of operation in 2002.

BACKGROUND INFORMATION

Natural enemies are recognized as important components of IPM of insect pests (Steinkraus, 2000). However, generally it has been difficult to quantify and predict the level of control natural enemies will provide in a way that cotton producers can readily use in making treatment decisions. In order to make use of natural enemies in IPM decisions, it is necessary to know the immediate impact of the natural enemies on the pest population and predict the near future impact. If the natural enemies will prevent the pest population from reaching the economic threshold or will reduce the pest population as efficiently as an insecticide, then cotton producers can rely on the

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natural enemies and reduce chemical input costs. However, this is not as simple as it may seem. It requires extensive basic research on the complex interactions between the natural enemies, pest arthropods, the crop, and the environment.

Since 1989 we have been working to utilize the naturally-occurring fungus, *Neozygites fresenii* (Entomophthorales: Neozygitaceae), to benefit cotton producers in the United States. This fungus has caused regular epizootics each year since 1989 that rapidly reduce cotton aphid populations in June and July across the mid-South and southeast cotton production areas of the United States. Basic research was conducted on the geographic distribution and impact of the fungus (Steinkraus et al., 1995), environmental effects on the fungus (Steinkraus and Slaymaker, 1994), the speed with which epizootics reduce aphid populations (Hollingsworth et al., 1995), sampling methods (Steinkraus et al., 1995), and how the fungus spreads so rapidly within and between cotton fields (Steinkraus et al., 1996). Methods were developed to artificially introduce the fungus to cotton fields (Steinkraus et al., 2002); however, unfortunately, the fungus cannot be produced in large quantities on artificial media in the laboratory, therefore, all research has been done with fungus produced in cotton aphids.

In 1993, with support from Cotton Incorporated we began a service to sample cotton fields in Arkansas to determine the fungus levels in cotton aphid (*Aphis gossypii*) populations. Based on the research of Steinkraus and Hollingsworth (1994) and Hollingsworth et al. (1995), it was shown that when about 15% of the aphid population in a field was infected a rapid decline in the aphid population could be expected. By determining the percentage of infected aphids within specific fields, we could predict whether a grower might be able to rely on this natural enemy for control of cotton aphids instead of applying a chemical insecticide. This has the direct effect of reducing input costs, a major goal of cotton research.

Initially the aphid fungus sampling service operated only in Arkansas; however, additional states have expressed interest in participating, and it has expanded to include Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina. In each state a cotton or IPM extension agent serves as a coordinator, providing names and addresses of potential participants. Participants may be consultants, researchers, extension agents, or growers. New participants are encouraged to utilize the service through our internet web site (http://www.uark.edu/misc/aphid/). The information about fungus levels in individual fields is immediately faxed to the participant, posted on our website, and also used extensively in extension newsletters and Agfax reports to keep the cotton community informed about the progress of fungal epizootics in counties and states.

RESEARCH DESCRIPTION

Each spring the extension coordinators in each state are contacted and provided with a list of the previous year's participants. The coordinators are asked to revise the list if needed, and provide names, addresses, and phone numbers of potential participants. Supplies needed to make the sampling kits and to perform the diagnoses are

ordered. These include vials, mailing tubes, Fed-Ex envelopes and address labels, ethanol, slides, coverslips, sampling instructions, and other supplies. Each participant is sent a set of sampling kits prior to cotton planting, and more are available upon request. Participants are requested to collect cotton aphids whenever the are perceived to be a problem or are increasing in the cotton fields they scout. Aphids are collected by placing aphid-infested leaves from 4 to 5 areas of the field into the vials containing 70% ethanol. The participant then sends the vials within the mailing tubes back to the service laboratory at the University of Arkansas via Fed-Ex next-day service.

Upon receiving samples, each sample is logged in, and a randomly selected subsample of 50 aphids is removed from each sample. This is done by trained technicians who use fine forceps and a dissecting microscope. Aphids are drained of excess ethanol by placing them on a dry tissue, then 10 aphids are squashed on a slide, 5 per coverslip, and the slides labelled with the sample data. Each aphid is individually diagnosed at 200x or 400x using a phase microscope. The diagnosis method is very accurate and, in addition to providing data on whether a particular aphid is positive or negative for *N. fresenii* infection, the diagnoses provide precise information on the stage of infection of each aphid (early, middle, late). These data are recorded and permit the service to describe not only the percentage infection in the sample, but the stage of the epizootic. It takes skilled technicians about 1 hour to mount and diagnose one sample.

The information for each field is immediately faxed to the participant who sent in the sample and in addition, the information is uploaded onto the service's internet website (http://www.uark.edu/misc/aphid/). Participants use the data to help them make IPM decisions about whether to spray cotton aphids with an insecticide or not. The information on the website can be used by large numbers of people in extension and consulting to determine whether epizootics have been observed in their states or counties yet. Information from the service is also provided to and used in extension newsletters and Agfax reports to inform large numbers of people with the status of fungal epizootics.

RESULTS AND DISCUSSION

Each year the sampling service diagnoses fungal prevalence rates from about 300 to 400 fields. This is as many samples as the service can handle based on current funding available and time required per sample. Usually the service has 4 technicians working full-time on handling and diagnosing samples between 1 June and 31 July. This is the period when most samples arrive. At most the four technicians can process 24 to 32 samples per day. The graph in Figure 1 shows the percentage of *N. fresenii*-infected aphids in the samples received in 2002 by the date samples were collected. In most years a relatively large number of samples are recieved early in the summer in which no fungus is present. This does not mean that the fungus is totally absent from the fields and providing no natural control of cotton aphids. We have unpublished

information that suggests late aphids flying into cotton fields are sometimes infected and die, resulting in failure to found colonies. While this is of biological control value, in most fields and in most years, little or no fungus has been present prior to 18 June. Whenever no fungus is found in samples, IPM decisions should consider application of an insecticide if the economic threshold for cotton aphids has been reached and no other factors will reduce the aphid population. Starting about the third week of June the fungus becomes more and more important. Generally the first fungus is found each year from samples collected in Louisiana and southern Mississippi. Prevalence is the term for the percentage of the aphid population at a moment in time from a particular field or area that is infected with *N. fresenii*. When prevalence in a particular field is ca. 15% we generally expect a decline in the cotton aphid population within 7 to 10 days. When prevalence levels are 30% or higher, then an epizootic is taking place and in almost all cases the fungus will rapidly reduce the aphid population as well as or better than an insecticide. In such cases, the producer can reduce input costs by letting the natural fungus reduce the aphid population. The graph in Figure 1 shows that in most mid-South and Southeast cotton fields, cotton aphid infestations are terminated by fungal epizootics beginning in late June and continuing throughout the season. The value of these epizootics to cotton growers is immense. The savings in insecticide applications is likely ca. $30 million per year over the mid-South and Southeast. Figure 1 also shows that even at dates when many field samples indicate that full-blown epizootics are wiping out the aphid populations in those fields, some fields still have zero percent infection. This indicates the importance of scouting each field whenever possible, and not totally relying on reports of epizootics in an area.

PRACTICAL APPLICATION

Over the years the service has received much positive feedback from extension agents, consultants, and growers. The information from the service is used in extension newsletters, is accessed from our website, and is publicized in Owen Taylor's Cotton Agfax. A rough estimate that the direct value of the service is ca. $600,000 per year in reduced input costs. However, the indirect value, from the information placed on the website and used by extension newsletters in Arkansas, Mississippi, and Louisiana, and in Owen Taylor's Agfax, provides the main value. Each year several million acres of cotton in the mid-South and Southeast experience *N. fresenii* epizootics that limit cotton aphid populations resulting in prevention of at least one insecticide application for aphids. Therefore, each year an estimated $30 million is saved from avoided insecticides. Considering the fact that the total cost of the service is about $30,000 per year and participants are not charged for the service, this is a good value.

The future of the sampling service is uncertain. As long as fungal epizootics occur in cotton aphid populations, there is interest from the cotton community, and funding continues, the service will continue. Environmental changes, cotton variety changes, new insecticidal chemicals, economics, and new technologies could all change the situation and increase or decrease the value of the aphid fungus sampling service.

ACKNOWLEDGMENTS

We gratefully acknowledge the support of Cotton Incorporated, Pat O'Leary, and our extension coordinators in each state: Barry Freeman, Blake Layton, Ralph Bagwell, Philip Roberts, and Tommy Walker. Over the years many hourly technicians and others have assisted in the sampling service; too many to list here. The assistance of all of them is gratefully acknowledged.

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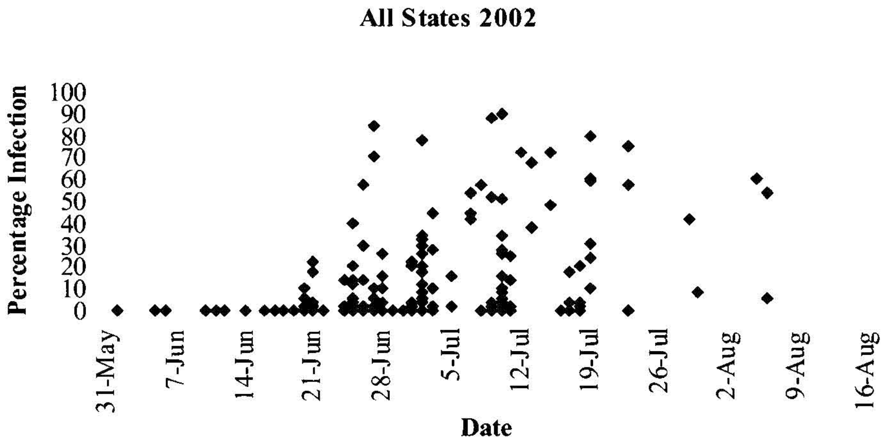

Fig. 1. The percentage of *Neozygites fresenii*-infected cotton aphids (prevalence) in each sample by collection date. Whenever prevalence is ca. 15% the aphid population within a particular field is considered to be in the early stage of an epizootic and the aphid population is expected to crash within a week or so. When the prevalence is above ca. 30% the aphid population is in the midst of an epizootic and in almost all cases the fungus will reduce the aphid population as well as, or better than, a chemical insecticide.

Control Options for Tarnished Plant Bug, *Lygus lineolaris*

Jeremy K. Greene and Chuck Capps[1]

RESEARCH PROBLEM

The tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois), has traditionally been considered an early-season pest in southeast Arkansas but has become more of a mid- to late-season pest as well. The expanded prominence of this pest necessitates continued applied research in the form of insecticide efficacy trials concerning its control. Our tests addressed the effectiveness of several new compounds when compared with existing compounds.

BACKGROUND INFORMATION

The TPB continues to be a major pest in southeast Arkansas cotton. It can be very damaging during early season, damaging pre-floral buds (squares) and terminal growth that often results in abortion of squares and inhibition of normal plant growth and development. It also can be a pest later in the growing season by feeding on small bolls, causing boll shed or losses in fiber quality and yield. The TPB will likely remain a primary pest in Arkansas with the Boll Weevil Eradication Program (BWEP) in place and widespread usage of *Bt* cotton. A successful BWEP has reduced, and will continue to reduce, the number of insecticide applications used that also help suppress plant bug numbers. Removal of that coincidental control will likely increase the importance of plant bugs in mid-South cotton. Furthermore, the increasing acreage of *Bt* cotton has reduced the number of insecticide applications that also provided suppression of the TPB.

RESEARCH DESCRIPTION

The cotton (*Gossypium hursutum* L.) cultivar Deltapine 451 B/RR was planted on 20 May 2002 at the Southeast Branch Experiment Station near Rohwer, AR. Plots measured 8 rows by 30 feet, spaced 38 inches apart, with four replications of each treatment

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arranged in a randomized complete block design. Mustard was seeded in early April on two rows between each eight-row plot to attract plant bugs. Standard fertilization and herbicide practices were followed according to current University of Arkansas Cooperative Extension recommendations (Chapman, 2000). Insect counts were conducted by sampling 6 meters of row per plot with a shake sheet (1 m^2) and counting adults and nymphs dislodged onto the cloth. Tests I, II, and III were conducted as early-season plant bug trials, with treatments applied soon after pinhead square. Test IV was a late-season trial, and applications were made post bloom. 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 I

While no treatments significantly lowered TPB totals across all four post-treatment sample dates, all treatments did provide adequate control for some of the sample dates (Table 1). All three insecticide treatments provided adequate control of TPB when compared with the untreated control (UTC) on the fourth sample date, seven days after the second treatment (7DAT2). Trimax at 0.0469 lb ai/acre (4DAT1), Orthene at 0.33 lb ai/acre (2DAT2), and Trimax at 0.0313 lb ai/acre (2DAT3) resulted in numerically reduced populations of TPB. There were no statistical differences in yield, but both rates of Trimax yielded the most numerically.

Test II

No treatments provided significant control across all sample dates, but Trimax at 0.0313 lb ai/acre (5DAT1) and Trimax at 0.0313 lb ai/acre + Bidrin at 0.33 lb ai/acre (2DAT2) provided significant reduction of TPB populations when compared with the UTC (Table 2). Treatments with Bidrin at 0.33 lb ai/acre or Trimax at 0.0469 lb ai/acre both resulted in significantly increased yields when compared with the UTC.

Test III

In this trial, both rates of the experimental compound F1785 were not applied until the last application date, and SC-AU was not applied on the first treatment date. These compounds should not be considered in yield or efficacy evaluations for the dates prior to their application. All treatments except Novaluron at 0.09 lb ai/acre provided significant control on 3 July (2DAT2) (Table 3). All treatments provided significant control on 8 July (7DAT2) and 10 July (2DAT3), except for F1785 at 0.071 lb ai/acre. Centric at 0.05 lb ai/acre, Trimax at 0.0469 lb ai/acre, and Vydate at 0.25 lb ai/acre produced significantly higher yields than the UTC. Similar results with Centric were observed in Arkansas during 2001 (Ngo et al., 2002).

Test IV

In this test, initial insecticide applications were not made until 8 August, resulting in difficulty in controlling plant bugs due to dense canopy enclosure. Orthene and Bidrin, both at 0.5 lb ai/acre, were the only treatments that provided significant control of TPB populations when compared with the UTC at 4DAT1 (Table 4). No differences were observed following the initial sample date and the second application.

PRACTICAL APPLICATION

Newer formulated compounds such as imidacloprid (Trimax) and thiamethoxam (Centric) provided control of TPBs comparable with that provided by older compounds such as acephate (Orthene), dicrotophos (Bidrin), and oxamyl (Vydate) and offer alternatives to aging and increasingly regulated insecticides.

ACKNOWLEDGMENTS

We thank the staff at the Southeast Branch Experiment Station, Rohwer Branch, for their assistance. We also thank Joe Belvedresi, Michael Dotson, Brian Lawhon, Heather Nutter, Greg O'Neal, Lydia Rice, and Adam Starks for their assistance in helping conduct our 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.

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Table 1. Effect of chemical treatments on the average number of adult and immature plant bugs per 6-m sample (Test I).

Treatment	Cost	6/25/02 (4DAT1)[z]	6/28/02 (7DAT1)	7/3/02 (2DAT2)	7/8/02 (7DAT2)	7/10/02 (2DAT3)	Yield
(lb ai/acre)	($/acre)						(37% lint)[y]
1. UTC		8.0 a[x]	13.8 a	4.8 a	13.5 a	3.8 a	492.0 a
2. Trimax (0.0313)	5.14	4.3 a	18.0 a	4.0 a	4.3 b	0.5 b	844.0 a
3. Trimax (0.0469)	7.70	7.0 a	9.8 a	4.0 a	5.3 b	2.3 ab	810.1 a
4. Bidrin (0.33)	3.66	7.8 a	11.8 a	2.5 a	4.0 b	1.8 ab	445.3 a

[z] 4DAT1 = 4 days after the first treatment.

[y] Gin turnout.

[x] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Table 2. Effect of chemical treatments on the average number of adult and immature plant bugs per 6-m sample (Test II).

Treatment	Cost	6/25/02 (pretreat)	7/1/02 (5DAT1)[z]	7/3/02 (2DAT2)	7/8/02 (7DAT2)	Yield
(lb ai/acre)	($/acre)					(37% lint)[y]
1. UTC		8.8 a[x]	12.5 a	5.8 a	10.0 a	364.8 c
2. Trimax (0.0313)	5.14	8.0 a	3.8 b	2.5 ab	7.3 a	489.9 bc
3. Trimax (0.0469)	7.70	9.3 a	8.8 ab	2.5 ab	6.0 a	672.3 ab
4. Trimax (0.0313)+Bidrin (0.25)	7.92	10.5 a	7.3 ab	2.3 ab	2.3 a	273.6 c
5. Trimax (0.0313)+Bidrin (0.33)	8.80	10.3 a	6.5 ab	1.8 b	1.0 a	504.7 bc
6. Bidrin (0.33)	3.66	12.3 a	8.5 ab	2.0 ab	7.8 a	882.2 a

[z] 5DAT1 - 5 days after first treatment.

[y] Gin turnout.

[x] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Table 3. Effect of chemical treatments on the average number of adult and immature plant bugs per 6-m sample (Test III).

Treatment	Cost	6/25/02 (pretreat)	7/1/02 (5DAT1)[z]	7/3/02 (2DAT2)	7/8/02 (7DAT2)	7/10/02 (2DAT3)	Yield
(lb ai/acre)	($/acre)						(37% lint)[y]
1. UTC		10.5 a[x]	6.3 ab	8.8 a	13.5 a	4.0 a	485.6 d
2. F1785 (0.071)						2.5 ab	769.8 a-d
3. F1785 (0.088)						1.0 bc	763.4 a-d
4. Bidrin (0.33)	3.66	9.5 a	8.0 ab	2.0 bc	3.8 bcd	0.8 bc	613.9 cd
5. Orthene (0.33)	2.96	9.5 a	3.8 b	2.8 bc	5.3 bc	0.3 c	615.0 cd
6. Novaluron (0.045)		9.5 a	5.8 ab	3.8 bc	2.3 bcd	0.8 bc	676.5 bcd
7. Novaluron (0.068)		9.3 a	7.0 ab	3.5 bc	0.3 d	1.5 c	668.0 cd
8. Novaluron (0.09)		9.8 a	8.0 ab	6.3 ab	1.3 cd	1.8 bc	551.4 cd
9. Centric (0.05)	6.94	8.0 a	6.0 ab	1.5 c	0.8 d	0.8 c	1094.3 a
10. Trimax (0.0469)	7.70	8.8 a	9.8 a	2.3 bc	4.3 bcb	0.5 c	1015.8 ab
11. Vydate (0.25)	4.35	7.5 a	7.5 ab	2.0 bc	4.0 bcd	1.0 bc	880.1 abc
12. SC-AU (1 qt/a)				1.0 c	1.8 cd	0.8 bc	453.8 d

[z] 5DAT1 = 5 days after the first treatment.

[y] Gin turnout.

[x] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Table 4. Effect of chemical treatments on the average number of adult and immature plant bugs per 4-m sample (Test IV).

Treatment	Cost	8/12/02 (4DAT1)[z]	8/15/02 (7DAT1)	8/22/02 (2DAT2)
(lb ai/acre)	($/acre)			
1.UTC		28.8 a[y]	16.8 ab	5.8 a
2.F1785 (0.071)		21.8 ab	16.8 ab	5.8 a
3.F1785 (0.088)		19.0 abc	11.5 b	3.3 a
4.Orthene (0.5 lb)	4.83	9.5 bc	11.3 b	4.8 a
5.Trimax (0.0469)	7.70	17.5 abc	23.5 a	3.5 a
6.Centric (0.0473)	6.94	21.5 ab	14.0 b	2.8 a
7.Intruder (0.05)	9.18	28.0 a	13.3 b	5.0 a
8.Vydate (0.25)	4.35	16.0 abc	13.0 b	7.3 a
9.Bidrin (0.5)	5.55	8.5 c	10.5 b	5.8 a
10.Methyl Parathion (0.5)	3.68	20.8 abc	15.0 b	4.3 a

[z] 4DAT1 = 4 days after the first treatment.
[y] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Efficacy of Select Insecticides and Tankmixes on the Tarnished Plant Bug

Donald R. Johnson, Gus M. Lorenz, III, Glenn E. Studebaker, and Kenneth D. Walsh[1]

RESEARCH PROBLEM

The tarnished plant bug is a major pest in Arkansas cotton production. Its significance continues to increase as the impact of the boll weevil is reduced through eradication efforts. The tarnished plant bug has also shown resistance to some insecticides. Therefore, continued research is necessary to test and monitor the efficacy of new chemicals and current control agents on the tarnished plant bug.

BACKGROUND INFORMATION

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is a polyphagous insect that has over 300 host species in the United States (Young, 1986), of which 169 species are located in the mid-South delta region (Snodgrass, 1984). The tarnished plant bug migrates into cotton fields as wild host species begin to fruit and senesce. They damage terminals, small squares, small bolls, and other tender plant parts by inserting their needle-like mouthpart into the plant. Excessive feeding by the tarnished plant bug may result in delayed crop maturity and decreasing yields. *Lygus* spp. ranked fourth behind the cotton fleahopper, boll weevil, and bollworm/budworm in yield loss in the mid-South causing a loss of 21,366 bales of cotton in 1999 (Williams, 2000).

The tarnished plant bug has shown resistance to insecticides, including the pyrethroid insecticides (Snodgrass, 2000) and the organophosphate and cyclodiene insecticides (Snodgrass, 1994). This proven insecticide resistance reinforces the need to continue testing the efficacy of existing and new insecticides on the tarnished plant bug.

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RESEARCH DESCRIPTION

Various foliar insecticides were evaluated for the control of tarnished plant bug in cotton located in Mississippi County, AR. The test consisted of eleven treatments arranged in a randomized complete block design with four replications. Plots were four-38-inch rows by 50 feet. Treatments were initiated based on pretreated tarnished plant bug counts. All treatments were applied on 23 August with a CO_2-pressurized two-man boom at 9.25 gal/acre. Each plot was evaluated 26 August, 3 days after treatment (3 DAT) with two counts from a 3-ft by 3-ft shake sheet placed between the center two rows. Data were processed using Agriculture Research Manager Version 6.0.1. Analysis of variance was conducted and Duncan's New Multiple Range Test (P=0.05) was used to separate means.

