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Summaries of Arkansas Cotton Research 2006

Derrick M. Oosterhuis

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Summaries of Arkansas Cotton Research 2006



Edited by Derrick M. Oosterhuis

ARKANSAS AGRICULTURAL EXPERIMENT STATION
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**SUMMARIES OF
ARKANSAS COTTON
RESEARCH 2006**

Edited by Derrick M. Oosterhuis

**University of Arkansas Division of Agriculture
Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701**

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PREFACE

An average of 1,045 lb lint/acre for Arkansas in 2006 was the second highest yield recorded for the state. The highest was in 2004 in which an average of 1,114 lb lint/acre was produced. Arkansas producers have harvested in excess of 1,000 lb lint/acre the last three seasons. These per-acre yields are surpassed only by those of Arizona and California. A record 2.525 million bales of cotton were picked from 1.16 million acres. Arkansas ranked second in the nation for total cotton production for the second year in a row behind Texas.

In 2006, early planting began in earnest by the middle of April. Dry conditions became a limiting factor as planting continued through April. As a result, cotton emergence was not uniform. Cool temperatures and wet conditions at the end of April delayed planting in most fields. Replanting was common for 1 May-planted cotton. By late-May, temperatures rebounded and remained above average for the season (Fig. 1). Most of the state endured droughty conditions while the extreme northeast area of the Delta received timely rainfalls. Irrigation typically began in mid-June and continued through late-August. Fruit retention was extremely high, while insect pressure was considered to be light in 2006. Frequent irrigation and rising fuel prices were responsible for making the 2006 cotton crop one of the most expensive ever produced in Arkansas. Although daytime temperatures were high during boll fill, excessive nighttime temperatures were not experienced. Nighttime temperatures were lower than the long-term average (see Fig. 1) and this may have contributed to the high yields.

Many of the Cotton Research Verification fields had over 85% retention at cutout. Growing conditions improved after cutout, resulting in a more vigorous plant than normally encountered at boll maturation, thus the boll opening process was slowed. The value of COTMAN was realized by many producers as a decision aid for defoliation timing. Although the crop had reached 850 heat units beyond physiological cutout and boll slicing revealed a mature crop, many fields were only 20 to 35% open. Defoliation was initiated and fields were harvested 10 to 14 days before those fields defoliated at 50 to 60% open.

Bill Robertson and Derrick Oosterhuis

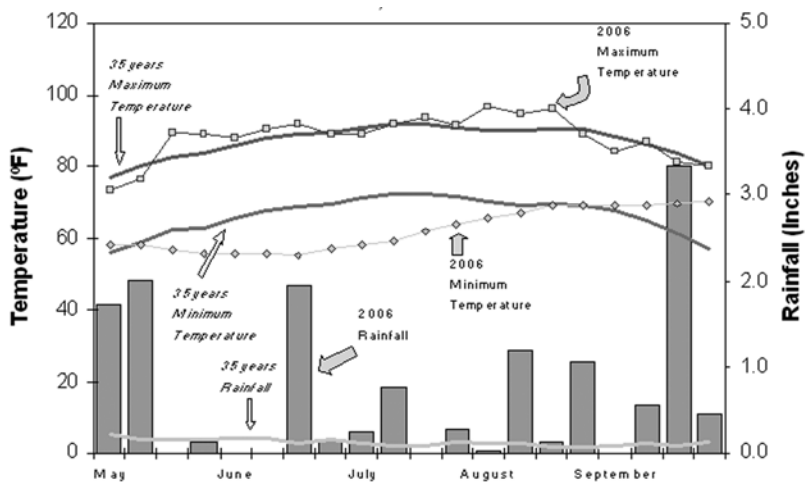


Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2006 compared with the long-term 35-year averages in eastern Arkansas.

ARKANSAS COTTON RESEARCH GROUP

2006/2007

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 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: Don Alexander, Fred M. Bourland, Frank Groves, Gus Lorenz, Gene Martin, Robert McGinnis, Derrick M. Oosterhuis (Chmn.), Bill Robertson, Craig Rothrock, James M. Stewart, and David Wildy.

Pest Management: Terry L. Kirkpatrick, Gus Lorenz, Randy Luttrell, Jason Norsworthy, Bill Robertson, Craig Rothrock (Chmn.), Kenneth L. Smith, Don Steinkraus, Glenn Studebaker, and Tina Teague.

Production: Sreekala Bajwa, Kelly Bryant, Mark Cochran, Leo Espinoza, Dennis Gardisser, Frank Groves, Robert Hogan, Gus M. Lorenz, J. Scott McConnell, Morteza Mozaffari, Jason Norsworthy, Derrick M. Oosterhuis (Chmn.), Lucas Parsch, Bill Robertson, Daniel Stephenson, and Phil Tacker.

Genetics: Fred M. Bourland, Hal Lewis, Bill Robertson, and James M. Stewart (Chmn.).

ACKNOWLEDGMENTS

The organizing committee would like to express 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 2006* has been published with funds supplied by the Arkansas State Support Committee through Cotton Incorporated.

Cotton Incorporated's mission is to increase the demand for cotton and improve the profitability of cotton production through promotion and research. The Arkansas State Support Committee is comprised of the Arkansas Directors and Alternates of the Cotton Board and the Cotton Incorporated Board, and others whom they invite, including representatives of Certified Producer Organizations in Arkansas. Advisors to the Committee include certain staff members of the University of Arkansas, the Cotton Board, and Cotton Incorporated. Seven and one-half percent of the grower contributions to the total Cotton Incorporated budget are allocated to the State Support Committees of the cotton-producing states. The sum allocated to Arkansas is proportional to the states' contribution to the total U.S. production and value of cotton fiber over the past five years.

The Cotton Research and Promotion Act is a federal marketing law. The Cotton Board, based in Memphis, Tennessee, administers the act, and contracts implementation of the program with Cotton Incorporated, a private company with its world headquarters in Cary, North Carolina. Cotton Incorporated also maintains offices in New York City, Los Angeles, Mexico City, Osaka, Singapore, and Shanghai. Both the Cotton Board and Cotton Incorporated are not-for-profit companies with elected boards. Cotton Incorporated's board is comprised of cotton growers, while that of the Cotton Board is comprised of both cotton importers and growers. The budgets of both organizations are reviewed annually by the U.S. Secretary of Agriculture.

Cotton production research in Arkansas is supported in part by Cotton Incorporated directly from its national research budget and also by funding from the Arkansas State Support Committee from its formula funds (Table 1). Several of the projects described in this series of research publications, including publication costs, are supported wholly or partly by these means.

Table 1. Arkansas Cotton State Support Committee / Cotton Incorporated Funding 2006.

Projects	Researcher	Short title	\$ Funding
02-291AR	Oosterhuis	Cotton Research Summaries	\$6,500
04-439AR	Kirkpatrick	Reniform nematode biology-Ark.	\$18,488
04-440AR	Oosterhuis	Temperature effects on yield	\$18,000
04-442AR	Oosterhuis	PGR effects on Bt translocation	\$2,950
04-443AR	Oosterhuis	Early-season low temperatures	\$15,300
04-444AR	Robertson	Late-planted cotton	\$16,790
04-445AR	Robertson	Technology transfer	\$25,130
04-447AR	Smith	Glyphosate-resistant horseweed	\$18,661
04-470AR	Bourland	Yield components	\$26,130
04-476AR	Baker	Remote sensing - stress	\$23,814
04-477AR	Robertson	Sub-surface drip irrigation	\$15,570
04-491AR	Lorenz	Stink bugs in BGII cultivars	\$13,000
04-492AR	Teague	Irrigation X insects	\$19,823
05-630AR	Cochran	Profitable N & K fertilization	\$34,114
05-631AR	Baker	Remote sensing - scouting	\$8,549
05-632AR	Savage	Liberty-Link vs. Roundup Flex	\$16,000
05-634AR	Robertson	Defoliation timing	\$19,140
06-797AR	Lorenz	Plant bug thresholds	\$21,520
TOTAL			\$319,479

**SUMMARIES OF
ARKANSAS COTTON RESEARCH
— 2006 —**



UNIVERSITY OF ARKANSAS

DIVISION OF AGRICULTURE

University of Arkansas Cotton Breeding Program - 2006 Progress Report

Fred M. Bourland

RESEARCH PROBLEM

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

BACKGROUND INFORMATION

Cotton breeding programs have existed at the University of Arkansas since the 1920s (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and possess good host plant resistance traits. Bourland (2006) provided the most recent update of the current program.

RESEARCH DESCRIPTION

Each year, breeding lines and strains are tested at multiple locations in the University of Arkansas Cotton Breeding Program. 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 individual plants. Once 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 and evaluated in replicated strain tests at multiple Arkansas locations to determine yield, quality, host plant resistance, and adaptation properties. Superior strains are subsequently evaluated

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¹ Director, Northeast Research and Extension Center, Keiser.

over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm or cultivars. Bourland (2004) described the selection criteria presently being used.

RESULTS

Breeding Lines

A primary focus of breeding-line crosses in 2006 was to combine lines having enhanced yield components and fiber characteristics. Additionally, transgenic forms of Arkot lines were crossed with lines possessing nectariless, frego bract, or high-glanding traits. In 2006, 28 new crosses, 26 F_2 populations 16 F_3 populations, 16 F_4 populations, 1051 first year progeny, and 192 advanced progeny were evaluated. Bolls were harvested from superior plants in F_2 and F_3 populations and bulked by population. A total of 55 F_2 transgenic plants (after discarding for fiber quality and absence of transgenes) and 649 plants (after discarding for fiber quality) from F_4 populations was selected and will be evaluated as progeny in 2007. Also, 228 superior F_5 progeny were advanced, and 72 F_6 advanced progeny were promoted to strain status.

Strain Evaluation

In 2006, 108 strains were evaluated in replicated strain tests at multiple locations. Within each test, strains were compared to standard cultivars (DP 393 or PSC 355 and SG 105). Based on their performance, 36 of the strains were selected and entered into 2007 New and Advanced Strain Tests. Superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality. The 2006 New and Advanced Strains were tested for host plant resistance (i.e., to tarnished plant bug, bacterial blight, fusarium wilt, root knot nematode) and resistance to seed deterioration. Selected lines were evaluated in regional strain tests and the 2006 Arkansas Cotton Variety Test.

Germplasm Releases

Germplasm releases are a major function of most public breeding programs. In 2006, the Arkansas Agricultural Experiment Station released seven cotton germplasm lines that were developed by this breeding program. These included Arkot 9304a, Arkot 9304b, Arkot 9308, Arkot 9314, Arkot 9506, Arkot 9513, and Arkot RM24. The first four are lines that possess the high-glanding trait (gossypol glands in all parts of the calyx), which provides some insect resistance. All of the lines are worthy or near-worthy of cultivar status relative to yield, fiber quality, and host plant resistance.

PRACTICAL APPLICATION

Genotypes that possess enhanced host plant resistance, improved yield and yield stability, and good fiber quality are being developed. Improved host plant resistance

should decrease production costs and risks. Selection based on yield components may help to identify and develop lines having improved and more stable yield. Released germplasm lines 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.

ACKNOWLEDGMENTS

Support for this research was provided by Cotton Incorporated and the Division of Agriculture, University of Arkansas.

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Development of the COTVAR Variety Selection Program

Fred M. Bourland and D.C. Jones

RESEARCH PROBLEM

Other than variation in transgenic technologies and seed treatment, costs of cotton planting seed are relatively constant. However, choosing the best cotton variety to plant can often determine whether the producer experiences a successful production year. The producer must assume that past performance of varieties is a good predictor of future performance. Generally, the best cotton variety to plant in the forthcoming year is the one that performs best over a wide range of environments. A computer program is needed to summarize variety test data from multiple states.

BACKGROUND INFORMATION

The advent of transgenic varieties, increased number of seed suppliers, and rapid turnover of varieties has provided growers a greater choice and the opportunity to choose a more productive variety. However, sorting through the large number of varieties has become very difficult. The task of sorting becomes even more daunting when a grower tries to compare results from different states. State Cotton Variety Trials have been conducted in approximately 15 states for decades. The results are published and made available in hard copy. On-line delivery of data has recently become available to growers. However, growers need a user friendly and customized delivery approach to allow comparisons to be made that are most relevant to them. The COTVAR variety selection program is a product that makes this a reality.

RESEARCH DESCRIPTION

Programming of COTVAR began in 2006 and came on-line in February 2007. Currently, COTVAR includes state variety test data from five states (Arkansas, Louisiana, Mississippi, Missouri, and Tennessee) for 2004 through 2006. Locations were

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¹ Director, Northeast Research and Extension Center, Keiser; and program director, Cotton Incorporated, Cary, N.C., respectively.

coded, grouped into regions, and described with regard to soil type, irrigation, and GPS coordinates. A total of about 30 test sites per year with up to four experiments per test site is included.