RESULTS AND DISCUSSION

All treatments provided significantly lower tarnished plant bug counts than the untreated check, except for Trimax at 0.0469 lb ai/acre (Table 1). The efficacy of Trimax plus Bidrin did not provide enhanced control over Trimax or Bidrin alone. The experimental compound F1785 provided similar control to the standard products. The lower rates of Trimax, Centric, and F1785 provided similar control to the higher rates the each product.

PRACTICAL APPLICATION

All products prove to be valuable control options for the tarnished plant bug. No benefit was found by mixing Trimax with Bidrin. Therefore, cost of control can be reduced by applying a single product. Lower rates proved to be as efficacious as the higher rates, again lowering cost. F1785 appears to have promise as a future control option for cotton producers.

ACKNOWLEDGMENTS

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Table 1. Efficacy of select insecticides on the tarnished plant bug.

Treatment	Rate	Number of tarnished plant bugs 3DAT[z]
	(lb ai/acre)	(#/6 row-ft)
Untreated control		6.5 a
Trimax	0.0313	2.0 a
Trimax	0.0469	3.0 ab
Trimax +	0.0313 +	
Bidrin	0.25	0.3 b
Trimax +	0.0313 +	
Bidrin	0.331	1.0 b
Bidrin	0.331	0.5 b
Centric	0.03	0.8 b
Centric	0.047	1.3 b
Intruder	0.05	1.5 b
F1785	0.036	1.0 b
F1785	0.053	0.5 b

[z] Means followed by same letter do not significantly differ (P=0.05, DNMRT).

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 (TPB), *Lygus lineolaris* (Palisot de Beauvois), has traditionally been considered an early-season pest in southeast Arkansas but has become more of a mid- to late-season pest as well. Their feeding on small bolls causes a loss of fiber quality, boll shed, and yield loss. While it is known that plant bugs damage 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 continues to be a major pest in southeast Arkansas cotton. It can be very damaging during early season, damaging pre-floral buds (squares) and terminal growth that often results in abortion of squares and inhibition of normal plant growth and development. It also can be a pest later in the growing season by feeding on small bolls, causing boll shed or losses in fiber quality and yield. The TPB will likely remain a primary pest in Arkansas with the Boll Weevil Eradication Program (BWEP) in place and widespread usage of *Bt* cotton. A successful BWEP has and will continue to reduce the number of insecticide applications used that also help suppress plant bug numbers. Removal of that coincidental control will likely increase the importance of plant bugs in mid-South cotton. Furthermore, the increasing acreage of *Bt* cotton has reduced the number of insecticide applications that also provided suppression of the 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.

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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. Approximately 1 acre of Deltapine 451B/R (*Gossypium hirsutum* L.) was planted on 8 May 2002. Plants were irrigated by 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% relative humidity, and a photoperiod of 14:10 (L:D) h. Small cages, designed to enclose a single boll, were constructed of 12-oz polystyrene foam cups, knee-high nylon hose, and wire ties. Bottom of cups and toe ends of nylons were removed, and cups were placed in the middle of the hose sleeves. The bottom end of the cage was placed over the boll to enclose it, and the sleeve was tied with a wire tie to the peduncle of the boll. An experiment was initiated by placing two plant bugs inside a cup with the boll and securing the top end of the nylon sleeve with the removed bottom portion of the cup. The cages were first taken to the field and placed on small first-position bolls that had been marked as white flowers 7 to 10 days earlier. Adult plant bugs were placed into 2-ml vials (2 plant bugs per vial) and released in cages 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 left on bolls until harvest to prevent damage from other insect pests. Trials were conducted on 17 July and 7 August 2002, with an equal number of cages for all five feeding regimes. Cotton was protected with insecticides (Capture 2 at 4 oz/acre and Orthene at 0.25 lb/acre on 12 July 2002 and 13 August 2002).

RESULTS AND DISCUSSION

On the first trial beginning on 17 July 2002, there were significant differences between the 4 feeding regimes. The 0-hour feeding regime produced the highest seed cotton weight per boll followed by the 36-hour, then the 24-hour, and the 48-hour regime yielded the least seed cotton weight per boll (Table 1). There were differences in fiber quality among the feeding regimes for both treatment dates (Tables 3 and 4). Significant differences in micronaire, fiber length, uniformity, strength, and reflectance were observed with most feeding treatments when compared with controls. For the second trial, 7 August 2002, there was a linear trend in yield, with the 0-hour regime yielding the most and the 48-hour regime yielding the least amount of seed cotton per boll (Table 2).

ACKNOWLEDGMENTS

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Table 1. Effect of duration of plant bug feeding on yield (17 July 2002).

Feeding regime (hours)	Seedcotton weight/boll (g)
0	4.20 a[z]
24	2.91 c
36	3.08 b
48	2.02 d

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

Table 2. Effect of duration of plant bug feeding on yield (7 August 2002).

Feeding regime (hours)	Seedcotton weight/boll (g)
0	5.01 a[z]
12	3.72 b
24	2.86 c
36	1.69 d
48	1.45 e

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

Table 3. Effect of duration of plant bug feeding on fiber quality (17 July 2002).

Feeding regime (hours)	Mic	Length	Uniformity	Strength	Reflectance	Yellowness
0	4.0 a[z]	1.07 a	81.9 a	19.3 a	73.0 b	10.3 c
24	3.6 c	1.04 c	80.2 d	16.5 c	73.8 a	11.1 a
36	3.6 c	1.05 b	81.6 b	15.5 d	73.0 b	10.2 d
48	3.9 b	1.05 b	80.7 c	18.5 b	71.5 c	10.5 b

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

Table 4. Effect of duration of plant bug feeding on fiber quality (7 August 2002).

Feeding regime (hours)	Mic	Length	Uniformity	Strength	Reflectance	Yellowness
0	4.5 b[z]	1.14 c	83.4 d	25.2 a	76.1 a	9.5 b
12	4.5 b	1.16 a	84.4 b	24.9 b	75.4 c	9.2 c
24	4.5 b	1.15 b	84.2 c	24.0 c	75.3 d	9.1 d
36	4.8 a	1.11 e	82.8 e	23.3 e	74.5 e	10.6 a
48	4.3 c	1.13 d	84.5 a	23.5 d	75.8 b	8.9 e

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

Changes in Cotton Fruiting Dynamics Following Pre-Flower Injury from Tarnished Plant Bug

Tina Gray Teague, Diana M. Danforth, and Eric J. Villavaso[1]

RESEARCH PROBLEM

Research efforts in Arkansas have been focused on development of decision guides for managing square retention prior to first flowers, concentrating on how square and boll retention affects crop carrying capacity and yield potential. These guides eventually will be incorporated into the COTMAN™ system (Danforth and O'Leary, 1998). An accurate evaluation of crop response to insect induced injury is critical to this work.

BACKGROUND INFORMATION

Plant response to pest feeding injury may differ between insect species because of differences in time and duration of the injury and the feeding habit of the insect, including injurious effects of digestive enzymes (Sadras, 1995). Squares injured by caterpillar feeding generally will shed. Feeding by tarnished plant bug (TPB) will result in small square shed. Larger squares typically are more tolerant. When anthers are hardly visible, the bug feeds on the totality of the floral bud, and it sheds. As the square grows, the anthers reach a large enough size for the bug to feed on individual pollen sacks. When feeding is localized on the anthers, a square rarely sheds. Squares with extensive anther damage may shed as bolls (Pack and Tugwell, 1976).

In TPB infestation studies in squaring cotton in Marianna, AR, Holman (1996) showed that TPB nymphs reduced cotton yield at increasing rates when first-position square shed exceeded 26%. Lint yields of treatments that sustained 19% shed rates were not significantly different from those that sustained 1 to 7% square shed. In fact, yields were numerically higher for treatments at the 19% square shed rate. One day of delay as measured by days to physiological cutout, NAWF=5 (Bourland et al., 1992) was associated with each 4% shed of first position squares. Similar delays were ob-

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served in our 2001 and 2000 TPB trials (Teague et al., 2001, 2002). In 2001 TPB trials, physiological cutout was delayed by 8 days in treatments where pre-flower first-position square shed rates were 34 to 38%. In our 2000 study, a 12-day delay was associated with 40 to 41% first-position square shed. The crop delay phenomenon was not observed when squares were removed mechanically, but it was apparent when shed resulted from plant bug induced injury. Square retention research was expanded in 2002 with the objectives: 1) to compare crop response to varying levels of square loss resulting from plant bug feeding, and 2) to assess plant responses using standardized COTMAN procedures including collection of information involving boll loading and crop carrying capacity.

RESEARCH DESCRIPTION

The experiment was conducted in 2002 at Wildy Farms located in northeast Arkansas near Manila. The cultivar, Stoneville 4892, was seeded on 29 April into a Routon-Dundee-Crevasse Complex sand. Different levels of pre-flower square loss were achieved by augmenting natural populations of plant bug with laboratory reared TPB nymphs. Each treatment received different numbers of TPB nymphs over 3 weeks. There were 5 treatments: 1) 1 bug/ft of row, 2) 3 bugs/ft, 3) 9 bugs/ft, 4) 0 bugs (natural population), and 5) 0 bugs and sprayed with Trimax insecticide (imidacloprid at 0.047 lb ai/acre). Bugs were released at weekly intervals during the first three weeks of squaring on 14, 21, and 29 June (49, 57, and 64 days after planting). Imidacloprid was applied to the sprayed treatment on 17, 25 June and 2 July. Plots were 6 rows wide and 30 ft long. Two sections of row, each 15 ft long, were selected in the center of each plot for plant bug treatments. All TPB nymphs were obtained from a colony maintained on artificial diet at the USDA-ARS Biological Control and Mass Rearing Research Unit at Mississippi State, MS. For release, TPB nymphs (2nd and 3rd instar) were aspirated from rearing containers into a 1.5-inch long section of opaque tubing. Tubes were placed at the base of each plant's main stem, and bugs were allowed to crawl out of the tube and up the plant.

Plants were monitored in each plot from the early squaring period through cutout using COTMAN procedures. Five consecutive plants in 2 treatment rows were monitored weekly. Prior to first flowers, sampling included measurement of plant height, number of squaring nodes, and sheds of first-position squares. Square shed data were divided into two categories of square size: total and small. Total squares were all first-position squares. Small squares were first-position squares located in the top three sympodial nodes. After first flowers, nodes above white flower were monitored. In addition, the ScoutMap procedure (Tugwell et al., 1999) was performed weekly. In all plant monitoring activities, samplers touched the plants as little as possible to minimize possible thigmonastic effects.

Plots were irrigated daily as needed using sub-surface drip irrigation (one drip line per bed placed four inches below the soil surface). All plots received a foliar application of imidacloprid on 17 and 22 July. On 2 Aug, imidacloprid was applied

through the drip irrigation system (i.e., Provado® 8oz/acre). Mepiquat chloride was applied three times at 6.5, 8, and 12 fl oz/acre on 18 and 25 June and 17 July, respectively. Defoliant was applied in all plots on 1 October.

Final plant mapping was performed on 18 October using COTMAP (Bourland and Watson, 1990) on ten plants in one row per plot. Plant height was measured as distance from soil to apex. Weekly hand harvests were conducted, and mean maturity date as well as total yields were determined. Plots were hand harvested over four dates on 23 September, 2, 14, and 21 October. Mean maturity date was calculated from yield measurements (Bourland et al., 2000). All crop monitoring and yield data were analyzed using AOV with mean separation using LSD.

RESULTS AND DISCUSSION

Spring conditions were not conducive to early crop development. Crop delay was quite apparent in COTMAN growth curves that show that first squares appeared nearly 10 days later than the target date, 35 days after planting (Fig. 1). Native plant bug population densities were low, and first-position square shed recorded in the first COTMAN sample was less than 2% in all treatments (Table 1). Following release of plant bugs at 46, 53, and 61 days after planting (DAP), square retention began to decrease in plants infested with nymphs compared to untreated and sprayed plants. Significant treatment differences in total percent first-position square shed among treatments were observed at 57 DAP and on every subsequent sample date. Following the 61 DAP plant bug release, total square shed averaged 44% in plots receiving 9 bugs/ft compared to 6% for the sprayed check and 11.8 % for untreated check. Plant bugs feed on tiny squares in the plant terminal (Tugwell et al., 1976). In this study high levels of small square shed were noted only in the 9 bug/ft treatment (Table 1). The shed rates in the 9 bug/ft treatment were comparable to those observed in previous studies following similarly high bug infestation levels (Teague et al., 2000, 2001), but it was unexpected that percent small square shed was at such low levels in the 1 and 3 bug/ft treatments.

Squaring node data were plotted as nodes above first square and nodes above white flower (NAWF) in COTMAN growth curves (Fig. 1). First flowers were observed in plots during the 8 July sample period, and until then, there were no differences in sympodial node production between treatments except for one sample date. Fewer squaring nodes per plant was observed in the 9 bug/ft treatment compared to sprayed and unsprayed treatments on 18 June (Table 2). No differences in numbers of pre-flower sympodia have been noted in response to TPB feeding in our previous studies (Teague et al., 2000, 2001). Our earlier studies showed that TPB damage to plant terminals reduced pre-flower sympodial growth, but this injury occurred to seedling cotton before squares were available.

Crop delay resulting from square loss and TPB feeding injury was apparent by 12 July; mean NAWF (squaring nodes) were significantly higher in the 9 bug/ft treatnent compared to all other treatments. By 30 July (92 DAP), NAWF values from protected

plots were significantly lower than in all other treatments (Table 2). Fewer days to physiological cutout (number of days from planting until mean NAWF = 5) were required for the protected compared to other treatments (Table 3). Boll retention levels just prior to cutout (Table 4) indicate there were significantly lower levels of boll shed in sprayed (24%) compared to other treatments (from 45 to 66% shed) at 86 DAP. By 93 DAP, boll shed in the sprayed treatments increased dramatically up to 50%. No insects or insect related injury was associated with this fruit loss; these were physiological sheds. By 101 DAP there was no difference in total boll retention among treatments.

In results from final plant mapping, percent early boll retention, defined as first plus second position bolls on the 5 lowest sympodia, was significantly higher in the sprayed compared to plants that were unprotected or that had been infested with plant bugs (data not shown). No other observations made during final plant mapping showed significant differences among treatments.

Yield data indicate that plant bug feeding in the 9 bug/ft treatment significantly reduced yields compared to other treatments (Table 5). Highest yields were associated with the unprotected check. Yield from the sprayed check was no different than that produced in plants that had been exposed to 1 and 3 bugs/ft. Mean maturity date did not differ among the 5 treatments and ranged from 154 to 158 days. Heat unit accumulation from flowering date of the last effective boll population (NAWF=5) until application of defoliants on 1 October ranged from 989 to 1029 DD60s.

PRACTICAL APPLICATION

The connection between boll retention and boll loading is a result of complex nutritional and hormonal influences and is poorly understood. It is known that if retention is high when first flowers appear, the cotton plant's natural feed-back mechanisms can cause small bolls and tiny squares to shed during boll filling. Preflower square shed resulting from plant bug feeding can lead to modification of actual boll loading stress after first flowers, which may affect both final boll retention and boll filling. In this study, plants with lowest retention at first flower produced lowest yield, but plants with highest retention at first flower did not produce the highest yields.

Square shed prior to first flowers can affect crop carrying capacity in a positive as well as negative way. Results from this and many other past studies indicate that high yields do not require complete annihilation of all herbivorous insects. Crop monitoring provides decision-makers a measure of square retention and can allow them to anticipate metabolic stress that will be associated with boll maturation. COTMAN is an efficient crop monitoring tool for use in documenting changes in plant fruiting dynamics. Pre-flower decision guides, including calculations of economic injury levels, are under consideration for future versions of COTMAN. These guides should aid growers in making decisions about managing square retention and anticipating its effect on crop carrying capacity.

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Table 1. Total and small square shed (percent of first position floral buds) as influenced by injury treatments.[z]

Sample size[y]	Time of injury	Sample time	Mean no. shed squares in each treatment					Pr>F	LSD 0.05
			9 Bugs[x]	3 Bugs	1 Bug	Natural	Sprayed[w]		
	-------- (DAP[v]) ---------		---------- (%) ----------						
Total		45	0.9	1.7	0.9	2.0	0.0	0.32	
	46	50	4.9	5.2	3.9	1.8	0.6	0.12	
	53	57	39.4	34.7	8.2	4.2	5.0	0.001	10.33
	61	63	51.4	37.9	24.2	7.3	4.4	0.001	12.48
		65	44.0	28.4	16.0	11.8	6.0	0.001	14.97
Small		45	0.0	0.0	0.0	4.0	0.0	0.35	
	46	50	3.4	0.0	0.0	0.0	3.3	0.79	
	53	57	26.7	10.0	0.0	0.0	0.0	0.05	8.5
	61	63	33.3	0.0	0.0	0.0	0.0	0.003	9.2
		65	20.0	6.7	0.0	0.0	0.0	0.008	7.0

[z] Square shed percentages were determined from 10 plants per plot using standard COTMAN procedures.

[y] Small squares were first position squares in the top three sympodia; total squares were all first position squares.

[x] No. of nymphs, second to third instar, released per plant per application. Bugs were released three times at weekly intervals during the first three weeks of squaring on 14, 21, and 29 June (46, 53, and 61 days after planting).

[w] Imidacloprid (0.047 lb ai/acre) was applied on 11, 19, 26 June, and 2 July.

[v] DAP = days after planting.

Table 2. Number of squaring nodes per plant as influenced by square injury treatment.[z]

Sample date (DAP)[w]	Mean no. squaring nodes for each treatment.					Pr>F	LSD 0.05
	9 Bugs[y]	3 Bugs[y]	1 Bug[y]	Natural	Sprayed[x]		
13 June (45)	2.6	2.8	2.5	2.7	2.4	0.38	
18 June (50)	3.6	3.9	3.7	4.2	4.2	0.05	0.48
25 June (57)	5.9	6.1	5.9	6.2	6.6	0.19	
01 July (63)	7.4	8.0	7.6	7.8	7.5	0.63	
03 July (65)	7.2	8.2	8.1	8.4	8.2	0.01	0.61
08 July (70)	9.0	8.8	8.3	8.8	8.6	0.62	
12 July (74)	8.4	7.7	7.6	7.7	7.3	0.01	1.1
16 July (78)	6.8	6.8	6.8	6.9	6.6	0.96	
19 July (81)	6.7	7.0	6.8	6.7	6.5	0.54	
23 July (85)	6.3	6.6	6.5	6.6	5.8	0.08	
30 July (92)	5.3	5.7	5.3	5.7	4.4	0.03	0.81
08 Aug (101)	3.6	4.3	3.7	4.4	3.7	0.45	

[z] Data are means of four replications. Squaring nodes were counted on 10 plans per plot using standard COTMAN procedures.

[y] No. of nymphs, second to third instar, released per plant per application. Bugs were released three times at weekly intervals during the first three weeks of squaring on 14, 21, and 29 June (46, 53, and 61 days after planting).

[x] Imidacloprid (0.047 lb ai/acre) was applied on 11, 19, 26 June, and 2 July.

[w] DAP = days after planting.

Table 3. Effect of injury treatments on number of days to physiological cutout, and mean number of heat units (DD60s) accumulated from date of physiological cutout until application of defoliants.

Injury treatment	Mean date of physiolgical cutout[z]	Mean no. days to cutout	DD60s from cutout to defoliation[y]
9 Bugs	29 July	92	1047
3 Bugs	02 Aug	96	965
1 Bug	31 July	93	1029
Natural	04 Aug	97	941
Sprayed	27 July	89	1114

[z] Date at which treatments reached mean NAWF = 5.

[y] Defoliation occurred 1 October.

Table 4. Total boll shed (percent of first position bolls) as influenced by injury treatment.[z]

Sample date (DAP)[w]	Mean no. squaring nodes for each treatment. 9 Bugs[y]	3 Bugs[y]	1 Bug[y]	Natural	Sprayed[x]	Pr>F	LSD 0.05
86	66.0	57.1	57.8	45.5	24.3	0.001	12.8
93	63.1	59.1	51.1	43.1	50.8	0.02	11.9
101	46.5	55.3	53.4	44.4	43.9	0.06	

[z] Data are means of four replications. Squaring nodes were counted on 10 plans per plot using standard COTMAN procedures.
[y] No. of nymphs, second to third instar, released per plant per application. Bugs were released three times at weekly intervals during the first three weeks of squaring on 14, 21, and 29 June (46, 53, and 61 days after planting).
[x] Imidacloprid (0.047 lb ai/acre) was applied on 11, 19, 26 June, and 2 July.
[w] DAP = days after planting.

Table 5. Cumulative mean lint yield over four harvest dates taken for each injury treatment.

Treatment	Mean lint yield picked on each harvest date[z, y] 23 Sept	2 Oct	14 Oct	21 Oct
	---------- (lb lint/acre) ----------			
9 Bugs/ft	418 bc	599 b	781 c	858 c
3 Bugs/ft	386 c	626 b	996 bc	1064 b
1 Bug/ft	613 ab	799 ab	1135 ab	1187 ab
Unprotected control	558 ab	806 ab	1266 a	1332 a
Protected control	704 a	860 a	1033 ab	1092 b
LSD (0.05)	223	207	241	200
Pr>F	0.05	0.05	0.01	0.01

[z] Means followed by similar letters within columns are not different (P=0.05).
[y] Lint percent calculated based on 33% turnout.

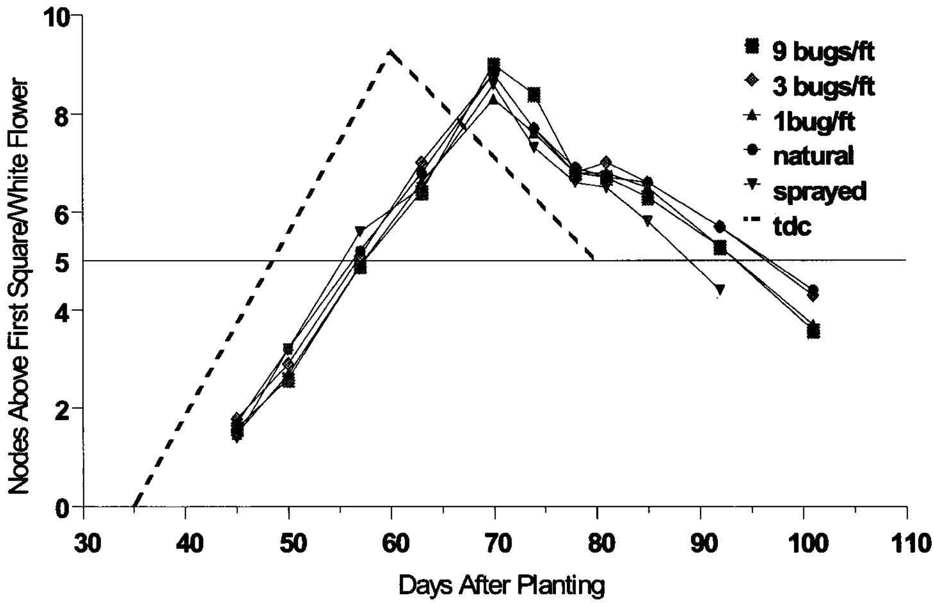

Fig. 1. COTMAN growth curves of plants exposed to 9, 3, or 1 tarnished plant bug nymph/wk for 3 weeks, untreated plants (natural infestations) or plants protected with insecticide compared to the target development curve (TDC).

Control Options for Thrips in Southeast Arkansas

Jeremy K. Greene, Chuck Capps, Bryan Myers, and Jack Reed[1]

RESEARCH PROBLEM

New insecticides continue to be developed to help control thrips and consist of both foliar materials and seed treatments. Aldicarb (Temik) continues to be a standard for thrips control in cotton, not only for its effectiveness against thrips but also because of its effectiveness in the suppression of nematodes. New seed treatments such as thiamethoxam (Cruiser) and other seed treatments such as imidacloprid (Gaucho) and acephate (Orthene) continue to be a valuable option for thrips control.

BACKGROUND INFORMATION

Heavy infestations of thrips can damage terminal growth of cotton plants, causing plant death in extreme cases, or more typically, abortion of the terminal. An aborted terminal results in branching and excessive vegetative growth, which can lead to delayed maturity and reduced yields (Micinski et al., 1990). Cotton plants can outgrow and compensate for thrips injury, but infestations can reach high enough levels to reduce yields if left untreated (Herbert, 1995; Roberts and Rechel, 1996).

RESEARCH DESCRIPTION

In Test I, cotton (*Gossypium hirsutum* L.) cultivars Deltapine 458 B/RR, 989 BG/RR, and Stoneville 4892 B/R were planted on 23 April 2002 at the Southeast Branch Experiment Station near Rohwer, AR, with four treatments (untreated, Temik 15G, Cruiser 5 FS, and Gaucho 600 FS) applied to all three varieties. Plots measured 8 rows by 40 feet, spaced 38 inches apart, with four replications of each treatment arranged in a randomized complete block design. Standard fertilization and herbicide practices were followed according to current University of Arkansas Cooperative Extension recommen-

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dations (Chapman, 2000). Thrips were collected on 8, 15, 22 and 28 May and on 4 June by randomly pulling 10 plants from rows 1 and 4 of each plot and washing them in 1-quart jars of 70% isopropyl alcohol. Nymphs and adults were counted following filtration procedures in the laboratory, and samples of adult thrips were identified to species. In Test II, Deltapine 451 B/R was planted on 21 May 2002 at the Southeast Branch Experiment Station near Rohwer, AR. The trial contained six treatments (untreated, Temik 15G at 3.5, 4.0 and 5.0 lb, Cruiser 5 FS, and Gaucho 600 FS). Plot size, agronomic practices, and sampling procedures were identical to those used in the first trial. 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

Tobacco thrips, *Frankliniella fusca,* was the predominant species (94-97%) in 2002 (Table 1). Western flower thrips, *F. occidentalis*, made up 4-5% of the populations sampled, and flower thrips and other species comprised less than 1% of species encountered in cotton at Rohwer, AR, during 2002.

Test I

On 8 May 2002, DP 458 B/RR untreated control (UTC) plots contained significantly higher thrips numbers than all treated plots (Table 2). On the second sample date, numbers of thrips in all Cruiser treatments and ST 4892 + Gaucho were significantly lower than in untreated plots in DP 458 B/RR. On the third sample date, all Cruiser treatments contained significantly lower numbers of thrips than the three untreated controls. There were no significant differences in thrips populations among treatments on the fourth sample date, but Cruiser treatments did have numerically lower numbers across varieties. On the fifth sample date (42 days after planting) there were no differences among treatments. Cruiser treatments resulted in numerically higher yields across varieties, followed by Gaucho and Temik, while 4892 B/R and 989 BG/RR resulted in numerically higher yields across insecticide treatments (Table 2).

Test II

On the second and third sample dates, all treatments were significantly better than the untreated control (Table 3). Temik at 4 and 5 lb/acre were the only treatments with significantly lower thrips numbers than the untreated control on the fourth sample date. On the last sample date, Temik at 4 lb/acre was the only treatment significantly lower than the untreated control.

PRACTICAL APPLICATION

Thrips continued to be an early-season pest in southeast Arkansas cotton during 2002. Cold, wet conditions during a critical 2-week period following planting, coupled with heavy thrips populations, resulted in pronounced stress on seedling cotton. Evaluation of newer seed treatments along with an existing standard in-furrow treatment on several different varieties demonstrated that thiamethoxam (Cruiser seed treatment) provided the best control of thrips and the highest yields under those conditions last year. In a second trial, only Temik at 4 lb/acre provided significantly better control than the untreated control across sample dates.

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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.

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Table 1. Thrips species composition for Rohwer, AR, in 2002.

Trial	Total thrips	*F. fusca*	*F. occidentalis*	*F. tritici*
Test I	6450	6296	99	55
% of total		97.61%	4.53%	0.86%
Test II	235	221	12	2
% of total		94.04%	5.11%	0.85%

Table 2. Effect of variety and chemical treatment on the average number of adult and immature thrips per 10 plants (Test I).

Treatment	5/8/02	5/15/02	5/22/02	5/28/02	6/4/02	Yield (37% lint)
1. DP458B/RR (UTC)	10.5 a[z]	24.5 a	155.8 a	93.0 a-d	176.0 a	753.9 e
2. 989BG/RR (UTC)	5.3 ab	18.0 abc	142.5 a	158.0 a	407.0 a	1199.2 abc
3. ST4892B/R (UTC)	0.5 b	14.0 abc	148.0 a	124.5 a-d	265.0 a	1116.5 bcd
4. 458+Cruiser	0.5 b	5.3 bc	46.5 c	88.0 a-d	321.0 a	1186.5 abc
5. 989+Cruiser	0.8 b	3.5 c	51.8 bc	54.8 d	242.8 a	1347.2 ab
6. 4892+Cruiser	0.8 b	5.3 bc	40.8 c	66.3 cd	214.0 a	1469.6 a
7. 458+Gaucho	3.0 b	19.5 ab	92.0 abc	133.5 abc	302.8 a	1013.2 cde
8. 989+Gaucho	2.8 b	16.0 abc	139.3 a	128.8 a-d	348.5 a	1146.8 bc
9. 4892+Gaucho	0.3 b	7.0 bc	88.3 abc	152.8 a	394.0 a	1356.7 ab
10. 458+Temik	2.0 b	17.3 abc	128.5 ab	143.5 ab	409.5 a	804.8 de
11. 989+Temik	1.0 b	13.8 abc	118.5 abc	76.8 bcd	283.0 a	1191.3 abc
12. 4892+Temik	0.3 b	11.8 abc	103.5 abc	90.8 a-d	329.8 a	1219.9 abc

[z] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Table 3. Effect of chemical treatment on the average number of adult and immature thrips per 10 plants (Test II).

Treatment	5/31/02	6/4/02	6/7/02	6/11/02	6/14/02
1. UTC	0.5 a[z]	39.3 a	32.3 a	24.0 a	12.8 ab
2. Temik 3.5lbs	0.0 a	17.5 b	1.6 b	10.3 ab	13.8 a
3. Temik 4.0lbs	0.3 a	2.8 c	1.8 b	4.3 b	5.0 c
4. Temik 5.0lbs	0.0 a	3.0 c	1.0 b	6.8 b	12.0 ab
5. Cruiser ST	0.0 a	5.3 c	5.7 b	14.3 ab	8.0 bc
6. Gaucho ST	0.0 a	7.8 bc	2.9 b	14.0 ab	15.0 a

[z] Means within a column followed by same letter do not significantly differ (P=0.05, LSD).

Simulating Insect Injury with Emphasis on Stink Bugs

Jeremy K. Greene and Chuck D. Capps[1]

RESEARCH PROBLEM

Reduced broad-spectrum insecticide use in cotton (specifically varieties producing proteins from *Bacillus thuringiensis*, i.e. *Bt* cotton) has allowed important phytophagous pentatomids – including the brown stink bug, *Euschistus servus* (Say); the green stink bug, *Acrosternum hilare* (Say); and the southern green stink bug, *Nezara viridula* (L.) – to become major pests of the crop (Greene and Turnipseed, 1996). Stink bugs damage cotton with their piercing/sucking mouthparts by injecting digestive enzymes and feeding on developing seeds within bolls. This process allows entry of microorganisms that also contribute to physiological damage and degradation of fruit (Watkins, 1981; Verma, 1986), resulting in reduced yield and lint/seed quality. Recently, questions have been addressing whether or not stink bugs damage other fruiting forms and terminal growth. In this project, we attempted to simulate mechanical injury to bolls, pre-floral buds (squares), and terminals as bugs (stink bugs) potentially do naturally in the field.

BACKGROUND INFORMATION

Predominant phytophagous (plant-feeding) stink bugs in Arkansas cotton include the green stink bug, the southern green stink bug, and the brown stink bug. In recent years, stink bugs have greatly benefited from a reduction of broad-spectrum insecticides applied for major pest groups. In the absence of these materials, stink bugs take full advantage of the "low-spray" environment and routinely infest and injure cotton. Stink bugs primarily feed on bolls and leave evidence of their feeding in and on bolls that is easily recognized and quantified. Affected bolls reveal damage to lint, seeds, and carpel walls when examined internally for feeding injury. Previous work has demonstrated that damage symptoms can appear within 24 to 48 hr after feeding and that bolls aged ca. 14 d from white bloom are an appropriate size for examination (Greene and Herzog, 1999). As stink bugs and bolls age, damage potential increases

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and decreases, respectively (Greene et al., 1999). Other researchers have conducted numerous trials with detailed study of natural and artificial insect injury to other cotton structures. In 2002, we investigated simulated mechanical injury to terminals, squares, and bolls in cotton, with an emphasis on bug (stink bug) injury.

RESEARCH DESCRIPTION

Plots (4 rows by 40 ft) of DP451B/R at the Rohwer Branch of the Southeast Research and Extension Center in Desha County, AR, were arranged in a randomized complete block design with six treatments (boll punctures), four treatments (terminal and square removals), and four replications. In a test to simulate the mechanical injury caused by pentatomid feeding, bolls (ca. 1 to 2 wk from anthesis) were punctured weekly with insect pins (38 x 0.55 mm) by inserting the pointed end into the boll in the middle of one lock through the carpel wall (ca. 0.25 in). Bolls from the center two rows were injured in each plot according to the treatment regime (no injury, 10, 20, 30, 50, and 100%). Bolls punctured were tagged with fluorescent flagging tape for identification. Prior to harvest, total bolls and injured (tagged) bolls were counted in each plot to determine actual percentages of simulated injury. Twenty feet of row were hand harvested from the center two rows of each plot.

In a test to simulate injury to terminal growth on young cotton, terminals were hand removed at the 6- to 7-true leaf stage on 19 June (near pinhead square) by aggressively pinching off terminal growth with thumb and index finger from plants at rates of 25, 50, and 100% in three treatments, with a fourth undamaged/untreated treatment for comparison. In a similar third test, pre-floral buds (squares) were removed weekly for 4 weeks from young cotton beginning at match-head square on 25 June. Squares were pinched off of plants in a like manner as terminals and at identical rates of 25, 50, and 100%, with an undamaged treatment for comparison. Two rows from the center of each plot, in both the terminal and square removal tests, were harvested by machine.

All injury simulation studies were protected from natural populations of insect pests by weekly or semi-weekly applications of insecticides. 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

Bolls punctured with insect pins, simulating mechanical feeding injury by stink bugs, at the 50 and 100% levels (actually 50.8 and 92%, respectively) resulted in significant damage and yield losses of over 300 lb (Table 1). Yields from bolls punctured at 10, 20, and 30% (actually 13.3, 23.9, and 33.2%, respectively) did not statistically differ from yields in undamaged plots. Although this study did not address damage sustained from digestive enzymes from natural bug feeding that cause physiological injury, researchers did simulate mechanical and pathological injuries that occur with biological

feeding injury. More injury would have undoubtedly occurred had physiological effects been incorporated into the study, and perhaps yield losses would have extended to lower percentages of simulated injury. In the absence of those effects, these data support the use of a boll injury threshold where injury is prevented from reaching and exceeding 50% of small-to-medium-sized bolls. It is our opinion that the most appropriate threshold for stink bug management in cotton is between 20 and 30% when sampling medium-sized bolls and using the damage criterion of at least one internal feeding injury per boll described previously (Greene et al., 1999, 2001).

Yields were significantly reduced when terminal growth was mechanically removed by hand at 25, 50, and 100% (Table 2) and when pre-floral buds were mechanically removed by hand at 100% for the first 4 weeks of squaring (Table 3). These results demonstrate that excessive terminal and square losses from insects, specifically the bug complex (stink bugs or plant bugs), in early-squaring cotton can result in significant yield loss. It is widely known that plant bugs can and will injure squares and terminal growth, and observational work has indicated that stink bugs may be able to injure meristematic tissue and pre-floral buds as well. Although stink bugs are primarily fruit/seed feeders, their potential capacity, along with related species of plant bugs, to injure terminal growth and squares should caution growers when elevated populations are encountered in young cotton.

PRACTICAL APPLICATION

Results from studies addressing simulated mechanical injury to bolls, terminals, and squares suggested that losses from bug feeding injury to young cotton and to small-to-medium-sized bolls could be significant under certain circumstances. Those conditions would presumably include the presence of considerable numbers of stink bugs on pre-bloom cotton for injury to squares and terminal growth. Conditions for injury to bolls already exist and have been well documented. These data support the use of a boll injury threshold when sampling medium-sized bolls and using the damage criterion of at least one internal feeding injury per boll described previously.

ACKNOWLEDGMENTS

We thank Cotton Incorporated, Arkansas cotton producers, AMVAC, Aventis, Bayer, Cheminova, Control Solutions, Dow AgroSciences, DuPont, FMC, Syngenta, and Valent for support of this work.

DISCLAIMER

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Table 1. Average lint yield from simulated mechanical injury to cotton bolls with insect pins at intended treatments and actual percentage injured, 2002.

Treatment (actual %)	Yield (lint lb/acre)
Untreated control	1278 a
10% punctured (13.3%)	1121 ab[z]
20% puncutred (23.9%)	1123 ab
30% punctured (33.2%)	1233 a
50% punctured (50.8%)	967 b
100% punctured (92.0%)	964 b

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

Table 2. Average yield and plant height from simulated terminal injury to young cotton by hand removal of terminal growth, 2002.

Treatment	Plant height	Yield
(actual %)	(in.)	(lint lb/acre)
Untreated control	33.95 a[z]	1573 a[z]
25% removed	32.78 ab	1339 b
50% removed	31.85 ab	1390 b
100% removed	31.53 b	1190 c

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

Table 3. Average yield from simulated pre-floral bud injury to young cotton by hand removal of squares, 2002.

Treatment	Yield
(actual %)	(lint lb/acre)
Untreated control	1505 a[z]
25% removed	1260 ab
50% removed	1319 ab
100% removed	1231 b

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

Insecticide Efficacy on Stink Bugs – 2002

Jeremy K. Greene and Chuck D. Capps[1]

RESEARCH PROBLEM

Stink bugs are becoming a major pest in cotton largely due to the reduced use of broad-spectrum insecticides. 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). Several other species are part of the plant-feeding stink bug complex but are of less importance.

BACKGROUND INFORMATION

In recent years, stink bugs have greatly benefited from the reduction of broad-spectrum insecticides applied for major pest groups. In the absence of these materials providing "coincidental" control of stink bugs, producers have had to shift to using "intentional" control for their management. Entomologists have been addressing this problem for several years now and have generated some useful information concerning insecticide efficacy and management of stink bugs in cotton (Greene and Herzog, 2000; Greene et al., 2001; Willrich et al., 2002; Greene and Capps, 2002). In 2002, 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), *A.hilare*, and the southern green stink bug (SGSB), *N. viridula*.

RESEARCH DESCRIPTION

Adults and nymphs of the GSB, the BSB, and the SGSB were collected from soybeans with a sweep net 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

[1] Extension entomologist and pest management technical support specialist, respectively, Southeast Research and Extension Center, Monticello.

bean before topical assays. Adults of *Leptoglossus phyllopus*, a closely related group of plant-feeding insects called leaffooted bugs, were collected from yucca blooms (*Yucca filamentosa*), held in the laboratory, and placed in cups as described previously.

Doses of each insecticide simulated the concentrations of field-use rates applied at a total volume of 10 gal/acre (Greene and Capps, 2002). 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 XL, Bayer, Kansas City, MO, 0.015 and 0.018 lb ai/acre); spinosad (Tracer 4, Dow AgroSciences, Indianapolis, IN, 0.067 lb ai/acre); esfenvalerate (Asana 0.66, DuPont, Wilmington, DE, 0.036 and 0.04 lb ai/acre); *lamda*-cyhalothrin (Karate 2.08, Syngenta, Greensboro, NC, 0.025 lb ai/acre); bifenthrin (Capture 2, FMC, Philadelphia, PA, 0.05 lb ai/acre); F0570 (FMC, 0.018 lb ai/acre); imidacloprid (Trimax 4, Bayer, 0.0469 lb ai/acre); acephate (Orthene 97, Valent, Walnut Creek, CA, 0.5 and 0.75 lb ai/acre); oxamyl (Vydate 3.77, DuPont, 0.25 lb ai/acre); methyl parathion (Methyl 4E, Cheminova, Wayne, NJ, 0.5 and 1.0 lb ai/acre); F1785 (FMC, 0.088 lb ai/acre); CS-AU-44-JO (Control Solutions, Pasadena, TX, 1 qt/acre); and XDE-225 (Dow AgroSciences, 0.015 lb ai/acre). To simulate practical efficacy in the field, 1 µl of each insecticide mixture was applied to the ventral abdominal segment 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 AND DISCUSSION

The predominant species of stink bugs in southeast Arkansas during 2002 were the green stink bug (GSB), and the southern green stink bug (SGSB). The brown stink bug (BSB) was not very common during 2002 until late in the season, therefore its numbers were not sufficient for statistical evaluation in laboratory efficacy trials.

Bidrin and methyl parathion provided excellent control (94 to 100% 24-hr mortality) of adults and nymphs of GSB and SGSB (Tables 1 through 3) at the 0.5 and 1.0 lb ai/acre rates. The pyrethroid insecticides applied alone provided variable control (50 to 100%) of nymphs and adults of both species after 24 hr (Tables 1 through 3). When pyrethroids were applied in combination with organophosphate or carbamate insecticides, control (67 to 98%) was also variable, depending on the grouping. As expected, Tracer, a lepidoptera-specific material, offered little or no control of both species. 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 (Greene and Herzog, 2000; Greene et al., 2001; Greene and Capps, 2002).

Two organophosphate insecticides (dicrotophos and methyl parathion) provided excellent control of adults of *Leptoglossus phyllopus*, an insect group closely related to stink bugs (Table 4). Acephate provided fair control at 24 hr and good control at 48 hr. The pyrethroid insecticides did not provide satisfactory control of this pest group

in terms of contact efficacy. As the pest spectrum has shifted in cotton, this pest group has become more of a concern in recent years in transgenic Bt cotton. These preliminary data are useful for this insect group and address initial questions about their control with commonly used cotton insecticides.

PRACTICAL APPLICATION

In laboratory bioassays concerning insecticide efficacy, methyl parathion (Methyl 4E) and dicrotophos (Bidrin 8), standard organophosphates used for control of bug pests, provided superior control (97 through 100% mortality) of field-collected fifth instars and adults of the green stink bug (GSB) and the southern green stink bug (SGSB) at 0.5 lb ai/acre. The 1.0 lb rate of methyl parathion provided 100% 24-hr mortality of both species but was only slightly better than the 0.5 lb rate and at twice the expense. A reduced rate (0.33 lb ai/acre) of Bidrin provided excellent control of GSB but provided reduced control (83%) of adults and nymphs of SGSB. Pyrethroid insecticides alone provided variable results (50 to 100% 24-hr mortality).

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We thank Cotton Incorporated, Arkansas cotton producers, AMVAC, Aventis, Bayer, Cheminova, Control Solutions, Dow AgroSciences, DuPont, FMC, Syngenta, and Valent for support of this work.

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Table 1. Cumulative mortality of field-collected adults of the green stink bug, *Acrosternum hilare* (Say), over a 4-d interval following exposure to insecticides (1-μl to ventral abdominal segments) in laboratory bioassays, 2002.

Treatment	Reps	Application cost	Cumulative mortality 24 hr	48 hr	72 hr	96 hr
(lb ai/acre)		($/acre/application)	(%)			
Untreated control	130	N/A	11	21	32	46
Methyl 4E 0.5	130	3.68	98	100	100	100
Methyl 4E 1.0	130	7.36	100	100	100	100
Baythroid XL 0.015	130	N/A	87	79	78	87
Baythroid XL 0.018	130	N/A	85	87	90	98
Bidrin 0.33	130	3.66	94	94	95	96
Bidrin 0.5	130	5.55	97	98	98	99
XDE-225 0.015	130	N/A	68	72	79	85
Orthene 0.5	130	4.48	54	72	80	88
Orthene 0.75	130	6.72	63	78	88	92
Capture 0.05	130	9.42	90	90	92	94
F0570 0.018	130	N/A	94	93	92	95
Asana 0.04	130	5.76	50	63	74	80
Vydate 0.25	130	4.35	80	88	92	94
Asana 0.036 + Vydate 0.25	130	9.53	80	82	86	88
CS-AU-44-JO 1qt/acre	130	N/A	98	99	99	99
Tracer 0.067	130	12.18	25	34	47	62
Karate 0.025 + Bidrin 0.25	130	6.71	98	98	98	99
Trimax 1.5oz/acre	130	7.70	73	78	81	84
F1785 0.088	130	N/A	30	45	50	68

Table 2. Cumulative mortality of field-collected nymphs (fifth instars) of the green stink bug, *Acrosternum hilare* (Say), over a 4-d interval following exposure to insecticides (1-µl to ventral abdominal segments) in laboratory bioassays, 2002.