Varieties were uniformly coded over locations then described relative to status (available, experimental line, or obsolete) and status (multiple transgenes, single transgene, or conventional). Mean data for lint yield, lint percentage, height, open boll percentage, seed index, lint index, seed per acre, leaf pubescence rating, fiber length, uniformity, micronaire, and strength were recorded. Also, a quality index (Q-score) was calculated by assigning different weights to normalized values of four fiber parameters. The Q-score may vary from 0 to 100, with higher values indicating lines with fiber quality that should meet market demands.

Programming of COTVAR has been done via the University of Arkansas Cooperative Extension Service initially by Chalmers Davis and then completed by Becky Bridges.

RESULTS AND DISCUSSION

Screens generated by the COTVAR program include:

1. Opening page. Introduction to COTVAR with hyperlinks to variety testing Web sites (Arkansas, Louisiana, Missouri, Mississippi, and Tennessee) and to Cotton Incorporated.
2. Step 1. Select year. As presently structured, the user must access one year at a time. The three most recent years are available as options.
3. Step 2. Select variety status. Each variety is characterized as being commercially available, experimental line, or obsolete. The user may select any or all status categories. Hyperlinks to the status categories are provided. Seed companies periodically update the status of their varieties.
4. Step 3. Select variety type. Each variety is characterized regarding transgenes as possessing multiple traits, single traits or none (conventional). The user may select any or all type categories. Hyperlinks to the type categories are provided.
5. Step 4. Select variety test locations. The user may select regions or choose to go to the next screen to pick specific sites. Use of multiple locations is encouraged.
6. Step 4, screen 2. All test locations are listed from north to south by state and region within states. Soil type, whether irrigated, and GPS coordinates of locations are listed. The user may pick any number of specific locations to be summarized.
7. Step 5. Select varieties for comparison. All varieties for status and type chosen are listed in the left column. The additional columns list experiments for states chosen and provide the number of locations where each variety was evaluated. Varieties are then sorted by number of variety by experiments (high to low), so the most frequently tested varieties are listed first. The user may then chose up to five varieties to compare.
8. Step 6. Output screen 1. Average yield, lint fraction, quality score, and fiber properties for selected varieties over all test locations are given, along with number of test sites used in calculations. Hyperlinks may be accessed to define the parameters.

9. Step 7. Output screen 2. Yields (as percentage of experiment means) for the chosen varieties are listed for each chosen test site. The sites are sorted by average experimental means from high to low. This chart allows the user to see how consistent the varieties performed at the different locations, and how they may have performed at relatively high and low yielding sites.
10. Step 8. Output screen 3. Additional parameters are listed for the selected varieties. These parameter means are not specific to the chosen test sites, but are averages over all sites where data for the parameters are recorded.

PRACTICAL APPLICATION

COTVAR may be accessed at <http://cotvar.uaex.edu/Intro.asp> and is available to anyone. COTVAR is not a substitute for variety test publications, but is useful to summarize variety test data. As such, it should be helpful to producers and to seed companies. Work has been initiated to establish data files for all other states that conduct cotton variety tests. Prior to incorporating these additional data into COTVAR, we will: 1) establish and assign a region to each test location, 2) develop descriptive information on test locations, 3) confirm variety names and determine variety status for varieties not in current variety list, and 4) make changes to programming to include the additional states and regions.

ACKNOWLEDGMENTS

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Radiation Use Efficiency of Cotton in Two Contrasting Environments

Evangelos D. Gonias, Derrick M. Oosterhuis, and Androniki.C. Bibi

RESEARCH PROBLEM

Yield variability in cotton (*Gossypium hirsutum* L.) from year to year in different environments (geographical locations) is a major production problem for farmers (Oosterhuis, 2002). Higher yields have been recorded in the drier environment of California, compared to the more humid environment of Arkansas. However, the effect of environmental factors, such as temperature, relative humidity, and vapour pressure deficit, on the radiation use efficiency in cotton have not been described for contrasting environments.

BACKGROUND INFORMATION

Crop growth (accumulation of dry matter) depends mainly on the amount of intercepted radiation and the time allowed for growth (Sinclair and Muchow, 1999). The effectiveness of a crop to convert intercepted radiation to dry matter is called radiation use efficiency (RUE), and is defined as the amount of dry matter produced (g) per unit of radiation intercepted (MJ) by the crop canopy. Monteith (1977) described this correlation as linear. Reported values of RUE for different cotton cultivars range from 1.31 to 1.92 g•MJ⁻¹ of intercepted photosynthetic active radiation (PAR)(Pinter et al., 1994; Rosenthal and Gerik, 1991; Sadras and Wilson, 1997). Reduced values of RUE at higher vapour pressure deficits (VPD) have been documented for crops other than cotton. For sorghum and corn, RUE values based on PAR decreased with increasing VPD with a slope of 0.65 and 0.85 g•MJ⁻¹•kPa⁻¹, respectively (Stöckle and Kiniry, 1990).

RESEARCH DESCRIPTION

To determine the effect of environmental factors on RUE, field studies were established in Marianna, Ark. (Cotton Branch Station, University of Arkansas) and

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Fresno, Calif. (Campus Farm, California State University, Fresno). In both locations the cotton cultivar DP444 was used. The studies included two plant populations (5 and 10 plants/m²) established two weeks after planting with five replications. Management practices were used as recommended for each location.

RUE was estimated by the slope of the increase in dry matter over the accumulated intercepted radiation. Dry matter was determined, at the pinhead square growth stage (PHS), first flower (FF), and three weeks later (FF+3), by collecting plant samples from 1 m² ground area. Intercepted radiation was calculated by multiplying the incident radiation (measured by a weather station located at the edge of the field) with the fraction of intercepted radiation. The light interception by the crop canopy was measured weekly, starting at PHS, by measuring photosynthetic active radiation above and below the canopy in unobstructed sunlight, close to solar noon, using a LI-191S line quantum-source quantum sensor (Li-Cor, Lincoln, Neb.).

RESULTS AND DISCUSSION

Although the study in Fresno, Calif., showed higher daily productivity of dry matter than in Marianna, Ark., the RUE in Fresno was lower (Table 1). The RUE was calculated as 1.771 g•MJ⁻¹ of intercepted PAR at Marianna and 1.353 g•MJ⁻¹ in Fresno. The higher values of productivity in Fresno can be attributed to higher amounts of incident and intercepted PAR between PHS and FF+3 compared to Marianna.