		Application	Cumulative mortality			
Treatment	Reps	cost	24 hr	48 hr	72 hr	96 hr
(lb ai/acre)		($/acre/application)	-------------------	(%)	-------------------	
Untreated control	39	N/A	8	13	21	31
Methyl 4E 0.5	39	$3.68	100	100	100	100
Methyl 4E 1.0	39	$7.36	100	100	100	100
Baythroid XL 0.015	39	N/A	87	92	100	100
Baythroid XL 0.018	39	N/A	100	100	100	100
Bidrin 0.33	39	$3.66	100	100	100	100
Bidrin 0.5	39	$5.55	97	97	97	97
XDE-225 0.015	39	N/A	69	82	90	95
Orthene 0.5	39	$4.48	67	74	79	90
Orthene 0.75	39	$6.72	69	82	82	87
Capture 0.05	39	$9.42	97	97	100	100
F0570 0.018	39	N/A	95	97	97	97
Asana 0.04	39	$5.76	62	59	77	85
Vydate 0.25	39	$4.35	90	90	95	95
Asana 0.036 + Vydate 0.25	39	$9.53	85	85	85	90
CS-AU-44-JO 1qt/acre	39	N/A	97	97	97	100
Tracer 0.067	39	$12.18	15	33	44	51
Karate 0.025 + Bidrin 0.25	39	$6.71	67	74	79	82
Trimax 1.5oz/acre	39	$7.70	79	87	90	92
F1785 0.088	39	N/A	41	44	67	69

Table 3. Cumulative mortality of field-collected adults and nymphs (fifth instars) of the southern green stink bug, *Nezara viridula* (F.), over a 4-d interval following exposure to insecticides (1-µl to ventral abdominal segments) in laboratory bioassays, 2002.

		Application	Cumulative mortality			
Treatment	Reps	cost	24 hr	48 hr	72 hr	96 hr
(lb ai/acre)		($/acre/application)	(%)			
Untreated control	18	N/A	11	11	17	22
Methyl 4E 0.5	18	$3.68	100	100	100	100
Methyl 4E 1.0	18	$7.36	100	100	100	100
Baythroid XL 0.015	18	N/A	89	89	89	89
Baythroid XL 0.018	18	N/A	89	83	94	100
Bidrin 0.33	18	$3.66	83	83	83	83
Bidrin 0.5	18	$5.55	100	100	100	100
XDE-225 0.015	18	N/A	89	83	89	89
Orthene 0.5	18	$4.48	78	78	83	100
Orthene 0.75	18	$6.72	78	78	83	89
Capture 0.05	18	$9.42	89	89	94	100
F0570 0.018	18	N/A	100	100	100	100
Asana 0.04	18	$5.76	56	56	50	56
Vydate 0.25	18	$4.35	67	67	72	78
Asana 0.036 + Vydate 0.25	18	$9.53	72	67	83	83
CS-AU-44-JO 1qt/acre	18	N/A	94	94	100	100
Tracer 0.067	18	$12.18	11	22	22	56
Karate 0.025 + Bidrin 0.25	18	$6.71	83	83	89	89
Trimax 1.5oz/acre	18	$7.70	44	39	39	44
F1785 0.088	18	N/A	11	22	22	28

Table 4. Cumulative mortality of field-collected adults of the leaf-footed bug, *Leptoglossus phyllopus*, over a 2-d interval following exposure to insecticides (1-µl to ventral abdominal segments) in laboratory bioassays, 2002.

		Mortality	
Treatment	Reps	24 hr	48 hr
(lb ai/acre)		(%)	
Untreated control	55	4	11
Bidrin 8 at 0.5	55	98	100
Methyl parathion 4 at 0.5	55	98	100
Baythroid XL 1 at 0.018	55	27	56
Capture 2 at 0.05	55	29	58
Asana XL 0.66 at 0.04	55	27	36
Orthene 90S at 0.5	55	53	73
Tracer 4 at 0.067	55	5	13

Pheromone Trapping of Stink Bugs

Jeremy K. Greene and Chuck D. Capps[1]

RESEARCH PROBLEM

Because stink bugs are challenging to detect in cotton with traditional sampling tools, we continued investigations of alternative methods of monitoring the pest complex for management decisions. Trapping of stink bugs in pheromone traps has potential as a monitoring tool for stink bugs in cotton. Stink bugs can be caught successfully using the combination of a commercially available lure for the brown stink bug complex (*Euschistus* spp.) and a trap designed to visually attract stink bugs. However, effectiveness of the trap is currently hindered by the unavailability of effective lures for other species, such as the green stink bug, *Acrosternum hilare* (Say), and the southern green stink bug, *Nezara viridula* (L.). Trap captures could have some predictive value in terms of population development in the crop, but additional research into this area is necessary.

BACKGROUND INFORMATION

Because of the difficulties in detecting stink bugs in cotton with traditional methods, a successful pheromone trap could have a significant place in our management strategies for this pest complex. Initial movement of bugs into fields and population changes thereafter might be monitored with trapping techniques. The concept is not new for these insects but is limited by the lack of effective attractants for the group. The spined soldier bug, *Podisus maculiventris* (Say), has been lured and trapped with a synthetic pheromone (Aldrich et al., 1984), but research on additional stink bug pheromones has produced few practical lures. One commercially-available compound, methyl 2,4 decadienoate, readily attracts *Euschistus* spp. in some trap designs. The "Florida stink bug trap" has shown potential as an efficient design in pecans (Mizell and Tedders, 1995; Mizell et al., 1997; Yonce and Mizell, 1997). In 2002, we continued investigations into the effectiveness of using this trap and lure combination to observe populations of stink bugs around cotton fields.

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RESEARCH DESCRIPTION

Nineteen traps, modified from Mizell and Tedders (1995), were placed in and around six cotton fields near Rowher, AR, during 2002. Major components of the traps were corrugated plastic, plastic jars, rubber septa, and synthetic pheromone. Trap tops were made from plastic jars, and trap bases were made from sheets (4 ft x 8 ft safety yellow) of 10-mm corrugated plastic board. Lures were placed in the plastic jar top of each trap and consisted of a rubber septum (sleeve stopper, Fisher Scientific) treated with 40 µl of methyl 2,4-decadienoate (Bedoukian Research), and replaced every 7 d. Traps were examined and emptied once per wk.

RESULTS AND DISCUSSION

Over a 10-wk sampling period, 1064 stink bugs were captured in 19 traps. Approximately 90% of those trapped were part of the brown stink bug complex, *Euschistus* spp. The majority were *E. servus*, with some *E. tristigmus*, *E. crenator*, and *E. ictericus*. Others included *Thyanta* sp., *A. hilare*, *N. viridula*, *Oebalus pugnax*, and *Holcostethus limbolarius*.

Weekly trap numbers (Fig. 1) appeared to follow field populations, with a slight delay. Highest trap numbers were obtained on the first sampling date (18 July) and declined from mid-July to mid-August, where a trend for increased capture resumed. Highest field populations were detected with shake sheet procedures during the last week of July and the last two weeks of August, when stink bugs characteristically require treatment. The populations in late August corresponded with resumed increase in trap capture on 22 August. Similar results were observed previously (Greene et al., 2001).

PRACTICAL APPLICATION

Because stink bugs are challenging to detect in cotton with traditional sampling tools, we continued investigations of other methods of monitoring the pest complex for management decisions. Pheromone trapping of brown stink bugs was useful in following in-field populations of stink bugs, but the reduced availability and increased expense of currently available lures and unavailability of lures for other important species continue to hinder research into the potential of pheromone trapping of the group. Although successful in capturing brown stink bugs, the availability of operative lures for other important species such as *N. viridula* and *A. hilare* would have undoubtedly increased capture and monitoring capacity of the traps. Until additional "field-ready" lures are available, we will continue to explore opportunities for monitoring stink bugs in cotton using this trap and lure combination. As a result of these continuing studies, alternative monitoring and management strategies continue to be developed for stink bugs in cotton.

ACKNOWLEDGMENTS

We thank Cotton Incorporated, Arkansas cotton producers, AMVAC, Aventis, Bayer, Cheminova, Control Solutions, 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.

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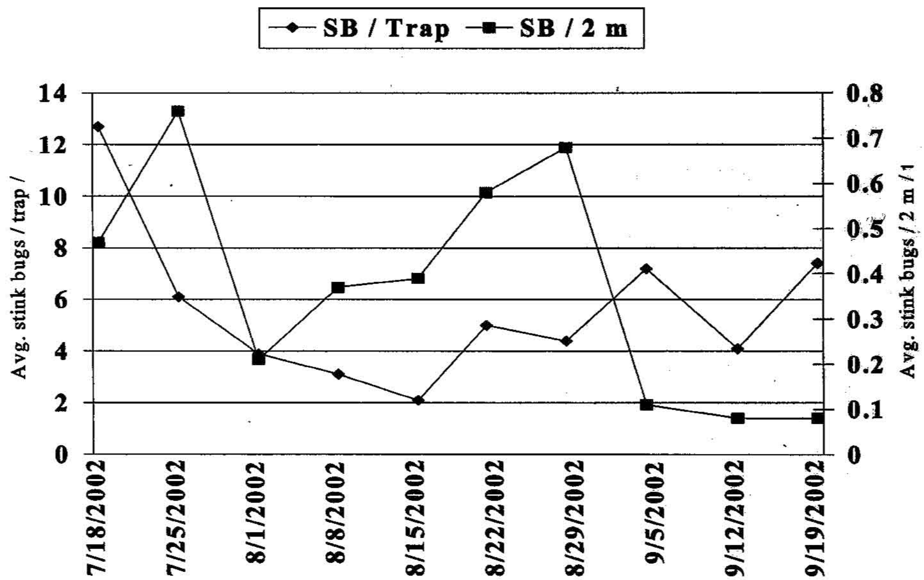

Fig. 1. Weekly average number of stink bugs in pheromone-baited traps and shake sheet samples from cotton near Rohwer, AR, 2002.

Thrips Management in Arkansas Cotton

Glenn E. Studebaker, Donald R. Johnson, Gus M. Lorenz, III, and Kenneth D. Walsh[1]

RESEARCH PROBLEM

Thrips are an annual problem in cotton production; however, the thrips population varies in severity from year to year. It is difficult, if not impossible, to predict when these pests are going to be severe. As a result, most growers apply insecticides in-furrow or as seed treatments. This study was conducted to evaluate the efficacy of several insecticides on thrips in cotton.

BACKGROUND INFORMATION

Thrips populations increase in the spring on early wild host plants and most likely on wheat. These hosts of thrips start to dry beginning in early May until mid-June and thrips begin to migrate to more favorable food sources. Unfortunately, this is about the same time that cotton begins to grow. The large host acreage for thrips and their reproductive capability create a situation, in most years, where young cotton sustains some level of damage from large thrips populations. In the mid-South production area, the tobacco thrips, *Frankliniella fusca*, is the predominate species that occurs on cotton. Other species that have been reported in cotton include the western flower thrips, *Frankliniella occidentalis*; the flower thrips, *Frankliniella tritici*; the soybean thrips, *Neohydatothrips variables*, (Burris et al., 2000); and the onion thrips, *Thrips tabaci* (Eddy and Livingstone, 1931).

Thrips injure cotton by feeding in the terminal area of the plant. This terminal feeding disrupts normal growth of the plant leaf structure. The result is usually severely deformed leaves, aborted terminals, and greatly reduced leaf area. This general injury of the plant structure greatly reduces the photosynthetic capacity of the plant. As a result, the general vigor of the plant is low, causing stunting, increased susceptibility to plant diseases, and often a delay in maturity. If not controlled, thrips injury can severely reduce stands. In addition, yields can be reduced by up to 50 or 60% in a year

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when thrips are numerous and not controlled by in-furrow insecticides, seed treatments, or foliar treatments.

RESEARCH DESCRIPTION

Two field tests were conducted in 2002 to evaluate the efficacy of selected insecticides on thrips. The tests were located at the University of Arkansas Northeast Research and Extension Center near Keiser, AR, and at the University of Arkansas Cotton Branch Station near Marianna. Both tests were arranged in a randomized complete block design with four replications. Plots were eight 38-inch rows wide by 50-feet long at Keiser and four 38-inch rows wide by 50-feet long at Marianna. The cotton (*Gossypium hirsutum* L.) variety planted at both locations was Deltapine 451 BR. Temik was applied in-furrow at planting. Gaucho, L0263 plus L0110, and Cruiser are seed treatments. Orthene was applied as a foliar treatment on 7 June at Keiser and 3 June at Marianna with a final spray volume of 11 gal/acre. Thrips samples were taken on 7, 14, 21, and 26 June at the Keiser location and on 3, 11, 17, and 25 June at the Marianna location. Five plants were randomly sampled per plot to determine the level of thrips infestation. Plants were processed using the wash procedure described by Burris et al. (1990). Samples were taken from the outside two rows of each plot to avoid influence on yield. Each plant was cut and immediately placed into a mason jar containing 70% ethyl alcohol. In the laboratory, plants were rinsed with alcohol to wash off thrips. To separate the thrips from alcohol, the solution was poured through grid-lined filters lining the inside of a buchner funnel. A vacuum pump was used to quickly evacuate the alcohol through the filter. Thrips were visually counted on the filter using a dissecting microscope. Plots were maintained according to University of Arkansas Cooperative Extension Service recommendations. Yields were determined by harvesting the center two rows of each plot. Lint yields were determined based on a 32% gin turnout.

RESULTS AND DISCUSSION

The thrips pressure was high in 2002, and tobacco thrips was the predominant species. Thrips pressure was similar at both locations. Damage was compounded by cold weather in early May.

All treatments, except Orthene, maintained control through 14 days after treatment (DAT) at both locations (Tables 1 and 2). At Keiser, all treatments, except Orthene, had significantly lower thrips counts than the untreated check through 21 DAT (Table 1). At 28 DAT, Temik (0.5 lb ai/acre), L0263 plus L0110, and Cruiser had significantly lower thrips populations than Orthene. All other treatments were not significantly different.

At the Marianna location, treatments began to differ by 21 DAT (Table 2). Temik (0.75 lb ai/acre), L0263 plus L0110, and Orthene were statistically similar to the untreated check at 21 DAT, and all other treatments had significantly lower thrips populations than the untreated check. All treatments were similar by 28 DAT.

All treatments, except Orthene, gave significantly higher yields than the untreated check at the Keiser location (Table 1). Orthene had a statistically similar yield to the untreated check and was significantly lower than all other treatments. There was a numerical trend of increased yield with increased rate of Temik at the Keiser location (Table 1). There were no significant differences in yield among the treatments at the Marianna location (Table 2).

PRACTICAL APPLICATION

Orthene as a foliar spray proved ineffective for controlling thrips. Temik and Gaucho remain good control tools for thrips, and the low rates of Temik gave equivalent, and in many cases better, control compared to the high rates. Combining the experimental compounds L0263 and L0110 as a seed treatment proved to be a good control option for the future.

ACKNOWLEDGMENTS

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Table 1. Effects of chemical treatment on thrips population counts and cotton yield at Keiser, AR.

Treatment	Rate	Number of thrips 14 DAT	21 DAT	28 DAT	33 DAT	Lint yield
		(no./5 plants)				(lb/acre)
Untreated	---	90.75 a[z]	95.00 a	44.25 ab	27.00 a	414.74 b
Temik	0.5 lb ai/acre	6.00 b	18.00 b	22.25 b	10.75 a	703.42 a
Temik	0.6 lb ai/acre	19.50 b	21.75 b	57.00 ab	13.50 a	730.53 a
Temik	0.75 lb ai/acre	2.75 b	19.50 b	35.50 ab	9.50 a	824.44 a
Gaucho	8 oz/cwt	5.50 b	44.75 b	39.50 ab	9.50 a	736.83 a
L0263 +	3.84 oz/cwt					
L0110	4.8 oz/cwt	10.00 b	33.50 b	24.50 b	17.25 a	765.19 a
Cruiser	7.65 oz/cwt	4.75 b	21.25 b	23.50 b	16.00 a	842.09 a
Orthene	0.35 lb ai/acre	131.50 a	84.50 a	78.75 a	39.25 a	306.96 b

[z] Means followed by the same letter do not significantly differ (P = 0.05).

Table 2. Effects of chemical treatment on thrips population counts and cotton yield at Marianna, AR.

Treatment	Rate	Number of thrips 14 DAT	21 DAT	28 DAT	33 DAT	Lint yield
		(no./5 plants)				(lb/acre)
Untreated	---	73.75 a[z]	90.00 a	35.00 a	35.00 a	875.29 a
Temik	0.5 lb ai/acre	3.25 b	17.50 b	20.25 a	18.25 a	947.02 a
Temik	0.6 lb ai/acre	2.25 b	15.25 b	42.50 a	38.75 a	904.47 a
Temik	0.75 lb ai/acre	5.75 b	32.50 ab	34.75 a	22.50 a	959.18 a
Gaucho	8 oz/cwt	2.75 b	18.25 b	15.75 a	22.00 a	988.35 a
L0263 +	3.84 oz/cwt					
L0110	4.8 oz/cwt	4.25 b	37.00 ab	26.00 a	27.75 a	925.14 a
Cruiser	7.65 oz/cwt	0.75 b	10.75 b	21.25 a	36.25 a	968.90 a
Orthene	0.35 lb ai/acre	66.50 a	82.25 ab	25.50 a	20.25 a	937.29 a

[z] Means followed by the same letter do not significantly differ (P = 0.05).

Treatment Tresholds for Stink Bugs

Jeremy K. Greene and Chuck D. Capps[1]

RESEARCH PROBLEM

Because of continued difficulties in detecting stink bugs in cotton, we continued testing the effectiveness of using symptoms of boll injury as a monitoring tool for treatment decisions. 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). Several other species are part of the plant-feeding stink bug complex but are of less importance. Research with treatment thresholds for stink bugs, based on monitoring internal feeding injury to bolls, supported treatment at 20% injury to mid-sized (ca. 14-d-old) bolls.

BACKGROUND INFORMATION

In recent years, most involved with cotton production have become increasingly aware of potential losses due to plant-feeding stink bugs (Pentatomidae). Many have realized that pentatomids have benefited from some of the major technologies and advancements available today and that they will continue to thrive under technological conditions that will be accessible in the very near future. The eradication of the boll weevil, *Anthonomus grandis* Boheman; availability of alternative chemistries for selective control of worm (Lepidoptera) pests; established use of transgenic *Bt* cotton; and the registration of second-generation *Bt* varieties enhanced in controlling worm pests, all offer significant reductions in broad-spectrum foliar insecticide usage. Stink bugs greatly benefit from the reduction of insecticides applied for major pest groups. In the absence of these materials providing "coincidental" control of stink bugs, producers have had to shift to using "intentional" control for their management. 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;

[1] Extension entomologist and pest management technical support specialist, respectively, Southeast Research and Extension Center, Monticello.

Greene et al., 2001a,b; Willrich et al., 2002; Greene and Capps, 2002). In 2002, we continued investigations into the development of boll injury-based thresholds for stink bugs.

RESEARCH DESCRIPTION

Plots (16 rows by 66 ft) of DP451B/R at the Rohwer Branch of the Southeast Research and Extension Center in Desha County, AR and ST4892B/R (24 rows by 200 ft) at a producer's farm in Ashley County, AR were arranged in a randomized complete block design with 6 to 7 treatments and 4 replications. Twenty-five bolls (50 to 75% full size, ca. 14 d from white bloom) were collected from each plot weekly and examined for internal symptoms of feeding by stink bugs. A boll was considered damaged if at least one internal growth (cell proliferation) or obvious staining of lint with associated feeding injury to seeds was observed. Dicrotophos (Bidrin 8, Amvac, Los Angeles, CA at 0.50 lb ai/acre) was applied to all plots in a treatment at or exceeding the following levels of damaged bolls: 10, 20, and 30% and at a density of 1 bug per 6 ft of row. Additional treatments included a 15% level in Ashley County and an untreated control at both sites. Two rows from the center of each plot were harvested by machine.

RESULTS AND DISCUSSION

In 2002, three test fields in southeast Arkansas were established for research addressing boll-injury thresholds for stink bugs. One field was lost due to the absence of satisfactory numbers of bugs and other circumstances. A second field in Ashley County was sampled all season, but a problem with harvesting resulted in the loss of yield data from the test. Yield data, along with boll injury and insect sampling data, were obtained from a third test site at the Rohwer Experiment Station in Desha County, AR. At that site, 4 applications of dicrophos (Bidrin 8) at 0.5 lb ai/acre at thresholds of 10, 20, and 30% internal boll injury resulted in 217, 227, and 151 lb/acre, respectively, increases in lint yield when compared with untreated plots. Three applications at the 50% level resulted in a 119 lb/acre increase. In-field populations were not detected at the threshold of 1 bug per 6 row feet using a shake sheet. These data support data summarized from 1999-2001 in Georgia cotton fields where 10, 20, and 30% thresholds had identical trends in yield (Fig. 1). When yield increases and insecticide costs were calculated, the 20% level of treatment (followed closely by 30%) yielded the best net return. Recommendations in Arkansas, Georgia, South Carolina, and many other states include some variation of a boll-injury threshold for stink bugs. As a result of these continuing studies, alternative monitoring and management recommendations are available for stink bugs in cotton.

PRACTICAL APPLICATION

Because stink bugs are challenging to detect in cotton with traditional sampling tools, we continued investigations of other methods of monitoring the pest complex

for management decisions. Research with treatment thresholds for stink bugs, based on monitoring internal feeding injury to bolls, supported treatment at 20% injury to mid-sized (ca. 14-d-old) bolls.

ACKNOWLEDGMENTS

We thank Cotton Incorporated, Arkansas cotton producers, AMVAC, Aventis, Bayer, Cheminova, Control Solutions, Dow AgroSciences, DuPont, FMC, Syngenta, and Valent for support of this work.

DISCLAIMER

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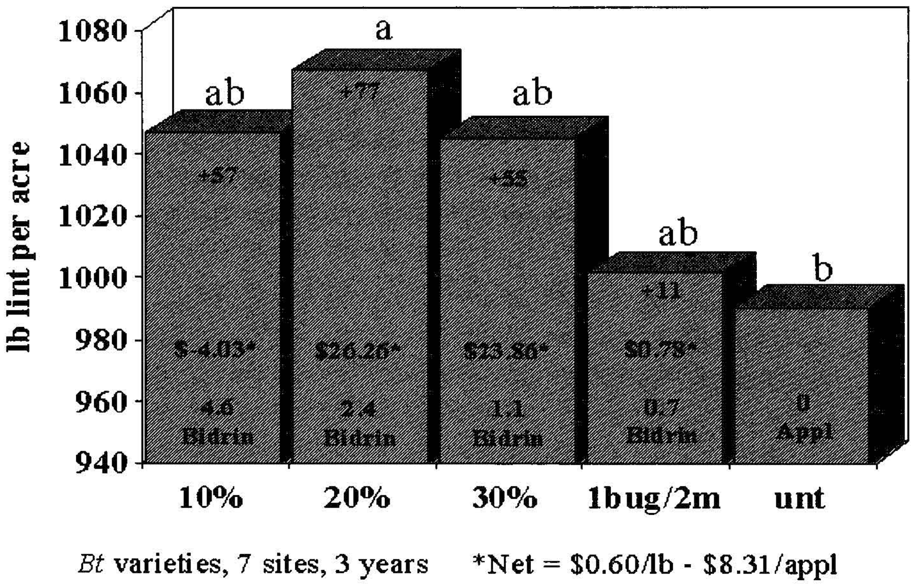

Fig. 1. Seven-site average (1999-2001) lint yield following treatment with dicrotophos (Bidrin 8, avg. no. of treatments per season) at various thresholds (percentage of internal boll injury or density) for stink bugs. *Net $ gain, calculated with yield gain at $0.60 per lb minus $8.31 per application ($5.31, insecticide plus $3.00, application costs). Treatment bars with a letter in common are not significantly different, P≤0.05, LSD = 74.

Production of *Helicoverpa zea* on Corn, Cotton, Soybean, and Grain Sorghum: Implications for Managing Insect Resistance to *Bt* Cotton

R.G. Luttrell, Dick Hardee, Marvin Wall, John Smith, Grayson Lindley, Thad Freeland, and Clint Allen[1]

RESEARCH PROBLEM

The purpose of this project is to determine whether *Helicoverpa zea* moths produced by alternate host plants effectively supplement the external unsprayed non-*Bt* refuge for *Bt* cotton. Extensive studies have been conducted on *H. zea* development on selected crop hosts. Harding (1976) and Hayes (1988) reported that *H. zea* produced in both field corn and grain sorghum were more fit than those in cotton with respect to larval developmental time and the ability of larvae to complete development. Other studies demonstrated that *H. zea* pupal and adult production was significantly higher in field corn compared to other agronomic crops, which indicates that adults emerging from field corn are more fit than those from other crop hosts (Hartstack et al., 1973; Roach and Ray, 1976; Sparks et al., 1971). Thus, *H. zea* adults emerging from alternate crop hosts are generally considered to be equally, if not more, fit compared to those produced in cotton. This study was designed to determine if non-cotton hosts of *H. zea* provide a quantity of moths sufficient to effectively supplement those produced from the external unsprayed cotton refuge. To be an effective refuge, moths from the alternate host plants must be synchronous with and in the proximity of moths produced in *Bt* cotton and must be produced in significant quantities.

RESEARCH DESCRIPTION

Overall objectives of this ongoing project are to follow the spatial and temporal distribution of bollworm moths in the Tillar, AR, area and attempt to relate the temporal and spatial patterns observed to proximity of crops identified as major sources of

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population increase. The study was closely coordinated with similar studies in Mississippi, Louisiana, Georgia, and North Carolina. Moths from the different sample sites were forwarded to Monsanto and Company, processed (forewings removed) and sent to the University of Georgia for analyses of the carbon content of each sample. Carbon analyses presumably will provide information about the host material used for larval development, specifically if the host plant was a C3 or a C4 plant.

To relate the frequencies of different carbon contents in moth wings associated with different sample sites, satellite images of the crops grown within 1 mile of each trap were produced by Southern Illinois University under contract from Monsanto and Company. We provided the crop descriptions necessary for detailed analyses and ground-truthing of the images. Relational studies between trap captures and proximity to various crops are in progress.

To relate potential differences in distribution patterns of the moths to sources of the different crops utilized by the species, heliothine numbers were monitored in the fields adjacent to each 3-trap group of pheromone traps. Commercial fields of *Bt* cotton, conventional cotton, early soybean, late soybean, corn, and grain sorghum were sampled weekly as possible. Applications of pesticides and scheduling of other cultural practices interrupted some sampling during the course of the year, but efforts were made to sample representative fields of each crop each week.

A replicated field study containing 0.25-acre plots of *Bt* cotton, conventional cotton, group IV soybean, group V soybean, group VI soybean, corn, and grain sorghum was planted and closely monitored on a weekly basis for heliothine densities. This test area was within an active zone of the Arkansas Boll Weevil Eradication Project and received numerous over-sprays of malathion. The plots did not receive any insecticide treatment for lepidopteran pests. A single application of acephate was applied late in August to suppress high densities of the tarnished plant bug, *Lygus lineloris*. These replicated plots were intensively sampled to understand the potential for production of heliothine larvae and possible temporal relationships with the pheromone trap captures.

RESULTS AND DISCUSSION

Numbers of bollworm moths captured at the interface of *Bt* cotton and other crops are summarized in Fig. 1. Over the course of the summer, 31,310 moths were captured. Peak trap capture was during the last two week of July. More moths (total of 5,163) were captured at the interface of *Bt* cotton and conventional cotton than at other crop interfaces over the entire length of the trapping experiment (6 June – 4 September). However, similar numbers were captured at all locations. The 5,163 moths captured at the *Bt* cotton and conventional cotton interface represented ~16% of the total trap captures. The fewest numbers of captures were associated with the *Bt* cotton and early soybean interface where a total of 3,393 moths, or ~11% of the total captures were obtained. Early in the season, trap captures were generally higher near corn (Fig. 1). Conventional cotton was the site of highest captures in mid- to late-July, and trap

captures increased around *Bt* cotton later in the season. Results of the carbon analyses studies are preliminary, but insects from non-cotton hosts were present at all sampling times.

Densities of heliothine (*H. zea* or *Heliothis virescens*) larvae found in *Bt* cotton were extremely low (Fig. 2). Only a few larvae were found prior to August, and no large larvae were observed until August (Fig. 3). More than 80% of the sample dates and sample fields had no detection of larvae. The highest densities observed in *Bt* cotton were during the first week of August in *Bt* cotton fields growing adjacent to soybean. Numbers were also low in the conventional cotton field being sprayed with insecticide with detectable densities of larvae being found only in August.

Numbers of total larvae and large larvae found in corn and sorghum production fields were much higher than those found in cotton (Fig. 4 and 5). A peak average density of 32,864 larvae/acre was observed in the production corn fields during the first week of July. Detectable densities of large larvae were found on corn for five weeks from late June to late July. Densities of large larvae on grain sorghum were high during a three-week period in July. Only a few large heliothine larvae were found on early soybean, but detectable numbers were found in August on late soybean. Average densities of large larvae for the production fields planted to alternative crops over the 10-week period were 114, 79, 7747, 6585, 7, and 665 larvae/acre for *Bt* cotton, conventional cotton, corn, grain sorghum, early soybean, and late soybean, respectively.

Small and large larvae were found in some plots of the replicated field study every week from mid-June to mid-August (Fig. 6 and 7). No large heliothine larvae were found after mid-August. Over the 10-week period, an average density of 5770 larvae/acre was found. The highest numbers were found during the third week of June (17,990) when peak densities in corn were being recorded. Densities across the study area ranged from 2402 larvae/acre in early August to the peak density of 17,990/acre in early July. The highest density observed in a single crop was 86,695 larvae/acre found in grain sorghum during the second week of July. Average densities/acre across the 10-week sample period for *Bt* cotton, conventional cotton, group IV soybean, group V soybean, group VI soybean, grain sorghum, and corn were 758, 3793 855, 2310, 1609, 17,084, and 13, 959 larvae/acre, respectively. The highest density observed on *Bt* cotton was 2413 larvae/acre during the first week of August. An average density of 14,484 larvae/acre was recorded for conventional cotton during the last week of July and densities averaged more than 10,000/acre in conventional cotton for a three-week period from late July to mid-August. Large larvae were found in all crops but more were found in cotton and grain sorghum which had higher overall densities. Seasonal average production of large larvae/acre/week was 345, 2207, 690, 1276, 1287, 3414, and 4699 large heliothine larvae/acre in *Bt* cotton, conventional cotton, group IV soybean, group V soybean, group VI soybean, grain sorghum, and corn, respectively. The corresponding percentages of total larvae that were classified as large larvae were 45, 58, 81, 55, 80, 20, and 34% for *Bt* cotton, conventional cotton, group IV soybean, group V soybean, group VI soybean, grain sorghum, and corn, respectively. While total densities of larvae varied from a weekly average of 758/acre in *Bt* cotton to 17,084/acre in grain

sorghum (a 23-fold increase as measured over the entire season), number of larvae varied from a weekly average of 345/acre in *Bt* cotton to a high of 4699 in corn (a 14-fold increase as measured over the entire season).

PRACTICAL APPLICATION

Given the known seasonal and spatial variability in the population dynamics of *H. zea*, the experiment needs additional replication over time. However, the coordinated nature of this work with other geographic sites will provide meaningful information about this economically important pest. In general, the moths seem to be widely distributed across time and across the Tillar and Company production area. Production of larvae occurs on most of the targeted crops, and larvae seem to be present at some low density throughout the crop-growing year. Overall numbers seem to be higher on corn and grain sorghum early in the year, and the peak densities of moths may be associated with the high numbers of larvae being produced on corn in the Tillar area. Densities of larvae on soybean were low but comparable to those on conventional cotton.

Comparisons of these data with those from the other research sites may provide some interesting insights into the relative importance of the different crops across broad geographic areas. Based on this single year of observation in the Tillar area, bollworm seems to be highly polyphagous with population densities coming from a diversity of crops. Other host plants, especially natural vegetation and weeds, may also be involved in the overall population structure. The numbers of moths captured seemed to be associated with peak production of larvae in the various crops, but the present research does not clearly address the relative contribution of long-range migrants to the population.

ACKNOWLEDGMENTS

This research was supported by a cooperative agreement between the USDA, ARS, Southern Fields Crops Research Unit, and the Arkansas Agricultural Experiment Station. Cooperators with the USDA, Monsanto Company, LSU, University of Georgia, and North Carolina State University are acknowledged for their support and input on the design of the studies. The farmers and managers of Tillar and Company were extremely helpful in organizing this work.

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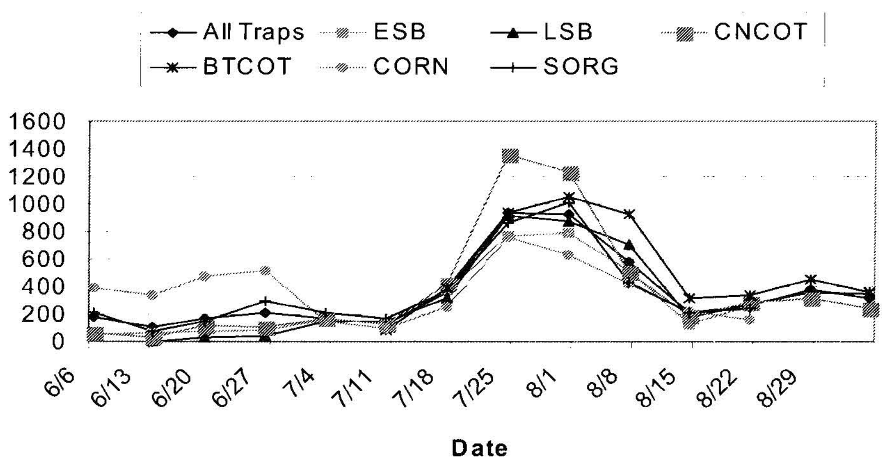

Fig. 1. Bollworm pheromone trap captures at borders of *Bt* cotton and alternative crops, Tillar, AR, 2002.

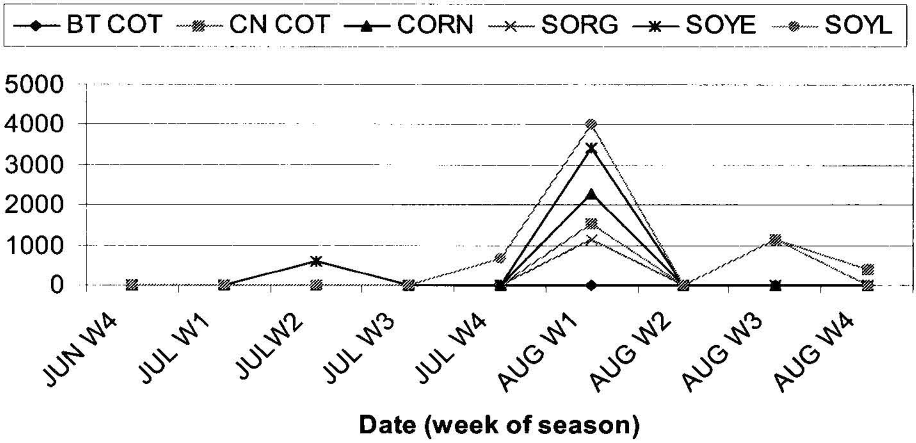

Fig. 2. Total heliothine larvae/acre in *Bt* cotton adjacent to pheromone traps and alternative crops, Tillar, AR, 2002.

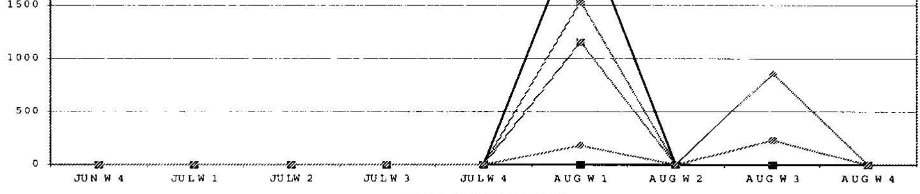

Fig. 3. Large heliothine larvae/acre in *Bt* cotton adjacent to pheromone traps and alternative crops, Tillar, AR, 2002.

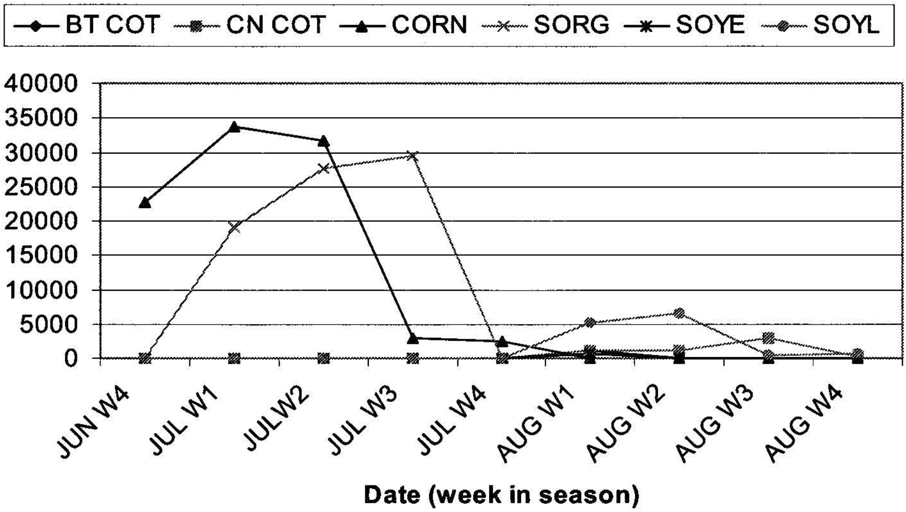

Fig. 4. Total heliothine larvae/acre in alternative crops adjacent to pheromone traps and *Bt* cotton, Tillar, AR, 2002.

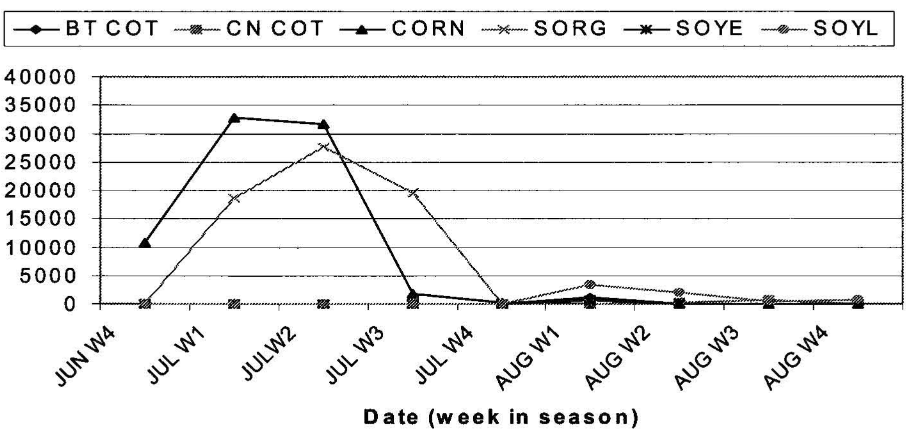

Fig. 5. Large heliothine larvae/acre in alternative crops adjacent to pheromone traps and *Bt* cotton, Tillar, AR, 2002.

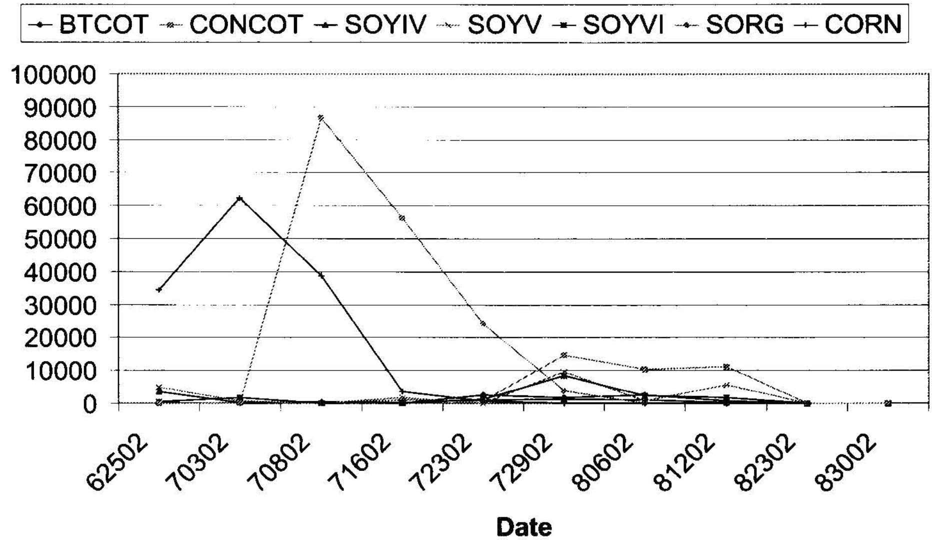

Fig. 6. Total heliothine larvae/acre in 0.25-acre small plots of *Bt* cotton, conventional cotton, and alternative crops, Tillar, AR, 2002.

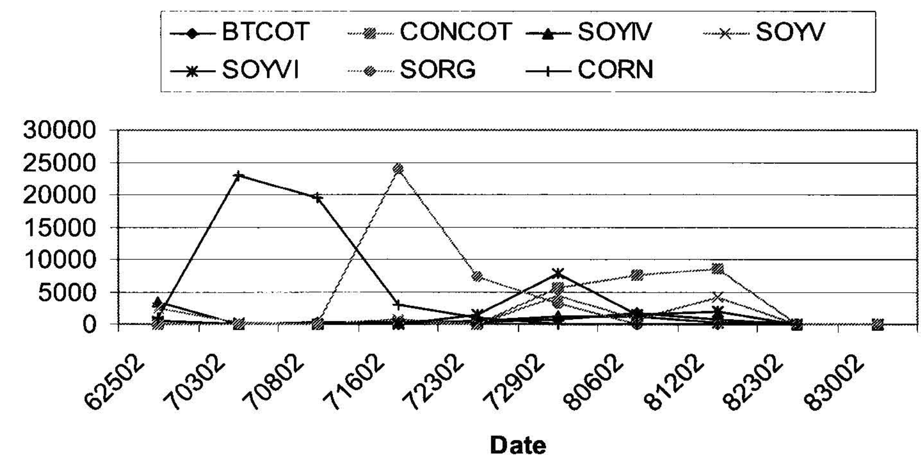

Fig. 7. Large heliothine larvae/acre in 0.25-acre small plots of *Bt* cotton, conventional cotton, and alternative crops, Tillar, AR, 2002.

Bollgard II Efficacy on the Heliothine Complex

Donald R. Johnson, Gus M. Lorenz, III, and Kenneth D. Walsh[1]

RESEARCH PROBLEM

Bollgard II, Monsanto line DPLX-01W94-D, was compared to Bollgard and conventional cotton varieties in Jefferson County, AR, to determine efficacy against the Heliothine complex.

BACKGROUND INFORMATION

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

Bollgard II was developed to contain an additional toxin, CryX , to enhance the control of lepidopterous pests in cotton and hinder the development of resistance. Previous studies have shown Bollgard II to have increased efficacy for bollworm and soybean looper (Allen et al., 2000; Stewart et al., 2000; Ridge et al., 2000). The purpose of this study was to compare the efficacy of Bollgard II to Bollgard and conventional cotton for control of lepidopterous pests. Observations were also made to compare agronomic characteristics of these cultivars.

RESEARCH DESCRIPTION

The study was conducted on the Hooker Farm in Jefferson County, AR. The studies were planted on 5 May 2002. Six treatments were arranged in a randomized complete split block design with four replications. The cultivars were SureGrow 125 (untreated control), SureGrow 125 BR (Bollgard), and DPLX01W94D (Bollgard II). Each

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[1] Extension entomologist-pest management section leader, extension entomologist-IPM coordinator, and technical support specialist, respectively, Cooperative Extension Service, Little Rock.

cultivar was either treated with the foliar-applied insecticide, Tracer, or left untreated, giving two treatments per cultivar. Plots were four 38-inch wide rows by 50-feet long. Tracer was applied at 0.067 lb ai/acre on 9 and 25 July and 5 August. Scouting data taken included damaged fruit counts and larval counts. Plots were machine picked 31 October. Lint cotton yields were determined based on a 32% gin turnout. Data were processed using Agriculture Research Manager Version 6.0.1. Analysis of variance was conducted and Duncan's New Multiple Range Test (P=0.05) was used to separate means.