The environmental conditions between PHS and FF+3 for both locations are summarized in Table 2. It is apparent that Fresno had higher day temperatures and lower night temperatures, and lower relative humidity than Marianna. In addition, vapour pressure deficit values were lower for Marianna than for Fresno (Fig. 1). The lower values of RUE in Fresno can be explained by the higher values of VPD compared to Marianna.

PRACTICAL APPLICATION

Although higher yields have been reported in drier environments, such as California, than in the more humid environment of Arkansas, this study described higher RUE in Arkansas. However, dry matter production, as measured by daily crop productivity, was higher for California, possibly due to the larger amount of incident and intercepted radiation. As in the case of crops other than cotton, high values of vapour pressure deficit appear to decrease the efficiency of the crop to convert radiation energy to dry matter.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Radiation use efficiency, productivity, heat units, and intercepted radiation at the two locations of the study recorded between PHS and FF+3.

Location	RUE (g•MJ ⁻¹)	Productivity (g•m ⁻² •d ⁻¹)	Heat units	Intercepted radiation (MJ•m ⁻²)
Marianna, Ark.	1.771	11.6	902	261.8
Fresno, Calif.	1.353	17.4	982	443.2
LSD _{0.05}	—	3.39	—	47.31

Table 2. Mean values of environmental factors at the two locations of the study recorded between PHS and FF+3.

Location	VPD (kPa)	High temperature (°C)	Low temperature (°C)	Relative humidity (%)	PAR (MJ•m ⁻²)
Marianna, Ark.	1.212	33.70	21.30	67.50	10.12
Fresno, Calif.	2.183	37.20	19.30	43.70	13.61
LSD _{0.05}	0.142	1.19	1.21	2.17	0.90

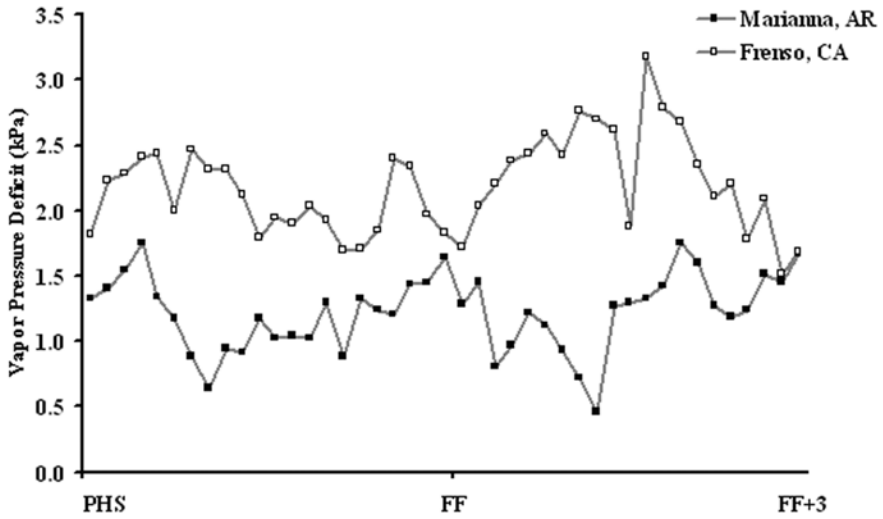


Fig. 1. Daily values of vapor pressure deficit between PHS and FF+3 for Marianna, Ark., and Fresno, Calif.

Effect of Plant Growth Regulators on Radiation Use Efficiency of Cotton

Evangelos D. Gonias, Derrick M. Oosterhuis, and Androniki.C. Bibi¹

RESEARCH PROBLEM

Plant growth regulators (PGRs) are a common and widely used input in cotton production for controlling plant growth, increasing yield, and improving management efficiency. Most of the PGRs used have an effect on plant growth, both vegetative and reproductive, and on dry matter partitioning. However, there have been no reports of effects of PGRs on radiation use efficiency (RUE). It is logical to assume that any chemical that affects canopy dynamics will change the RUE of the crop. The objective of this study was to quantify the effect of PGRs on the RUE of cotton.

BACKGROUND INFORMATION

The amount of intercepted radiation and the time allowed for growth determines the accumulation of dry matter (Sinclair and Muchow, 1999). Dry matter production (g) per unit of intercepted radiation (MJ) can be defined as the effectiveness of the crop to convert intercepted radiation to dry matter. This correlation has been described as linear (Monteith, 1977) and the slope is the RUE of the crop. Reported values of RUE for different cotton cultivars range from 1.31 to 1.92 g•MJ⁻¹ of intercepted photosynthetic active radiation (PAR)(Pinter et al., 1994; Rosenthal and Gerik, 1991; Sadras and Wilson, 1997).

RESEARCH DESCRIPTION

The study was conducted at the University of Arkansas Agricultural Research and Extension Center, in Fayetteville, Ark. For the calculation of RUE, the dry weight of the crop and the amount of intercepted radiation are required. Dry matter was determined, at the pinhead square growth stage (PHS), first flower (FF), and three weeks later (FF+3), by collecting plant samples from 1 m² ground area. The light interception

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by the crop canopy was measured weekly, starting at PHS, by measuring photosynthetic active radiation above and below the canopy in unobstructed sunlight, close to solar noon, using a LI-191S line quantum-source quantum sensor (Li-Cor, Lincoln, Neb.). Intercepted radiation was calculated by multiplying the incident radiation, measured by a weather station located next to the field, with the fraction of intercepted radiation. Treatments were applied with a backpack CO₂ sprayer calibrated to deliver 10 gal/acre and consisted of (1) untreated control, (2) mepiquat chloride at 8 oz/acre at PHS, PHS+10, and FF, and (3) Chaperone™ at 5 oz/acre at PHS+10 and FF.

RESULTS AND DISCUSSION

While the crop productivity was not significantly different between treatments, RUE values appeared to be higher for the mepiquat chloride treatment than the untreated control and the Chaperone treatment. At the end of the study (FF+3) the Chaperone treatment had a significantly higher fraction of light intercepted (Fig. 1); however, no differences were observed in total intercepted PAR between PHS and FF+3 (Table 1). Mepiquat chloride applications had a significant effect on plant height and leaf area at FF (Table 2) and at plant height at FF+3 (data not shown).

PRACTICAL APPLICATION

This research suggests that radiation use efficiency of cotton can be potentially changed after application of PGRs. The production of dry matter is determined by the amount of intercepted radiation by the crop canopy and the efficiency with which the light energy is converted to organic compounds. Increase in the amount of intercepted radiation, as with Chaperone, or increase in the efficiency of energy conversion, as with mepiquat chloride, may increase dry matter production and yield of cotton.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Sinclair, T.R. and R.C. Muchow. 1999. Radiation use efficiency. Adv. Agron. 65:216-265.