RESULTS AND DISCUSSION

Populations of tobacco budworm and cotton bollworm were lower in 2002 than observed in previous years. Normally, tobacco budworm populations are highest in late July through early August. While this trend held true, the overall bollworm:budworm complex was lower throughout the growing season than normal.

No significant difference in square damage was observed between Bollgard and Bollgard II based on the seasonal average (Table 1). Both the Bollgard and Bollgard II cultivars resulted in fewer seasonal live larvae in plots when compared to untreated SureGrow 125 regardless of insecticide treatment. However, no differences were observed when compared to treated SureGrow 125, indicating a possible result of low Heliothine pressure throughout the growing season (Table 2).

All treatments achieved significantly higher lint cotton yields than the untreated SureGrow 125, a direct result of increased heliothine control (Table 3). No significant difference in yield was observed between Bollgard and Bollgard II regardless of insecticide treatment. Lint cotton yields of both untreated and treated Suregrow 125 were significantly lower that treated and untreated Bollgard and Bollgard II. Bollgard and Bollgard II were effective in controlling the heliothine complex. The Bollgard II cultivar, DPLX01W94D, maintained the heliothine larvae numbers and square damage at very low levels.

PRACTICAL APPLICATION

Both Bollgard and Bollgard II proved to control the heliothine complex and prevent significant square damage, thereby increasing cotton yields. Supplemental applications of Tracer improved yield for the conventional cotton cultivar. However, Tracer did not improve the lint yield for the Bollgard and Bollgard II cotton cultivars.

ACKNOWLEDGMENTS

The authors thank Mr. Chuck Hooker for assistance with this research and our chemical industry cooperators for funding and supplies.

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Table 1. Bollgard and Bollgard II efficacy on heliothine damage.

Cultivar	Treatment	Seasonal average[z]
		(#/50 squares)
SG 125	untreated	2.25 a
SG 125	treated[y]	1.25 b
SG 125 BR	untreated	0.125 b
SG 125 BR	treated	0.188 b
DPLX01W94D	untreated	0.0 b
DPLX01W94D	treated	0.0 b

[z] Means followed by the same letter do not differ significantly (P=0.05).
[y] Treated with foliar application of Tracer (0.067 lb ai/acre).

Table 2. Seasonal average of heliothine larvae with Bollgard, Bollgard II, and conventional cotton cultivars.

Cultivar	Treatment	Seasonal average[z]
		(#/50 squares)
SG 125	untreated	0.188 a
SG 125	treated[y]	0.125 a
SG 125 BR	untreated	0.063 a
SG 125 BR	treated	0.063 a
DPLX01W94D	untreated	0.0 a
DPLX01W94D	treated	0.0 a

[z] Means followed by the same letter do not significantly differ (P=0.05).
[y] Treated with foliar applications of Tracer (0.067 lb ai/acre).

Table 3. Lint cotton yield as affected by Bollgard and Bollgard II heliothine control.

Cultivar	Treatment	Lint cotton yield[z, y]
		(lb/acre)
SG 125	untreated	749 c
SG 125	treated[x]	897 b
SG 125 BR	untreated	1036 a
SG 125 BR	treated	1033 a
DPLX01W94D	untreated	1097 a
DPLX01W94D	treated	1129 a

[z] Lint cotton yield is based on a 32% gin turnout.
[y] Means followed by the same letter do not significantly differ (P=0.05).
[x] Treated with foliar applications of Tracer (0.067 lb ai/acre).

Pest Management Strategic Plan for the Mid-South Production Region

Ples Spradley, Elmo Collum, and Matt Shipp[1]

RESEARCH PROBLEM

What are the current components of pest management in cotton grown in the mid-South production region (Arkansas, Louisiana, and Mississippi)? In other words: what are the major pests of cotton, the practices used to control these pests, the acres treated/managed for each pest, and the current limitations on pest management in cotton? Additionally, what are the priorities for the research, regulation, and educational activities aimed at pest management in cotton?

BACKGROUND INFORMATION

The Environmental Protection Agency is in the process of re-registering pesticides under the requirements of the Food Quality Protection Act (FQPA) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The EPA is examining dietary, ecological, residential, and occupational risks posed by the "high risk" pesticides (organophosphates, carbamates, and B/2 carcinogens). EPA's regulatory focus on these chemistries has created uncertainty as to their future availability. At some point the EPA may propose to modify or cancel some or all of these pesticides. The USDA, EPA, land-grant universities, and the cotton industry need to proactively identify regulatory, research, and educational needs for replacing or modifying the use of the pesticides of concern with cost-effective alternatives as FQPA is implemented.

PROJECT DESCRIPTION

A project to develop a Pest Management Strategic Plan (PMSP) for cotton growth in the mid-South was initiated in 2001. Extension specialists, university researchers, consultants, growers, commodity groups, Farm Bureau, state lead agencies, EPA, and

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other stakeholders from Arkansas, Louisiana, and Mississippi were asked to aid in this endeavor. The project is being funded by a grant from the Southern Region Pest Management Center, currently located at the University of Florida.

The primary objectives of the PMSP are to identify the key pests of cotton grown in the mid-South, the current pest management practices, and why other currently registered pesticides and/or management practices are not being used (e.g., cost, efficacy, resistance, and quality and quantity impacts). In addition, the plan will prioritize the research, regulatory, and educational needs for cotton pest management into the foreseeable future.

RESEARCH / ACTIVITIES

One of the primary components of this project was the establishment of advisory committees in each of the three states. The committees are composed of extension specialists, university researchers, consultants, growers, commodity groups, Farm Bureau, state lead agencies, EPA, and other stakeholders in cotton production. All of the state committee members were also asked to serve on the multi-state advisory committee.

A draft PMSP document was prepared using data from previous pesticide use surveys of cotton producers, surveys of advisory committee members concerning current pest management practices in cotton, and various cotton publications produced by researchers and specialists. A meeting of the Arkansas Advisory Committee was held in Little Rock in March 2002 to critique and finalize the Arkansas PMSP.

After the completion of the Arkansas PMSP, a multi-state PMSP was drafted using information provided by the Louisiana and Mississippi advisory committees. The draft multi-state PMSP was provided to all of the advisory committee members in the three states in March 2003 for their review.

A meeting of the multi-state advisory committee was held in Vicksburg, MS, on 24-25 April 2003. The primary goals at the Vicksburg meeting were to finalize the multi-state PMSP and to develop pest-specific priorities for research, regulatory, and educational activities aimed at cotton pest management. The bulk of the multi-state meeting was spent on the development of the priority lists.

We are currently working with the multi-state advisory committee to finalize the PMSP and priority lists.

PRACTICAL APPLICATION

We expect the final document to be ready in the summer of 2003. Once completed, the PMSP will be disseminated to advisory committee members, the Southern Region Pest Management Center, and other identified stakeholders. It will also be placed on the USDA Pest Management Center website, http://www.pmcenters.org/CropProfiles/

ACKNOWLEDGMENTS

We wish to thank all of the members of the advisory committees from Arkansas, Louisiana, and Mississippi for their participation in this project. Special thanks is extended to Dr. Gus Lorenz, University of Arkansas Cooperative Extension Service; Dr. Blake Layton, Mississippi State University Extension Service; and Dr. Randy Luttrell, University of Arkansas, for their extension help with the PMSP and priority lists.

Evaluation of Insecticide Termination Decisions in Southeast Arkansas

Jeremy K. Greene and Chuck D. Capps[1]

RESEARCH PROBLEM

Cotton growers face the difficult decision every year of determining when to stop spraying for insect pests. Late-season pests such as the Heliothine complex, comprised of the cotton bollworm, *Helicoverpa zea* (Boddie); and the tobacco budworm, *Heliothis virecens* (F.); along with the stink bug complex comprised of the brown stink bug, *Euschistus servus* (Say), the green stink bug, *Acrosternum hilare* (Say), and the southern green stink bug, *Nezara viridula* (L), make late-season insecticide applications necessary for viable cotton production in southeast Arkansas. If farmers fail to treat when pests reach threshold levels before the crop reaches cutout, they can suffer severe losses in yield and fiber quality, but if they treat long after fields have passed cutout, they protect fruit that does not contribute significantly to yields.

BACKGROUND INFORMATION

An important decision made by Arkansas cotton growers every year is when to stop treating for insect pests. For years, this decision consisted of "judgment calls" made by the grower or consultant with no practical application model on which to base this decision. While no system can provide absolute answers for every situation, recent research based on the COTMAN (COTton MANagement Model) can provide a system to help growers make these crucial management decisions (Kharboutli and Allen, 2001; Greene and Capps, 2002). 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 (Bagwell, 1995; Oosterhuis et al., 1996; Kharboutli and Allen, 2001; Kim et al., 1997).

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

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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 last effective boll (Oosterhuis et al., 1996) and is considered to be at physiological cutout (Oosterhuis et al., 1999).

RESEARCH DESCRIPTION

Two fields of cotton (*Gossypium hirsutum* L.) were planted to Fibermax 958 variety - Y-19 on 15 April 2002 and Y-16 on 16 April 2002. The fields were located at Yancopin, AR, on the Steve Stevens Farm. Plots were 20 rows wide, the width of one plane pass, by approximately 1000 ft in length and replicated four times. Both tests were designed to have insecticide treatments terminated on the following: NAWF=5 to NAWF=5 + 350 heat units (HU), NAWF=5 + 350 HU, NAWF=5 + 450 HU, NAWF=5 + 550 HU, and NAWF=5 + 650 HU. Neither Test 1 nor Test 2 followed these termination treatments exactly because of variability in insect pressure and application dates of insecticides. Test 1 termination of insecticides resulted in the following treatments: NAWF=5 + 258 HU, NAWF=5 + 465 HU, and NAWF=5 + 568 HU. Treatments after cutout were Baythroid at 2.1 oz/acre and Tracer at 1.6 oz/acre applied on 5 August, Baythroid at 2.1 oz/acre and Tracer 1.6 oz/acre on 15 August, and Baythroid at 2.1 oz/acre and Tracer at oz/acre applied on 20 August. Test 2 termination of insecticides resulted in the following treatments: 5 days prior to NAWF=5, NAWF=5 + 286 HU, and NAWF=5 + 359 HU. Treatments after cutout were Baythroid at 2.1 oz/acre and Tracer at 1.6 oz/acre applied on 5 August, Karate at 1.8 oz/acre and Tracer at 1.8 oz/acre applied on 7 August, Baythroid at 2.1 oz/acre and Tracer at 1.6 oz/acre on 15 August, and Baythroid at 2.1 oz/acre and Tracer at 1.6 oz/acre applied on 20 August. Net returns were calculated using the cost of insecticides applied after cutout (all treatments received same insecticide treatments prior to cutout), 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. Net returns were highest for the NAWF=5 + 465 HU treatment in Test 1 and the NAWF=5 + 0 HU in Test 2. Similar results have been seen in previous tests (Kharboutli and Allen, 2001; Greene and Capps, 2002).

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.

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Table 1. Insecticide termination data from field Y-19, cultivar Fibermax 958, planted on 15 April 2002 (Test 1).

Event	Date	DAP[z]	Days after NAWF=5[y]	DD60[x] after NAWF=5	Lint yield	Insecticide cost	Net return
					(lb/acre)	($/acre)	($)
Last trt	5 Aug	101	11	258	1242.7	14.45	631.75
Last trt	15 Aug	111	21	465	1280.0	28.90	636.70
Last trt	20 Aug	116	26	568	1279.3	43.35	621.89

[z] DAP = days after planting.
[y] NAWF = nodes above white flower.
[x] DD60 = degree days (threshold 60° F).

Table 2. Insecticide termination data from field Y-16, cultivar Fibermax 958, planted on 16 April 2002. (Test 2).

Event	Date	DAP[z]	Days after NAWF=5[y]	DD60[x] after NAWF=5	Lint yield	Insecticide cost	Net return
					(lb/acre)	($/acre)	($)
Last trt	29 July	104	0	0	1115.5	10.66	569.40
Last trt	15 Aug	121	12	286	1122.5	52.59	531.11
Last trt	20 Aug	126	17	359	1149.2	67.04	530.54

[z] DAP = days after planting.
[y] NAWF = nodes above white flower.
[x] DD60 = degree days (threshold 60° F).

Evaluation of an Upper Temperature Limit in Heat Unit Calculations for Use in COTMAN End-of-Season Decisions

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

RESEARCH PROBLEM

Maximum and minimum temperatures are used to calculate heat units for use in the COTMAN crop monitoring program for following fruiting and determining production inputs. However, some controversy exists about the real value of these heat units because although a lower threshold for growth is used (60°F), there is no such upper threshold for extreme temperatures. It is suggested that under conditions of high temperature, the calculated heat units may not correspond to measurable growth and yield, and therefore, may not be appropriate for predicting production inputs and decisions. This project was designed to investigate the effect of extreme temperatures on the calculation of heat units for improving their use in the COTMAN crop monitoring program.

BACKGROUND INFORMATION

Information on cotton response to temperature is lacking, particularly with regard to the upper temperature threshold and effects on physiological processes and yield. The current method of calculating heat units needs to be refined. We currently calculate heat units by [(maximum temperature + minimum temperature)/2] - 60°F, where 60°F is the lower limit threshold for physiological activity. Most researchers worldwide do not use an upper limit for calculating heat units although there is strong evidence that cotton metabolism decreases dramatically at high day temperatures (Burke et al., 1988). In Arizona an upper temperature threshold of 86°F is used (Brown, 1989).

RESEARCH DESCRIPTION

The upper temperature thresholds used in the heat unit (HU) calculation [HU= (max temp+min temp) - 60°F] were 85°F, 90°F, 95°F, and 100°F. The treatments selected

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included (a) potassium (high K and low K plots), (b) nitrogen (high N and low N plots), (c) boron (high B and low B plots), (d) water status (well-watered and water-stressed plots), and (e) night temperature (raised and lowered). The geographical locations included: Arkansas and Louisiana. COTMAN data was compiled for each treatment and location, the program run with the different upper-limit thresholds, and the "number of days" from physiological cutout (NAWF=5) to insecticide termination (NAWF5+350HU) and to defoliation (NAWF5+850HU) calculated.

RESULTS AND DISCUSSION

The effect of imposing an upper temperature limit on the heat-unit calculation is shown in Table 1 for two locations (Arkansas and Louisiana) and five treatments (potassium, nitrogen, boron, water stress, and temperature). The lower the "upper limit threshold," the longer it took to reach the two management stages (insecticide termination and defoliation). However, there was little or no effect above a threshold of 95°F. Also, treatment did not have much of an effect on the days to reach NAWF5 +350 or 850 heat units. This could be because the stresses were not all that severe. It would be of interest to include a mepiquat chloride (PIX) treatment in 2003.

When the "days to reach NAWF5+350HU" and "days to reach NAWF5=850HU" were averaged over location and treatment, it was evident that there was only a small effect (delay) of a few days on the time to insecticide termination, but a larger effect on the time to defoliation. For example, for an 85°F upper threshold it took an average of 2.2 days longer than no threshold at all to reach NAWF5+350HU, and 1.9 days for a 90°F threshold and no further delay above 95°F. The current heat unit calculation, therefore, may be predicting these two COTMAN end-of-season management decisions a little too early. Graphic displays of these trends (data not shown) suggest an upper temperature threshold for heat units of about 92°F.

PRACTICAL APPLICATION

Incorporating an upper threshold temperature in the heat unit calculation had a small effect on the number of days to physiological cutout (NAWF5+350 HU), i.e. 2.2 days longer (than the current method) for an 85°F limit, 1.9 days longer (than the current method) for a 90°F limit, and no further effect above 95°F. Use of an upper threshold temperature for defoliation (NAWF5+ 850HU) resulted in 6.4 days later (than the current method) for a 90°F limit and 7.8 days later (than the current method) for a 95°F limit. The suggested upper-temperature threshold for heat unit calculation is 92°F. However, before this is included in the COTMAN program, additional testing is needed, particularly on stressed cotton fields.

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Table 1. Effects of varying upper threshold temperatures (°F) in the calculation of heat units for determination of the number of days to insecticide termination and defoliation.

Study	Treatments	Days to NAWF 5+350				Days to NAWF 5+850			
		85	90	95	100	85	90	95	100
2001									
Arkansas									
Boron (Clarkedale)	High N	21	18	18	18	59	50	48	48
	Low N	21	18	18	18	59	49	47	47
KWS (Clarkedale)	High K	21	18	18	18	59	50	48	48
	Low K	21	18	18	18	59	49	47	47
Wildy Farms	Field 01	19	17	17	17	47	43	42	42
	Field 06	41	40	40	40	79	71	70	70
	Field 575	54	52	51	51	–[z]	–	–	–
Louisiana									
Water deficit	2" deficit	19	18	17	17	54	47	45	45
(St. Joseph)	3" deficit	41	40	40	40	79	71	70	70
	Tensiometer	19	18	17	17	54	47	45	45
	Non-irrigated	20	18	17	17	47	42	41	40
2002									
Arkansas									
Boron (Clarkedale)	Low N	20	18	17	17	65	49	45	45
	High N	25	23	23	23	–	–	64	64
KWS (Fayetteville)	High Dry K	21	19	19	19	59	54	53	53
	High Water K	21	19	19	19	71	56	56	56
	Low Dry K	21	19	18	18	59	52	50	50
	Low Water K	21	20	20	20	59	57	56	56
High Night Temp	Control	21	20	20	20	59	57	56	56
(Fayetteville)	Cool	21	20	20	20	59	57	56	56
	Heat	21	20	20	20	59	57	56	56

[z] NAWF 5+850 HU was not accumulated due to low temperatures in September.

[y] Improved for one week during the third week of flowering.

Table 2. Effects of varying upper threshold temperatures in the calculation of heat units for COTMAN determinations averaged over two locations and five treatments.

Threshold	Days to NAWF 5+350 HU[z]	Days to NAWF 5 + 850 HU
85	20.6	57.5
90	18.7	51.1
95	18.4	49.7
100	18.4	--[y]

[z] HU = heat units calculated as [(max temp < threshold) + min temp] - 60°F.
[y] Insufficient heat to accumulate 850 heat units.

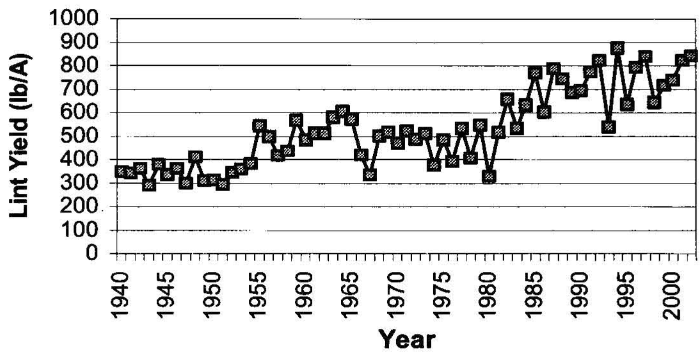

Fig. 1. Lint yield in Arkansas from 1940 to 2002.

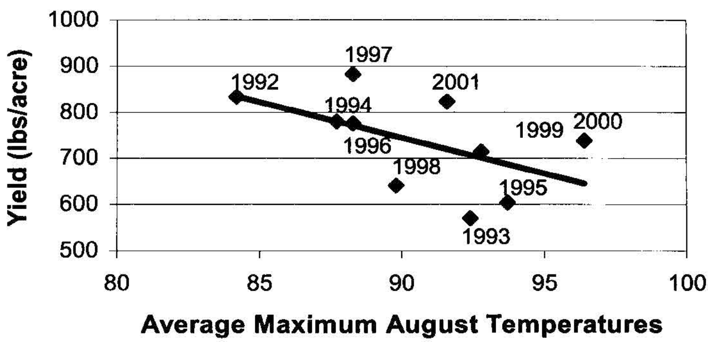

Fig. 2. Relationships between yield and average maximum temperatures in Arkansas in August from 1992 to 2000.

Defoliation Timing Based on Heat Units Beyond Cutout

William C. Robertson, Brian Weatherford, and Ray Benson[1]

RESEARCH PROBLEM

Timing of harvest aids continues to be a difficult decision for producers. Producers and crop advisors often are tempted to wait as long as possible for young immature bolls in the top of the plant to develop before making the decision to defoliate. These bolls are often insect damaged, small, and account for little additional gain, but the perception of additional harvestable lint is difficult to overcome. Validation of the heat unit (HU) concept of timing defoliation beyond the last effective boll population as defined by COTMAN would allow producers to make this decision with greater confidence and allow for an earlier harvest.

BACKGROUND INFORMATION

Traditional timings for defoliation include four or less nodes above cracked boll (NACB) and open bolls at 60% to 65% (Robertson, 2000). The crop status at the different timings indicates this to occur near 950 HU after physiological cutout (NAWF = 5) (Table 1). However, in practice grower standards tend to approximate 1050 HU. Average delays in defoliation from a timing of 850 HU to a standard of 1050 HU are approximately 12 days. This time delay is often enhanced in comparing harvest dates. Yield penalties are consistently observed with defoliation timings prior to 850 HU. Yields generally plateau between 850 and 1050 HU. Harvest losses due to rainfall events are primarily responsible for the yield plateau. Impact of the earlier defoliation on reducing micronaire of our most common cultivars grown, and the quality deterioration as a result of weathering with delayed harvest dates in a wet environment, can result in greater value (pounds lint X loan price) generated per acre.

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[1] Extension agronomist - cotton, and agronomy technician, Cooperative Extension Service, Little Rock; and research associate, Northeast Research and Extension Center, Keiser, respectively.