Table 1. Effect of PGRs on radiation use efficiency, productivity, and intercepted radiation of cotton recorded between PHS and FF+3.

Location	RUE (g•MJ ⁻¹)	Productivity (g•m ⁻² •d ⁻¹)	Intercepted radiation (MJ•m ⁻²)
Untreated control	2.438	13.57	184.70
Mepiquat chloride	2.701	14.61	187.08
Chaperone	2.478	14.78	215.29
LSD _{0.05}	—	NS ^z	NS

^z NS = not significant (P = 0.05).

Table 2. Effect of PGRs on growth parameters measured at first flower.

Location	Height (cm)	Dry weight (g•m ⁻²)	LAI
Untreated control	85.18	352.71	2.54
Mepiquat chloride	72.59	282.56	1.98
Chaperone	84.25	339.53	2.51
LSD _{0.05}	6.03	42.68	0.31

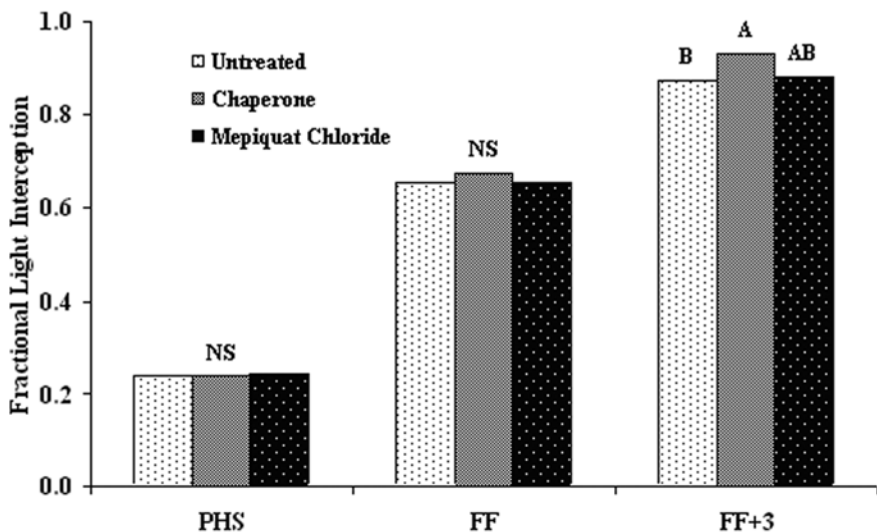


Fig. 1. Fraction of light intercepted at PHS, FF, and FF+3. Columns within a growth stage with different letters are significantly different (P=0.05).

Physiological Response of Okra- and Normal-Leaf Cotton Isolines at Two Temperature Regimes

Evangelos D. Gonias, Derrick M. Oosterhuis, and Androniki.C. Bibi¹

RESEARCH PROBLEM

Variations in leaf shape range from highly divided leaves (okra leaf) to normal-leaf shape (Meredith, 1984). Heitholt et al. (1992) described higher yields of okra-leaf isolines for a given amount of intercepted radiation, indicating that the okra-leaf types utilized more efficiently the intercepted radiation than the normal-leaf types. However, information on physiological parameters of the cotton isolines that can explain the differences in radiation utilization is limited.

BACKGROUND INFORMATION

The variation in cotton leaf shape results in differences in canopy architecture and light interception characteristics (Wells and Meredith, 1986). The okra-leaf cotton compared to normal-leaf types has been characterized by smaller leaf-area per leaf (Heitholt et al., 1992), reduced leaf-area index (Kerby et al., 1980), and less but sufficient vegetative growth (Wells and Meredith, 1986). In a three-year experiment, okra-leaf cotton produced more lint yield than the normal-leaf isoline, while normal-leaf type had higher seasonal light interception (Heitholt, 1994). The same author reported that the okra-leaf isoline had greater yields at plant populations above 10 plants/m and lower yields at leaf-area indices below 4.0, while the normal-leaf type had higher yields at 5 plants/m and lower yields at leaf-area indices above 5.0. In addition, higher canopy CO₂ uptake (Kerby et al., 1980) and higher single-leaf photosynthesis (Pettigrew et al., 1993) have been reported for okra-leaf type cotton.

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RESEARCH DESCRIPTION

The study was conducted at the University of Arkansas Agricultural Research and Extension Center, in Fayetteville, Ark., using two large growth chambers (Model P36, Conviron, Winnipeg, Canada). The normal- and okra-leaf isolines of the cotton cultivar FM832 (provided by Dr W.R. Meredith, USDA) were planted in twelve 2-L pots containing Sunshine mix (Sun Gro Horticulture Distribution Inc., Bellevue, Wash.) in each of the two growth chambers. The plants were grown in day/night temperature regimes of 30/20°C and watered with half-strength commercially available Peter's nutrient solution (Spectrum Group, St. Louis, Mo.) as necessary. At the pinhead square stage of growth the temperature regime of one chamber was changed to 38/20°C. Measurements taken a week later included leaf photosynthesis (PN), chlorophyll fluorescence yield test (FL), membrane leakage (ML), SPAD, and specific leaf weight (SLW). All measurements were recorded close to midday on the uppermost, fully expanded main-stem leaf located four nodes below the terminal of the plant. The study was statistically analyzed as a two factors (temperature and isolines) factorial using JMP 6.0.2.

RESULTS AND DISCUSSION

No statistically significant interaction between temperature and isolines was observed for all the parameters measured (Table 1), indicating that both isolines reacted physiologically the same at the two temperature regimes. Increasing the day temperature from 30°C to 38°C significantly decreased leaf photosynthesis (Fig. 1) and chlorophyll fluorescence, as well as membrane leakage ($P=0.057$). The decrease in membrane leakage might be explained by potentially higher wax accumulation on the leaf surface due to the prolonged temperature stress. Isolines had a statistically significant effect on SPAD with the okra-leaf isoline having higher value than the normal-leaf. Specific leaf weight did not significantly differ between both temperatures and isolines.

PRACTICAL APPLICATION

The results of this study indicate that the two isolines responded similarly at the two temperature regimes. Although leaf photosynthesis and chlorophyll fluorescence were reduced under temperature stress, the isolines did not significantly differ. The more efficient utilization of intercepted radiation reported for other cotton isolines is possibly due to canopy architecture characteristics and not due to differences in physiological parameters.

ACKNOWLEDGMENTS

The authors thank Dr. W.R. Meredith for supplying the cotton isolines. Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. P-values for the main effects and interactions of temperature and isolines for the physiological parameters measured.

	PN ^z	FL	ML	SPAD	SLW
Temperature	0.002	0.035	0.057	0.320	0.149
Isolines	0.277	0.234	0.121	0.001	0.228
Temperature* isolines	0.963	0.793	0.551	0.522	0.523

^z PN = leaf photosynthesis; FL = chlorophyll fluorescence; MS = membrane leakage; SPAD = an estimate of chlorophyll; and SLW = specific leaf weight.

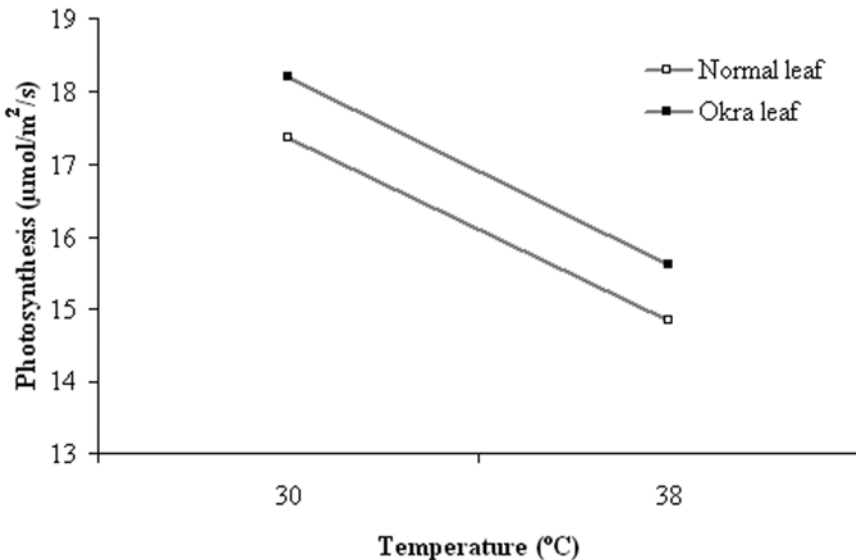


Fig. 1. Effect of temperature on leaf photosynthesis of the two cotton isolines.

Effect of High Night Temperatures on Cotton Gas Exchange and Carbohydrates

Dimitra Loka and Derrick M. Oosterhuis¹

RESEARCH PROBLEM

The unpredictability of cotton yields is a great concern to the cotton industry. The five-year average yield for cotton in the U.S. is 718 lb lint/acre, whereas the theoretical maximum lint yield is 3720 lb lint/acre (Hesketh and Baker, 1969). High temperatures are considered to be one of the main environmental factors contributing to variable yields in cotton. This is apparently due to a negative effect on respiration and carbohydrate accumulation. Yield comparisons between areas with the same day temperatures and different night temperatures have shown that the areas with higher night temperatures have lower yields. In this study it was hypothesized that high night temperatures have a negative effect on cotton photosynthesis and respiration that results in a significant loss of carbohydrates and ultimately in a yield decrease.

BACKGROUND INFORMATION

U.S. cotton production suffers from extreme and unpredictable year-to-year yield variability that has been attributed to genetics, management practices, and unfavorable weather conditions (Robertson, 2001). High temperatures are considered to be the main environmental factor contributing to variable yields (Oosterhuis, 1994), but limited information exists on the effects of high night temperature on cotton growth and yield (Bibi et al., 2006). Although cotton originates from hot climates, the ideal temperature range for its growth is between 20° and 30°C (Reddy et al., 1991) with the optimum being 28°C (Burke et al., 1988). However, at higher temperatures, as often experienced in the U.S. Cotton Belt, plant metabolism and photosynthesis decrease dramatically compromising the reproductive efficiency of the crop.

Additionally, reports in the literature suggest that high night temperatures cause respiration rates to increase resulting in further depletion of carbohydrates and yield reduction (Arevalo, 2005). This suggestion is supported by comparisons of yield and

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temperature regimes in Arkansas and Greece (Oosterhuis, 2000). Greece has comparable production systems, with similar day temperatures but lower night temperatures than Arkansas especially during the boll development period, and produces nearly fifty percent more lint yield per acre than Arkansas.

Most reported studies of the effects of night temperature on growth do not involve solely the night temperature as a contributing factor to yield compromise; i.e. when night temperature increased so did the day temperature, making it impossible to determine the effect of increased night temperature alone. Therefore, the objective of this study was to quantify the immediate effect of high night temperatures on gas exchange and carbohydrate accumulation.

RESEARCH DESCRIPTION

Two growth chamber studies were conducted in September and October 2006 at the Altheimer Laboratory, University of Arkansas. The cotton (*Gossypium hirsutum* L.) cultivar DP444BR was planted into 2-L pots containing Sunshine horticulture mix. The growth chambers were set for two 12-h photoperiods with day/night temperatures of 30°/20°C. Half-strength Hoagland's nutrient solution was applied daily to maintain adequate nutrients and water content. A completely randomized block with two replications was used.

For the first experiment (September, 2006), three night temperature regimes were imposed (20°, 25°, and 28°C) starting at pinhead square with 3-day intervals between each temperature regime. The experiment was repeated under two day temperatures (30° and 35°C) with the same night temperature regimes. Respiration measurements were taken daily at 10 p.m. on each plant using the fourth main-stem leaf from the terminal with LICOR-6200 infra-red gas analyzer (LICOR Inc., Neb.).

For the second experiment (October, 2006), plants were divided into two groups at pinhead square. One night temperature regime was imposed on the treated group (28°C) for three days, while the control plants remained under the normal temperature regime (30°/20°C). The antioxidant Glutathione was measured from fresh fourth-position main-stem leaves sampled at 5 a.m. The samples were stored at -80°C prior to being extracted and analyzed with a Biospec-1601 enzyme analyzer using the method of Anderson et al. (1992).

RESULTS AND DISCUSSION

The results were unexpectedly variable with no clear trend of the effects of high night temperature on respiration during the night or photosynthesis the following day (data not shown). There appeared to be an increase in photosynthesis with increased day temperature, but no clear effect from increased night temperature. There was also no clear effect on plant carbohydrate status (data not shown). This lack of effect on gas exchange and carbohydrates may have been because of the short duration of the temperature treatment. Arevalo et al. (2005) showed that a stress period greater than two weeks duration is needed to cause a significant effect on yield.