RESEARCH DESCRIPTION

The defoliation timing study was conducted over two consecutive years with locations in northeast, central, and southeast Arkansas. Replicated strips ran the length of the field and standard defoliation treatments were used at all locations. Dropp (0.1 lb prod./acre) + Def (0.5 pt. prod./acre) + Ethephon (5.3 oz prod./acre) followed by Ethephon (1 qt prod./acre) + Def (0.67 pt prod./acre) was used at each location and timing. Defoliation timings were scheduled on 750, 850, 950, and 1050 HU beyond cutout. The replicated strips were harvested with the producer's picker as each treatment became ready for harvest as weather allowed. Lint fraction, fiber quality, and loan values were determined from large samples, which were processed through a 20-saw gin with one lint cleaner. Loan values were calculated from HVI analysis. Value per acre was calculated by multiplying pounds of lint produced by the calculated loan value.

RESULTS

Defoliation at 750, 850, 950, or 1050 HU's after physiological cutout had no significant effect on yield or crop value. However, defoliation prior to 850 HU's resulted in lower yields and loan values. Also, loan values were greatest at the 850 HU timing. Defoliation at 850 HU resulted in numerically greatest returns per acre (Fig. 1).

PRACTICAL APPLICATION

Defoliation timing based on heat units beyond cutout is an effective and easy way of determining the most economical time to terminate the crop without suffering from yield loss and or discountable fiber qualities. The 850 HU timing allowed the crop to be terminated earlier and without yield loss in both years of the study on the most widely planted cultivars grown across Arkansas at the time. It is important to remember that as cultivars we grow change, especially with regard to maturity and fiber quality, these defoliation timings could likely change as well.

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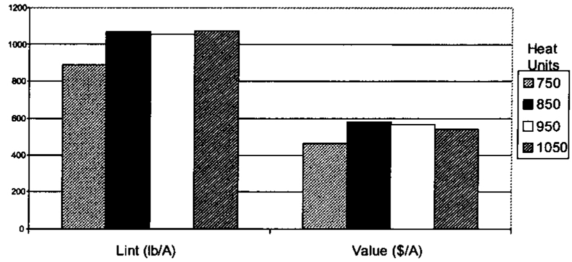

Fig. 1. Lint yield and value of crop per acre with harvest aid programs initiated at various heat units beyond cutout (2001-2002). Differences between treatments were not significantly different (P=0.05).

Table 1. Percent open bolls and NACB at various heat units beyond cutout (2001-2002).

	Heat units beyond cutout[z]			
Variable	750	850	950	1050
Percent open bolls	27	43	57	70
NACB	5+	4.5	3.3	2

[z] Physiological maturity at NAWF=5.

County-Based Early Warning Program for Micronaire Estimation Utilizing the Hal Lewis Procedure for Predicting Field Micronaire

William C. Robertson, Brian Weatherford, and Fred M. Bourland[1]

RESEARCH PROBLEM

The timing of defoliation is critical to insure optimum yield and fiber quality. The use of micronaire testing to determine the optimum time to defoliate can reduce the risk of discounts from high micronaire. A program such as the Hal Lewis method (Lewis, 1994) can be invaluable to producers in Arkansas to avoid discounts associated with micronaire.

BACKGROUND INFORMATION

Discounts associated with high micronaire are significant. It has been reported that producers lost about 100 million dollars to high micronaire discounts alone from the 2001 crop (Lewis, 2002). Approximately 25% of this loss was from the mid-South. A tool such as the Hal Lewis method is very effective in predicting the micronaire values by measuring that of the lowest four first-position open bolls and factoring in the proposed defoliation timing. This procedure can be very time consuming and sample collection must follow protocol exactly.

RESEARCH DESCRIPTION

The objective of this study was to determine whether the Hal Lewis method was consistent across various locations in northern, central, and southeast Arkansas and across cultivars at the same locations. Samples where collected from 93 fields with 13 different cultivars, which covered 12 counties in eastern Arkansas. Four areas from each field where sampled. Each sample was hand picked and consisted of all the open first-position bolls from the first four fruiting branches. Seed cotton was open, fluffed, and dry when picked for a sample. Eight plants were sampled from each of the four

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sample sites. Samples were ginned and classed for micronaire. Based on the micronaire from the results of the fiber analysis, a predicted micronaire was assigned to that field. Micronaire values were adjusted according to the procedures set forth in the Hal Lewis method based on temperatures during boll fill.

RESULTS

No significant differences were seen for the predicted micronaire versus the actual field micronaire across the locations sampled. Variability observed between 13 cultivars sampled did not vary significantly among one another or across location. The average of the 93 fields sampled were within 0.02 of the state's average of 4.60 from the 1.65 million bales harvested from 920,000 acres (Table 1). Micronaire in the discountable range of 5.0 to 5.2, and 5.3 and greater for the fields sampled was also comparable to the state's average. Location and cultivar were determined not to be a factor in predicting micronaire across the state.

PRACTICAL APPLICATION

The Hal Lewis method seems to be an effective tool that could be used across various regions in Arkansas. Samples collected from 93 fields with 13 different cultivars across 12 counties in Arkansas closely mirrored the cotton fiber quality of the state's 920,000 harvested acres with regards to micronaire as reported by USDA/AMS. The program provides great potential in identifying the levels of risks for high micronaire on a regional basis coupled with the widespread practice of monitoring NAWF for crop termination as a component of COTMAN. We hope to expand this program in 2003.

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Table 1. Comparisons of 93 fields sampled from 12 counties encompassing 13 cultivars to that of the 2002 state average for micronaire-related fiber quality parameters.

Parameter	Sampled fields	State average
Average micronaire	4.82	4.60
Discount range 5.0 to 5.2	10.34%	16.90%
Discount range 53. and greater	1.60%	4.00%

Examination of Production and COTMAN Records on a Large Arkansas Farm: A Foundation for Area-Wide Insect Management

R.G. Luttrell, Tina Gray Teague, Mandy McFall, Diana M. Danforth, David Wildy, Dale Wells, Clint Allen, Jeremy Greene, Gus Lorenz, and Patricia F. O'Leary[1]

RESEARCH PROBLEM

A detailed database of cotton production inputs, insect management histories, and COTMAN records for a large production farm in Arkansas was organized in a spatial format to explore entire-farm or area-wide approaches to insect management. Data were incorporated into an Access database and linked to ArcView spatially descriptive files. The spatially descriptive data were used to study 2002 insecticide use patterns and illustrate future applications of the information rich process to large management units. The evolving data management system is intended as a prototype for other area-wide or community management programs in Arkansas. Crop production information and spatially explicit data on insect distributions and crop damage will form the technological foundation for these expanded management approaches. As the information process matures, we intend to explore new educational and information delivery processes needed to implement improved management systems across large production areas.

BACKGROUND INFORMATION

Arkansas has a long history of innovative cotton insect management programs. Community-wide management systems conceived by J.R. Phillips and colleagues in the 1970s and 1980s (Cochran, 1996; Phillips et al., 1980) clearly founded the concept of

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entire-farm or community cooperation in targeted insect-management strategies. More recent advances in management capabilities, especially the ability to monitor crop stress through the COTMAN system (Danforth and O'Leary, 1998) and availability of spatially descriptive information-management systems, have created new opportunities to refine these entire-farm or community-management approaches.

Data mining and KDD (Knowledge Discovery in Databases) approaches to information collection are extremely popular concepts (Frawley et al., 1992). Numerous business groups, including a wide range of agricultural firms, are actively marketing new management systems at the farm level. Concepts of precision farming and geographic information management are practical, relevant components of today's cotton production environment.

Our historical involvement with simulation models (Luttrell et al., 1998) and the COTMAN management systems (Danforth and O'Leary, 1998) influenced our interest in the "data mining" concept and its potential use in refined approaches to community management of insect pests. More important, however, was our long-standing cooperation with Wildy Farms and their elaborate historical records of cotton production and COTMAN information.

RESEARCH DESCRIPTION

The current database includes seven years of production records, insect scouting information, and COTMAN archives. Wildy Farms created the original database in a Q&A format. We started our study with these original data sources and worked closely with the farmer and consultant to fill in data gaps and test general accuracy of information in the existing files. Information collected during 2002 was immediately incorporated into the system as a prototype example of data management capabilities and efficiency of "real time" data processing.

Insecticide spray histories for 107 different fields of Wildy Farms were studied relative to proximity to boll weevil overwintering sites and perceived quality of the overwintering sites. Each field was classified by an index of boll weevil hazard based on the product of the proximity index times the quality index (Fig. 1). Fields with higher hazard index rating were fields closer to high-quality overwintering sites. Fields with lower hazard index ratings were fields further from the high-quality overwintering sites. Proximity was grouped from 0-3 based on 0.25-mile distances from the identified overwintering sites. Habitat quality was a general rating of abundance of leaf litter, exposure, and general ground cover. Higher quality habitats were those with an abundance of ground litter and hardwood vegetation.

The distribution of the different tillage practices across the farm was captured in our spatial descriptions and used as an independent variable to study insecticide use patterns. Date of planting and crop physiological cutout (NAWF=5) were also obtained from the elaborate COTMAN records collected for each field on the farm and were used to explore relationships with insecticide use patterns.

Dependent variables included in the preliminary analyses were number of border sprays for boll weevil early in the season, total number of border and within season sprays for boll weevil, number of sprays for thrips, number of sprays for plant bugs, number of sprays for spider mites, number of sprays for bollworm, number of sprays for tobacco budworm, number of sprays for fall armyworm, total number of insecticide sprays, and days to crop cutout as measured by COTMAN (NAWF=5). A descriptive analysis of the different independent variables was conducted with information spatially registered on detailed maps of Wildy Farms. Correlation analyses were conducted to measure relationships among the different independent and dependent variables.

RESULTS AND DISCUSSION

Days to cutout was not generally related to insecticide use patterns. A significant negative correlation was observed between and tillage category. Tillage categories were 1 = conventional tillage, 2 = no tillage, and 3 = ridge tillage (no till plus cover crop). Date of planting was negatively correlated with proximity to overwintering sites, habitat categories, number of border sprays, and total sprays. Later planted fields tended to receive more insecticide sprays but the relationship was relatively weak and significant variability existed in the data. Date of planting was highly correlated with proximity to overwintering sites, habitat, and border sprays. Earlier planted fields tended to be those closer to preferred overwintering sites and those more likely to receive early-season border sprays for boll weevil suppression. Proximity to overwintering sites was highly correlated with habitat category, quality of the overwintering site, and number of border sprays. Habitat category was also correlated with number of sprays for spider mites and number of sprays for fall armyworm, suggesting a possible linkage between the border sprays for boll weevil and subsequent problems with these polyphagous pests.

Tillage had a major influence on the spectrum of insecticide sprays (Fig. 2). Lower tillage rankings (no tillage or minimum tillage practices) were associated with lower numbers of total insecticide sprays, especially those associated with boll weevil and tobacco budworm. Conversely, more sprays for thrips were associated with fields with conventional tillage fields.

Total number of insecticide sprays was associated with the number of sprays for all pest species except fall armyworm, which tended to be isolated cases associated with fields treated for plant bugs and tobacco budworm. Sprays for boll weevils, especially the border sprays early in the year, tended to be the most influential sprays in terms of influence on total insecticide usage. Of the 107 fields managed in 2002, 40 received two early-season border sprays and averaged 2.8 more sprays than the 67 fields not receiving early-season border sprays.

PRACTICAL APPLICATION

This compilation of production and COTMAN records for Wildy Farms and the initial use of 2002 data for studying insect use patterns represent a "data mining" application to real-world production agriculture. More efficient management of historical information will foster creative management approaches at the farm level. Our experiences with this project illustrate an "end of the season" analysis of production efficiency that will allow farm managers to develop site-specific management practices. A more refined system will eventually facilitate "real time" decision-making through rapid turnaround of the collected data. Our progress would not have been possible without the open cooperation and support of David Wildy, the farmer, and Dale Wells, the agricultural consultant.

ACKNOWLEDGMENTS

This research was possible through the generous support of Cotton Incorporated and the long-standing cooperation of Wildy Farms. The Arkansas Agricultural Experiment Station, Arkansas State University, and the University of Arkansas also contributed to the effort and are acknowledged for their encouragement of innovative management systems.

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Fig. 1. Classification of production fields relative to proximity and quality of boll weevil overwintering sites (index of 0-9 was a product of relative proximity to overwintering and relative quality of the defined habitat).

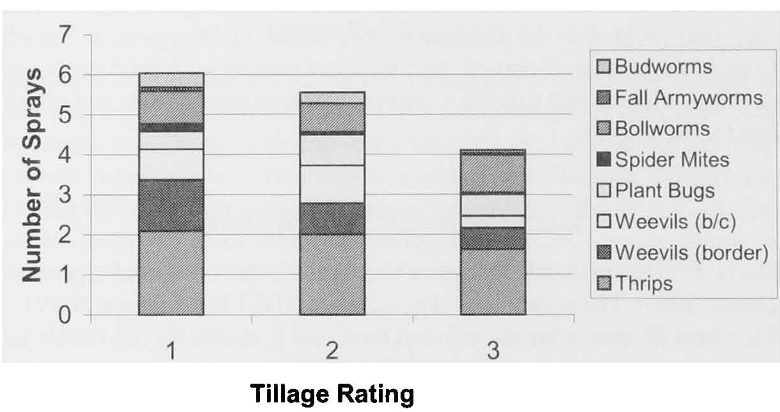

Fig. 2. Influence of tillage system on number of insecticide sprays.

Using Multispectral Imagery to Identify Stressed Cotton as a Means to Improve Cotton Profitability

Katy S. Sisk, Clint W. Jayroe, William H. Baker, Jennie H. Popp, Donald E. Plunkett, Terry L. Kirkpatrick, and H. Scott Styles[1]

RESEARCH PROBLEM

Arkansas State University, in cooperation with the University of Arkansas Extension Service, has implemented a study to assess opportunities to improve cotton profitability using multispectral imagery in conjunction with field observations. The State of North Carolina Center for Geographic Information and Analysis has indicated that a significant increase in overall accuracy can be achieved by combining topographic data with spectral data (Anon, 1994). In addition, this same group determined that classification of images proves to be a good source of data for the user to improve profitability (Anon, 1994).

The first objective of this study was to integrate airborne multispectral imagery with ground-truthed geographic information as a means to identify factors in cotton crop growth and development that can be correlated to stress. The second objective was to see if stressed areas could be identified and categorized into high, medium, and low classes that could offer the potential to save money for the growers. The effectiveness of combining remotely sensed, multispectral images with field-scouting data to develop variable treatments may do a better job of managing inputs and may be more profitable for the grower.

BACKGROUND INFORMATION

The NDVI (Normalized Difference Vegetation Index) was used to preclassify the image (Anon, 2000). The equation used to calculate NDVI is as follows: NDVI = (IR-R) / (IR+R), where IR stands for the infrared band and R stands for the visible red band.

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NDVI works by subtracting the intensity (DN value) of one band from another on a pixel-by-pixel basis. Then, a value is obtained by dividing by the sum of the values of the pixel in each band of data. The resulting index value of a pixel typically ranges from around 0.1 to 0.6 for vegetation (the higher the value, the denser the vegetation).

For better understanding, images are generally classified to group and identify specific crop class features, such as stressed and non-stressed areas. Classifications are needed to reduce the data from a potential of 256 divisions down to three divisions used to form manageable groups of crop productivity (stress). ArcView, the GIS software used in this study (ESRI, Redlands, CA), uses the ISODATA (Iterative Self-Organizing Data Analysis) algorithm, a set number of iterations with a convergence threshold to categorize (classify) image data. ISODATA conducts a categorization of single or multiband continuous data to create a thematic data layer. ISODATA is called self-organizing (unsupervised) because groups of data are created with little input from the user (the user determines how many classifications should be used). The convergence threshold is a percentage that represents pixels that do not change the class they are assigned to between iterations of the ISODATA technique. This threshold determines the minimum percentage that must be met before the categorization is performed, while the iteration parameter keeps it from running indefinitely.

Image enhancing provides meaning to the image data by using tools that redistribute the image data. A useful enhancement, the histogram-equalize enhancement, stretches to the image data across the range of values (256) that makes up the image to better fit the dynamic range of the display. Enhancement allows the user to change the brightness and contrast of the image. A stretch enhancement will generally increase the visual contrast of the raster (image).

RESEARCH DESCRIPTION

Image Enhancement

Vegetative conditions and insect infestations were observed in each training area. Field data were recorded with a GPS unit, and geo-spatial data were mapped in ArcView. Image processing (histogram equalize) was used to enhance the image contrast to reveal areas where cotton was stressed. The histogram enhancement was utilized as the true map (true image) to assess the quality of the ISODATA classification based on the weekly field observations (ground-truthing) by the cotton verification coordinator.

Image Classification

Since there is a potential of 256 divisions (the maximum number of digital values represented in 8-bit computer encoding), the enhanced image needed to be reduced to fewer, more workable numbers of classes. Prior work suggested that the ISODATA algorithm needed to group the data into 7 classes. This accurately depicted the zones

of cotton reflectance observed in the enhanced image (true map). Pre-classification was performed using the NDVI calculation, which was based on the red (550-580 nm) and near-infrared (800-830 nm) bands. The ISODATA algorithm was then used to reduce the image data from the results of the NDVI calculation. As mentioned above, 7 classes were found to best represent the crop productivity illustrated by the enhanced image (true map). The 7 classes were then reduced to 3 categories: high, medium, and low stress based on ground-truthed information in training areas depicted by the histogram equalize-enhanced image. The location of the cotton fields and the dates the imagery was acquired for each field are listed in Table 1.

These images were obtained with a Duncan Tech multispectral high-resolution camera (Duncan Tech, Inc., Auburn, CA). This camera delivers high-quality pixel-registered 24 or 30 bit images at up to 30 frames per second. Each image consisted of three separate bands, which consisted of wavelengths from 550 nm to 800 nm (Table 2).

RESULTS AND DISCUSSION

The classification process was driven by comparing the presence and richness of green hues in the enhanced image with the classified image. In the enhanced image (McClendon loation, Fig. 1; data for Dodds and Ramey sites not shown), the green to dark-green pixels were grouped together and found to represent higher productivity areas (low stress) based on field observations. Light-green to white pixels were found to represent medium-low stress areas. Intermediate hues were found to represent medium stress. The darker pixels represent the high-stress areas (low productivity). Overall, this corresponded well to the vitality of the cotton plants based on the scouting activities in the training sites. The first attempt at classification was with twenty-four classes. The second attempt was with twelve classes. The final attempt was with 7 classes, which was found to be the best match for each field in this study - the findings held true to the enhanced image (true map). The 7 classes were then recombined into a total of 3 categories to describe plant stress: high, medium, and low. The low-stress area denoted that the cotton was productive or rank. The lightest color was assigned to this low category. The light gray color was assigned to the medium category, and the darkest color was assigned to the high -stress category.

The study fields contained numerous soil mapping units and soil features. This soil variability was a strong contributor to the observed plant stress (Table 2). The high-stress areas in the McClendon field were due to poor drainage. The high-stress areas in the Dodds field were due to the clay lenses in the field, which also resulted in poor drainage. The high-stress areas in the Ramey field were correlated to sand intrusions (Crevasse soil) and moisture stress in the field. Overall, differences in the growth rate appeared to have been due to differences in water stress in various parts of the fields.

Table 3 shows the budget savings for each field using a variable rate approach based on a 3 category system. Budgets from the University of Arkansas Extension Service were researched to determine the profitability of the three fields discussed (Bryant and Windham, 2003). The low-stress (high productivity) areas received a full

rate of the application, medium-stress areas received a half rate, and the high-stress areas (low productivity) did not receive any inputs. The variable rate application saved each grower approximately $34 on the McClendon field, $31 on the Dodds field, and $22 on the Ramey field.

The image classification results demonstrated that a significant increase in overall accuracy can be achieved by combining scouting data with spectral information. The enhanced image proved to identify the stressed areas well. This information would allow a farm manager or grower to locate the identified infestations in a field, and apply a more measured amount of pesticides.

PRACTICAL APPLICATION

Image information can provide growers with a more cost-effective method of controlling insects by improving the placement and timing of pesticide applications. Thus, the grower does not have to spray an entire field at one rate. This system allows growers to vary the coverage and therefore allows less chemical usage and money spent. This information can also be used to allocate resources more efficiently, address crop growth problems, and, perhaps, improve the profitability of their farm operation. Growers, consumers, and the environment as a whole benefit.

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Table 1. Dates the images were acquired and the location of each field.

Field name	Date	Location
McClendon field	30 August 2002	Lee County
Dodds field	30 August 2002	Lincoln County
Ramey field	28 July 2002	Mississippi County

Table 2. Soil mapping units and description for the McClendon, Dodds, and Ramey study sites (Lee County Soil Survey, 1977).

McClendon	
Calhoun	Poorly drained; formed in thick deposits of loess
Calloway 0-1% slopes	Poorly drained; formed in thick deposits of loess
Calloway 1-3% slopes	Poorly drained; formed in thick deposits of loess; erosion has removed some of original surface layer
Commerce silt loam	Poorly drained; in lower part of levees; formed in loamy sediments
Commerce soils	Frequently flooded; between the levee and the Mississippi River
Convent	Poorly drained; on alluvial fans at the foot of Crowley's Ridge; formed in loamy sediments
Grenada	Moderately well drained; formed in thick deposits of loess
Henry	Poorly drained; formed in thick deposits of loess
Hillemann	Poorly drained; formed in thick deposits of loess
Jeanerette	Poorly drained; formed in sediments similar to loess but are of uncertain origin
Lagrange	Poorly drained; formed in moderately thick loamy deposits
Loring	Moderately well drained; formed in sediments washed from loess
Zachary	Poorly drained; formed in sediments washed from loess
Dodds	
Portland	Poorly drained; very slowly permeable; formed in thick beds of fine textured, slack water deposits from Arkansas river
Rilla	Well drained, moderately permeable; on terraces and natural levees of former channels of Arkansas river
Ramey	
Alluvial land	Soil material deposited along the Mississippi River
Amagon	Sandy and silt loam; formed in loamy alluvium in levees that border stream channels
Convent	Poorly drained; on alluvial fans at the foot of Crowley's Ridge; formed in loamy sediments
Crevasse	Excessively drained; formed in sandy alluvium in levees
Hayti	Poorly drained; formed in loamy alluvium in the lower part of levees

Table 3. Costs of conventional and variable rate application for the McClendon study site (UACES Cotton, Furrow Irrigation, Loamy Soils, Boll Weevil Eradication, Budget for Southeast Arkansas, 2003).