High night temperature was shown to significantly ($\alpha=0.2$) increase the activity of the antioxidant enzyme glutathione (Fig. 1). This indicates that the plant was experiencing stress and the increased antioxidant levels were to detoxify the plant of excessive, harmful free radicals. However, there was no obvious effect on gas exchange that we hypothesized should have been detrimentally affected by the high night temperature. This study will be repeated with a longer duration of high night temperature, similar to what would be experienced in the field, and thereby hopefully ensure a measurable effect on gas exchange as well as plant stress.

PRACTICAL APPLICATION

High night temperature was shown to have a stressful effect on the plant that elicited an increase in antioxidant enzyme activity. However, the short duration of high night temperature had little or no effect on gas exchange and carbohydrates and therefore on expected yield. The study will be repeated with longer periods of high night temperature.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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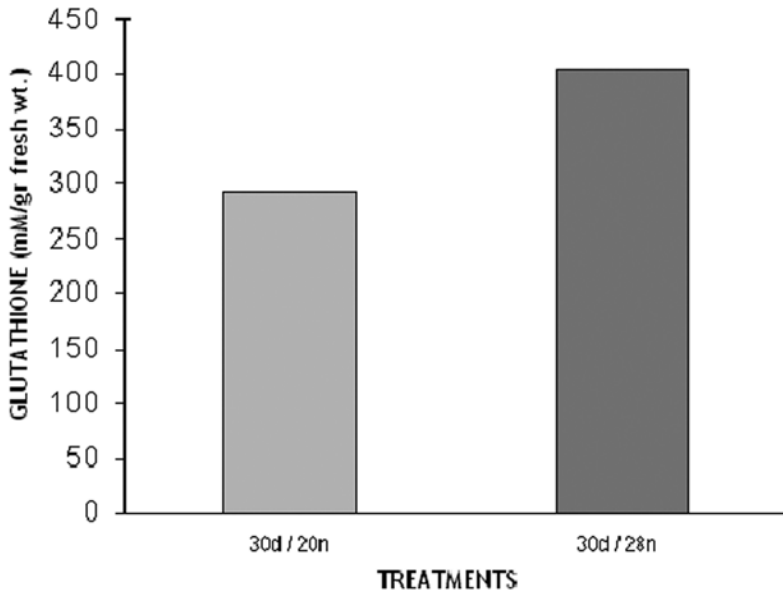


Fig. 1. The effect of night temperatures of 20°C and 28°C on the antioxidant enzyme glutathione. The plants were grown at 30/20°C (day/night) temperatures until pinhead square, after which the night temperature was increased (20°C and 28°C) for three days at each temperature with the day temperature of 30°C remaining the same. Measurements were taken the next day for each temperature regime.

Comparison of Boll Internal Temperatures with Ambient Temperatures for Calculation of Heat Units to Determine Defoliation Timing

Derrick M. Oosterhuis, Evangelos D. Gonias, and Androniki C. Bibi¹

RESEARCH PROBLEM

The heat unit concept is an integral part of the COTMAN crop monitoring program for predicting the time after physiological cutout (NAWF=5) to terminate insecticides and to defoliate. However, some controversy and skepticism have arisen about the accuracy of the accumulated heat units rule (i.e., 850 HU's after NAWF=5) to determine when to defoliate. This is because the time to accumulate 850 heat units for timing defoliation for optimal yields has varied tremendously from year to year. It has been suggested that the actual temperatures of the developing bolls in the canopy may not be closely represented by ambient temperatures measured in a meteorological site. The results should help to verify the reliability of the current method of timing defoliation or provide information to fine tune this method.

BACKGROUND INFORMATION

Accurate measurements of boll temperatures are required for determinations of the effects of high temperature on fiber growth and yield development. However, research on internal boll temperatures is limited. Anderson (1940) reported that internal temperatures of cotton bolls during the day may be 6 to 8°C higher than ambient temperature. Chu and Henneberry (1992) investigated the influence of ambient temperature, temperature at 30 cm below canopy top, vapor pressure deficit, solar radiation, and wind velocity on internal boll temperature. They concluded that the ambient temperature accounted for 96.3% of the boll temperature variation, while the other parameters provided little additional precision in predicting internal boll temperature. It is imperative for physiological studies of the effects of temperature on boll growth and yield to be able to accurately measure boll temperature and quantify the difference from ambient temperatures.

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Studies were conducted in 2004 and 2005 to determine the best and most practical method of measuring boll temperatures (Gonias et al., 2006). Although the infrared (IR) thermometer provided an easy and fast measurement of cotton boll surface temperature, the measurements made did not correlate well with the thermocouple (TC) thermometer measurements. The temperature readings made with the IR thermometer were more variable than readings made with the TC thermometer. Diurnal changes in boll temperature were recorded, with internal temperatures being similar to the ambient temperature early and late in the day. However, boll temperatures measured with the TC thermometer were as much as 5°C warmer than ambient temperature, whereas boll surface temperature did not differ much from ambient temperature. Boll temperature measurements made at 0.5 and 1.0 cm depths were similar and there were no differences in internal temperatures between bolls in a similar position in the canopy of six contrasting *Gossypium hirsutum* L. cultivars tested.

RESEARCH DESCRIPTION

Defoliation Based on Heat Unit Accumulation Calculated using Boll Temperature

Boll temperatures were measured weekly starting at NAWF5 (last effective harvestable boll) using a thermocouple probe and handheld meter. This was part of a regional study investigating the use of boll temperatures, instead of ambient temperatures, to calculate heat unit accumulation after NAWF5 for the purposes of predicting defoliation of cotton. The data were also used to formulate a predictive equation using ambient temperature to predict internal boll temperature.

Heat units were calculated after NAWF5 using ambient temperature (conventional) and internal boll temperature (as estimated by the predictive equation for boll temperature). Defoliation was based on the heat unit accumulation of the two techniques and the effect on yield and fiber quality properties determined. The trial was laid out in a randomized block design with five replications. The defoliants used were Def and Prep at conventional rates. Harvesting was conducted with a mechanical picker on the two center rows of each plot. HVI fiber quality testing was performed by Louisiana State University.

RESULTS AND DISCUSSION

Boll Temperature and Predictive Equation.

The ambient temperature at the time of each boll temperature measurement was recorded. The average internal boll temperature was then plotted against ambient temperature for each measurement (Fig. 1). From the graph the following equation ($r^2=0.8143$) relating boll temperature to ambient temperature was derived:

$$\text{Boll temperature} = 0.5928 \times \text{Ambient} + 19.38$$

Effect of Heat Unit Technique Used on Defoliation, Yield, and Quality

Accumulation of 850 heat units for defoliation in 2006 using the internal boll temperature was reached on 31 August and on 8 September 2006 using the ambient temperature. However, the difference of eight days in defoliation timing of the two techniques did not have any statistically significant effect on yield (Table 1) and fiber quality properties (Table 2).