		Conventional	Variable rate application					
		Total field acres	Low stress acres	Med stress acres	High stress acres			
		55.32	16.25	25.92	13.15			
Item	Cost per acre	a Total cost	b Full rate cost	c Half rate cost	d Zero rate cost	e Total cost b+c+d	Total savings a - e	Savings per acre
Mehpiquat cl	12.48	690.39	202.80	161.74	0	364.54	325.85	
Ethephon	14.86	822.06	241.48	192.59	0	1270.98	373.13	
Def or Folex	7.50	414.90	121.88	97.20	0	641.48	188.33	
Dropp	5.80	320.86	94.25	75.17	0	496.07	145.64	
Pyrethroid	11.00	608.52	178.75	142.56	0	940.83	276.21	
Tracer 4L	23.12	1279.00	375.70	299.64	0	1977.45	580.54	
Total	74.76	4135.72	1214.85	968.89	0	2246.02	1889.70	$34.16

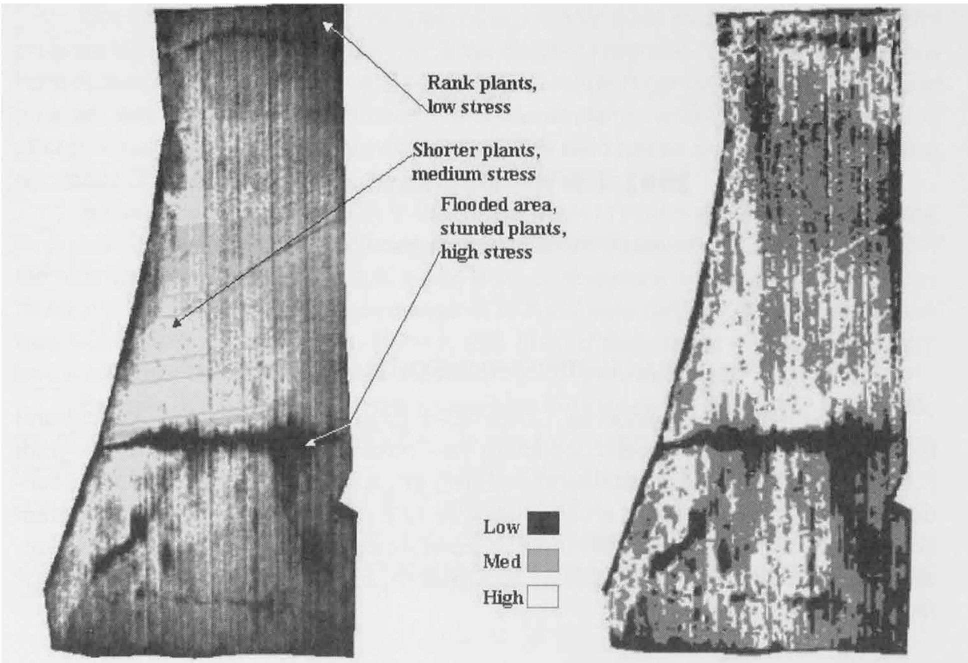

Fig. 1. The enhanced image (true map) and the classified image of the McClendon study site.

2002 CRVP Demonstrations

Donald E. Plunkett, William C. Robertson, and Kelly J. Bryant[1]

BACKGROUND INFORMATION

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. The program began its twenty-third year in 2002 as a broad-scale demonstration of not only production practices but timing of pesticide applications, irrigation, and utilization of new technologies.

RESEARCH DESCRIPTION

There were nine fields enrolled in the 2002 CRVP demonstrations. Eight of the fields were irrigated. One field utilized center pivot irrigation and the other seven were furrow irrigated. The fields were located from Chicot-Mencer in the southern part of the state to Mississippi-Ramey in the northeast part of the state. All but one of the fields utilized a Roundup Ready cotton cultivar. The one conventional cultivar field utilized the PSC 355 cultivar. Other varieties used were DP 451 B/R, ST 4793, SG 215 B/R, and PM 1218 B/R.

General field information regarding location, acres per field, planting date, variety, yield, and soil type is included in Table 1. Field size ranged from approximately 37 acres in Jefferson County (Bonds) to 86 acres in the Chicot-Mencer field. The average field size was about 54 acres for the eight irrigated fields. The most diverse soils were those in the Mississippi-Ramey field. Blowing sand from the fine sandy loam portions of the Mississippi County field was justification for recommending a wheat cover crop program as a deterrent to sandblasting of cotton seedlings after emergence in 2002.

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The Lincoln-Dodds field also had a mix of soil types in the field, and growth of the crop varied according to the soil diversity.

The Jefferson-Sites field was carried as a CRVP field in 2002 as part of a pilot program initiated within existing research verification programs. This pilot program has been dubbed the "Integrated Crop Research Verification Program (ICRVP)." This pilot program was started because of a need to demonstrate to certain farmers the benefits of crop rotation for suppressing certain pests; this field has an infestation of reniform nematode (RN) and corn is a good non-host crop for this pest.

A number of the CRVP fields in 2002 were noted to have some level of nematodes, with root knot nematode (RKN) being more dominant than the reniform nematode. Of the nine fields enrolled, seven had some level of nematode according to soil assays taken in the fall of 2001. The highest number of RKN were noted in the Chicot-Mencer field followed by the Mississippi-Ramey field. Each of these fields were shown to have levels well over the treatment threshold of 250 RKN per pint of soil.

Because of a collaboration with researchers William Baker and Terry Kirkpatrick, remote sensing of eight of the CRVP fields was performed in late summer 2002. This remote imagery seemed to correspond to field-truth data collected through the normal process of data collection in the CRVP demonstrations.

All CRVP fields were sampled for micronaire using the Hal Lewis method (Lewis, 1994) of early sampling. This early warning system was used in an effort to enhance timing of defoliation.

RESULTS AND DISCUSSION

Yield and quality factors are the most commonly reported results cotton producers have been taught to examine. The weighted average yield for all nine fields was computed to be 1030 lb/acre with a high of 1165 lb lint /acre and a low of 724 lb lint/acre for irrigated fields. The non-irrigated field had a final yield of almost 1025 lb lint/acre.

Color Grade

Color grade information is presented in Table 2. Of the 1036 total bales from all fields, over 95% graded 41 and better. Almost 18% of the bales graded 31 and better even though fall rains were frequent from mid-September through final harvest in November.

Staple

Short staple (33) occurred on less than four percent of all bales. Approximately 96% of all CRVP bales measured greater than a 34 staple length (Table 3).

Micronaire

High micronaire bales – measuring greater than 5.0 – were evident in just over 15% of all bales (Table 4). Of the high micronaire bales, 100% of the Lee-McClendon bales (PM 1218 BG/RR variety) measured over 5.0. This field was defoliated at 70% or higher open boll, which could have contributed to the high micronaire problem.

Strength

Strength (Table 5) was good in most fields with over 95% of all bales averaging greater than 25.5 g/tex. About 14% 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

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. Actual quantities of all operating inputs as reported by the cooperators were used in this analysis. The prices used for these inputs were the same as those reported in the "2002 Cost of Production Estimates" published by the Cooperative Extension Service. If an input was used whose price was not published, a price quote was obtained from a supply dealer.

Fuel and repair costs for both machinery and irrigation equipment were calculated using a budget generator based on parameters and standards published in the American Society of Agricultural Engineers 1993 Handbook. Therefore, the producers' actual machinery costs will vary from the machinery cost estimates that are presented in this report. However, the producers' actual field operations were used as a basis for calculations and his equipment size and type were matched as closely as possible to the existing data set used in the annual set of state crop budgets.

Direct expenses for the eight irrigated CRVP fields ranged from $266.36/acre for Mississippi County to $454.60/acre for Jefferson County 2 and averaged $319.43/acre. Direct expenses per pound of lint ranged from $0.24 in Mississippi County to $0.55 in Poinsett County and averaged $0.34/lb.

Fixed Expenses

The fixed expenses category in Table 6 represents the cost of owning and using farm equipment. These costs can vary greatly from one farm to another depending on the farm size, management skills, and annual use. The fixed expenses presented in

Table 6 include depreciation and interest. These costs are based on estimated initial cost and expected useful life of machinery similar to that used by the producer. Ownership costs were allocated on a per-acre basis using estimated performance rates and hours of annual use. Calculations were made by using a budget generator based on parameters and standards published in the American Society of Agricultural Engineers 1993 Handbook. These are economic costs and may differ from short-run tax based cash accounting figures for a particular year. The economic approach spreads these costs over the entire useful life of the machinery. In the long run, the farm business must cover these costs to remain viable. Fixed expenses for the eight irrigated fields ranged from $44.23/acre for Phillips County to $112.48/acre for Mississippi County and averaged $82.54/acre. High fixed expenses can be the result of numerous trips across the field, twice-over picking, and/or center-pivot irrigation. Using custom operators rather than owning equipment replaces fixed expenses with direct expenses (custom work). Counties with high Fixed Expenses but low Custom Work Expenses probably used high-clearance sprayers for insecticide, growth regulator, and/or defoliation treatments instead of using custom aerial application.

Total Specified Expenses

Since fixed costs can be substituted for direct cost and vice versa, 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. The overhead and management costs would be better addressed in a whole-farm analysis and will not be dealt with in this discussion. Total specified expenses per acre for the eight irrigated fields ranged from $378.84 for Mississippi County to $553.81 for Jefferson County 2. Total specified expenses per pound of lint ranged from $0.34 to $0.66 and averaged $0.42 for the eight irrigated fields.

Land Costs

Land costs incurred by producers participating in the Cotton Research Verification Program would likely vary from land ownership, cash rent, or some form of crop-share arrangement. Therefore, a comparison of these divergent cost structures would contribute little to this analysis. For this reason, a 25% crop-share rental arrangement with no cost sharing was assumed. 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.

Table 6 presents the cost of production per pound of lint after 25% of the yield is given to the landlord. These break-even prices ranged from $0.45/lb in Mississippi County to $0.88/lb in Poinsett County. The average cost of production for the nine fields (non-irrigated included) was $0.55/lb.

PRACTICAL APPLICATION

Second-Year Pilot Program – ICRVP

The grid soil testing performed in the Jefferson-Sites field after a year of corn (RVP) in 2001 indicated a 90% or higher reduction in reniform nematode populations. After one year back to cotton (RVP) in 2002, the reniform counts escalated greatly with a high of over 16 times the high level from the previous fall. This validates the recommendation to rotate fields infested with reniform nematodes to non-host crops like corn. We believe this also validates a recommendation to place these highly infested fields in a one-to-one crop rotation program so that corn follows cotton in an every-other-year rotation.

First-Year Pilot Programs

Remote Sensing

There seems to be a high probability that remote sensing of CRVP fields can validate weak zones of fields that may be stressed due to soil type, lack of proper irrigation, or nutrient deficiencies. The correlation to soil type differences is easily noted when viewing aerial imagery and comparing to ground-truth data such as grid soil-test data. For imagery to review, contact the author(s) and ask for a CD of the 2002 Annual CRVP Report.

Micronaire – Early Warning (pilot) Project

This pilot demonstration allowed cooperators in the CRVP who had early warning of potential for high micronaire problems to defoliate early or on time to aid in reducing the number of high-mic bales. Harvest data indicated about 15% of all CRVP bales had high micronaire. One hundred percent of the Lee-McClendon bales high miked; this field was not defoliated before 70% open boll. Surprisingly one-third of the Jefferson-Bonds bales also high miked as did approximately ten percent of the Lincoln-Dodds bales.

Although weather conditions caused early-season growth delays and some replanting in CRVP fields, a moderate weather pattern coupled with frequent rainfall during July and August aided in fruit retention and boll development on most fields. There were some insect situations that caused added expense to both conventional (non-Bt cotton) and varieties with the Bt gene. In the final analysis of yield and quality for all bales, there was an above-average quality with white grades much more evident than would have been expected due to the frequent rains that fell during boll opening. Yields were above the 5-year norm for CRVP fields and averaged over two bales per acre.

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 were lower than the average cost of production of all fields. The economic information

shown in Table 6 would indicate there is a need for higher market prices for cotton to enable producers to remain viable for the next crop year.

The pilot programs of ICRVP, Remote Sensing, and Early Warning – Micronaire have shown to be effective tools and more work should be done with these concepts to enhance the CRVP program's overall objective of bringing new technology and techniques to producers.

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Plunkett, D.E., W.C. Robertson, and K.J. Bryant. 2002 Cotton research verification program annual report. University of Arkansas, Cooperative Extension Service, Little Rock, AR.

Table 1. Irrigated and non-irrigated field information, 2002 CRVP program,

County	Acres	Cultivar	Date of planting	Yield	Soil series
				(lint/acre)	
Chicot-Mencer	86	DP 451 B/RR	4-24-02	1165	Hebert and Crowley silt loam
Crittenden-Sharp	48.75	SG 215 BG/RR	5-24-02	1026	Dubbs silt loam, Jeanerette silt loam
Jefferson-Bonds	37.5	DP 451 B/RR	4-23-02	1119	Hebert and Rilla silt loams
Jefferson-Sites	46	PSC 355	5-16-02	1070	Roxanna and Rilla silt loam
Lee-McClendon	55.8	PM 1218 BG/RR	5-21-02	972	Jeannerette silt loam; Marvell fine sandy loam; Zachary soils, frequently flooded
Lincoln-Dodds	56	DP 451 B/RR	4-26-02	1156	Rilla silt loam; Perry clay
Mississippi-Ramey	73.5	ST 4793 R	5-3-02	1111	Hayti series (fine loamy sand), Amagon sandy loam, Crevasse loamy sand
Phillips-Hargraves	55	DP 451 B/RR	5-16-02	754	Convent silt loam
Poinsett-Craig	38	ST 4793 R	5-16-02	724	Sharkey-Steele complex

Table 2. Color grade, 2002 CRVP, total bales.

	Grade							
County/cooperator	21	31	32	41	42	51	52	53
Lincoln-Dodds	0	105	0	23	0	5	0	0
Mississippi-Ramey	0	30	1	130	2	1	0	0
Jefferson-Sites	0	1	0	92	0	3	1	0
Jefferson-Bonds	0	21	0	62	1	0	0	0
Chicot-Mencer	0	16	0	190	0	3	0	0
Poinsett-Craig	0	0	0	46	11	0	0	0
Lee-McClendon	0	12	1	87	6	0	0	0
Crittenden-Sharp	0	0	0	100	0	2	0	0
Phillips-Hargraves	0	3	0	73	8	0	0	0
Total	0	188	2	803	28	14	1	0

Table 3. Average staple length, all bales, 2002 CRVP demonstrations.

	Staple					
County	32	33	34	35	36	37
Chicot-Mencer	0	0	1	68	128	12
Crittenden-Sharp	0	11	61	29	1	0
Jefferson-Bonds	0	0	0	3	39	42
Jefferson-Sites	0	0	1	8	52	36
Lee-McClendon	0	0	0	106	0	0
Lincoln-Dodds	0	1	8	92	32	0
Mississippi-Ramey	0	1	0	163	0	0
Phillips-Hargraves	0	0	1	14	48	21
Poinsett-Craig	0	27	30	0	0	0
Total	0	40	102	483	300	111

Table 4. Average micronaire values, all bales, 2002 CRVP demonstrations.

	Micronaire		
County	<3.5	3.5-4.9	>5.0
Chicot-Mencer	0	200	9
Crittenden-Sharp	0	102	0
Jefferson-Bonds	0	56	28
Jefferson-Sites	0	93	4
Lee-McClendon	0	0	106
Lincoln-Dodds	0	119	14
Mississippi-Ramey	0	164	0
Phillips-Hargraves	0	84	0
Poinsett-Craig	0	57	0
Total	0	875	161

Table 5. Average strength, all bales, 2002 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
Chicot-Mencer	5	32	62	74	24	9	3
Crittenden-Sharp	43	36	17	4	1	0	1
Jefferson-Bonds	0	0	3	11	31	26	13
Jefferson-Sites	0	0	1	14	25	35	22
Lee-McClendon	0	0	12	66	28	0	0
Lincoln-Dodds	0	25	49	46	13	0	0
Mississippi-Ramey	0	1	0	54	95	14	0
Phillips-Hargraves	1	0	5	33	32	11	2
Poinsett-Craig	0	0	0	0	42	15	0
Total	49	94	149	302	291	110	41

Table 6. Estimated costs per acre and breakeven prices: 2002 Cotton Research Verification Program.

Item	Chicot 87 acres	Crittenden 48.75 acres	Jefferson 1 37.5 acres	Jefferson 2 46 acres	Lee 55.8 acres	Lincoln 56 acres	Mississippi 74 acres	Phillips 55 acres
	($/acre)							
Direct expenses								
Crop seed	12.70	15.24	12.70	24.96	13.33	12.70	14.12	32.60
Custom work	23.75	28.25	21.58	33.89	8.00	21.50	21.50	103.70
Fertilizer and lime	34.60	32.32	46.92	44.04	38.81	46.52	41.57	47.59
Fungicide and seed treatments	11.69	0.00	4.00	14.84	0.00	0.00	4.00	4.00
Growth regulators	13.64	9.92	6.20	17.36	6.20	9.92	11.16	12.40
Harvest aids	21.82	22.51	22.70	12.76	16.27	15.66	22.90	23.47
Herbicides	33.82	32.27	38.54	53.36	39.46	43.46	22.51	40.72
Insecticides	49.73	21.99	33.90	99.43	32.24	29.33	38.41	33.14
Misc. labor				6.23	0.00	0.00	0.00	0.00
Misc. irrigation	5.75	0.00	5.75	5.75	5.75	5.75	0.00	5.75
Technology fees	69.00	67.40	69.00	35.00	65.70	69.00	8.80	45.60
Operator labor	11.57	12.52	13.66	18.23	15.00	17.46	12.70	10.15
Irrigation labor	1.91	0.00	1.27	0.63	0.42	1.75	0.24	0.79
Diesel fuel	24.77	14.50	23.75	26.20	18.91	33.53	24.24	15.15
Repairs and maintenance	31.41	29.22	33.79	46.93	33.03	40.32	36.37	13.76
Interest on operating capital	12.55	9.84	12.67	14.99	9.89	12.37	7.84	13.05
Total direct expenses	358.71	295.98	346.43	454.60	303.01	359.27	266.36	401.87
Total fixed expenses	71.34	56.28	79.55	99.21	79.45	92.59	112.48	44.23
Total specified expenses	430.05	352.26	425.98	553.81	382.46	451.86	378.84	446.10
Per acre yield	1165	1026	1119	1070	972	1156	1111	754
Breakeven price over:								
Direct expenses	0.31	0.29	0.31	0.42	0.31	0.31	0.24	0.53
Total expenses	0.37	0.34	0.38	0.52	0.39	0.39	0.34	0.59
Total expenses and rent	0.49	0.46	0.51	0.69	0.52	0.52	0.45	0.79

APPENDIX I

STUDENT THESES AND DISSERTATIONS IN PROGRESS IN 2002

Agudelo, Paula. A study of the diversity of geographic populations of reniform nematodes in the cotton growing areas of the U.S., and observations on compatible and incompatible reactions with cotton. (PhD., advisor: Dr. Robbins, co-advisor: Dr. Stewart).

Antoine, Wesner. Genotype independent transformation of cotton with Agrobacterium. (M.S., advisor: Dr. Stewart).

Arevalo, Milenka. Effects of night temperatures on boll growth and yield, and determination of upper temperature thresholds for improving COTMAN management decisions. (M.S., advisor: Dr. Oosterhuis).

Branson, Jeffrey. Characterization and utilization of CGA 362622 for broadleaf weed control in cotton. (M.S., advisor: Dr. Smith, co-advisor: Dr. Barrentine)

Brown, Robert S. The dynamics of dry-matter partitioning in the cotton boll of modern and obsolete cotton cultivars. (Ph.D., advisor: Dr. Oosterhuis).

Coker, Dennis. Effect of water deficit on potassium partitioning and the efficiency of foliar-applied potassium in cotton. (Ph.D., advisor: Dr. Oosterhuis).

Conway, Hugh. Development of cotton aphid threshold that incorporates natural enemies. (Ph.D., advisor: Dr. Kring).

Coy, Steven. Crop response to fleahopper and tarnished plant bug injury in pre-squaring cotton. (M.S., advisor: Dr. Teague).

Dighe, Nilesh. Hybridization of exotic germplasm as the first step in transfer of resistance to reniform nematode in upland cotton. (M.S., advisor: Dr. Stewart).

Fairbanks, Mike. Evaluation of thrips resistance in cotton cultivars. (Ph.D., co-advisors: Dr. Kring and Dr. Johnson).

Groves, Frank. Biology and control of *Cyperus esculentus* in cotton. (M.S., advisor: Dr. Smith, co-advisor: Dr. Barrentine).

Hornbeck, James. Variation in trichomes on cotton bracts, stems, and leaves. (M.S., advisor: Dr. Bourland).

Jayroe, Clint. Acquisition of multispectral imagery on Arkansas CRVP fields. (M.S., advisor: Dr. Baker).

Malo, Juan P. Risk-returns of major Arkansas field crop counties. (M.S., advisor: Dr. Parsch).

Meek, Cassandra. Physiological and molecular characterization of cotton (*Gossypium hirsutum* L.) genotypes in response to water-deficit stress. (PhD., advisor: Dr. Oosterhuis, co-advisor: Dr. Stewart).

Robertson, William. Potential economic benefits of soil electrical conductivity (EC_a) field maps. (M.S., advisor: Dr. Baker).

Sparks, Oscar. Weed and heliothine-complex management in transgenic cotton. (Ph.D., co-advisors: Dr. Barrentine and Dr. Burgos).

Studebaker, Glenn. Impact of early-season cotton insecticides on predators. (Ph.D., advisor: Dr. Kring).

Yates, Chuck. Alteration of cotton plant stress dynamics by feeding of the tarnished plant bug. (M.S., advisor: Dr. Tugwell).

APPENDIX II

RESEARCH AND EXTENSION 2002 COTTON PUBLICATIONS

CHAPTERS IN BOOKS

Khan, M.A., G.O. Myers, and J. McD. Stewart. 2002. Molecular markers, genomics, and cotton improvement. Pp. 252-284. *In:* M.S. Kang (ed.). Crop Improvement: Challenges in the twenty-first century. Haworth, NY.

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ABSTRACTS

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