PRACTICAL APPLICATION

The defoliation study in Arkansas, using the internal boll temperature to calculate heat unit accumulation, predicted defoliation 8 days earlier than the conventional method (use of ambient temperature). However, that difference in defoliation timing did not have an effect on lint yield, number of bolls, average boll weight, and gin turnout. Similarly, no differences were observed in fiber length, strength, micronaire, and uniformity. The study will be repeated.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Effect of defoliation timing by heat unit accumulation on yield and yield components of cotton in Arkansas. Heat unit accumulation was calculated by conventional and boll temperature methods.

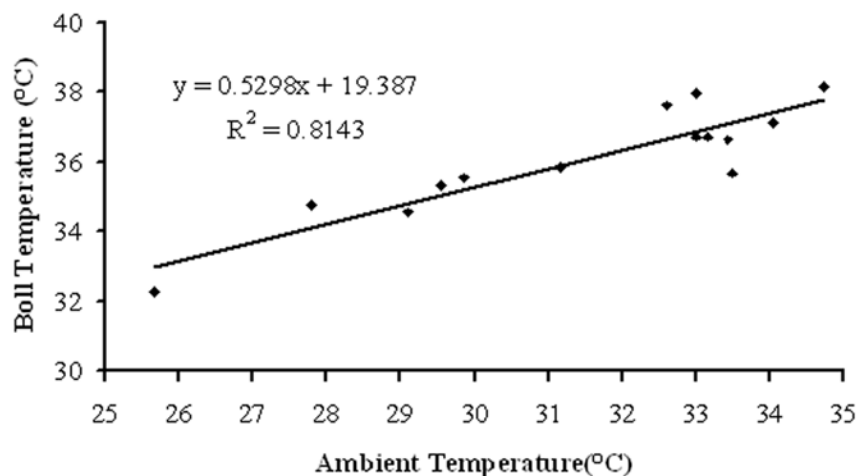
Defoliation method	Lint	Bolls	Boll weight	Gin turnout
	(kg/ha)	(#/ha)	(g)	(%)
Conventional	1216	540,306	4.99	45.1
Boll temperature	1166	540,349	4.81	45.0
	NS ^z	NS	NS	NS

^z NS = not significant at P=0.05.

Table 2. Effect of defoliation timing by heat unit accumulation on fiber quality. Heat unit accumulation was calculated by conventional and boll temperature methods.

Defoliation method	Length (in.)	Strength (g/tex)	Micronaire	Uniformity (%)
Conventional	1.07	28.8	4.75	83.38
Boll temperature	1.10	29.6	4.55	83.33
	NS ^z	NS	NS	NS

^z NS = not significant at P=0.05.

**Fig. 1. Comparison of ambient to boll internal temperatures measured with thermocouple thermometers.**

Effect of the Plant Growth Regulator BM86 on Polyamines and Seed Set Efficiency of Cotton During the Reproductive Stage

Androniki C. Bibi, Derrick M. Oosterhuis, and Evangelos D. Gonias¹

RESEARCH PROBLEM

Naturally occurring polyamines in plants have been implicated in cell division, metabolic activity, floral initiation, and fruit development. The plant growth regulator BM86 was formulated to stimulate seed production and fruit growth. In this study, it was hypothesized that the addition of BM86 would increase levels of polyamines for seed induction and have a direct benefit of improving fertilization and seed set in cotton. This benefit may enhance yield under extreme environmental conditions when endogenous polyamine content is reduced.

BACKGROUND INFORMATION

Polyamines are substances that occur naturally in plants and act as promoters of growth (Costa et al., 1984). The diamine putrescine and the polyamines spermidine and spermine appear in young tissues where they are involved in cellular multiplication, in cellular differentiation during organogenesis, flowering, pollination, and early fruit development (Costa et al., 1984). Generally, it appears that polyamines are indispensable to plants at the time of flowering and early fruit development (Kloareg et al., 1986). Even though the importance of polyamines in plants is well established, their role in the physiology of the plant is still uncertain and little is known about their role in cotton during reproductive development. The overall objective of this study was to determine the effect of the plant growth regulator BM86 on polyamines and seed set efficiency of cotton.

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RESEARCH DESCRIPTION

A field study was conducted in 2006 at the Cotton Branch Station in Marianna, eastern Arkansas. The cultivars used in this study were DP444BR, ST5599BR, and FM960BR. The soil was a Captina silt loam. A randomized complete block design with five replications and a split-split block arrangement of treatments were used. The main factor was cultivars, sub-factor BM86 application, and sub-sub factor nodal position. The plot size was 4 rows by 15 m. The study was irrigated based on an irrigation scheduler program. The fertilization program was determined by preseason soil tests and recommended values for cotton. Weed and insect control were conducted according to Arkansas recommendations.

At first flower on 8 July 2006 the PGR BM86 (Goëmar Laboratories, Saint Malo, France) was applied to the right 2 rows of each plot at 2 pt/acre with a backpack CO₂ sprayer calibrated to deliver 10 gal/acre (94 L/ha). The left two rows were used as the control. The day before the application, the flowering node was determined and 10 first-position white flowers were collected from each plot. Sampling was performed weekly using first-position flowers two nodes higher than the previous position, for a total of three weeks. The PGR BM86 was reapplied two weeks after the first application. At harvest, five bolls were picked from each plot from the similar node from which flowers had been previously collected, for both control and BM86-treated plants. Half of the flowers were used to determine the number of ovules per ovary. The procedure involved separating the ovary from the petals and sepals, and dissecting the ovaries to determine the number of locules and the number of ovules. The remaining flowers were stored at -80°C for subsequent polyamine determination. Polyamines were measured with HPLC and included Putrescine (Put), Spermine (Sp), and Spermidine (Sd) (Davies and Smith, 1985). The final number of seed was determined from the hand-picked bolls, and seed set efficiency was calculated using the equation: [seed set efficiency = (# of seeds/ # of ovules) x 100].

RESULTS AND DISCUSSION

The statistical analysis showed that there was no significant cultivar x BM86 interaction (Fig. 1). The effect of BM86 was highly significant for Put ($P=0.0339$) and for Sd ($P=0.0327$). One week after the first BM86 application a significant increase in Put and Sd levels was observed (Fig. 1A). In addition to this, the cultivar effect was not significant for Put and Sp; however, there was a significant cultivar effect on Sd (Fig. 1B). The cultivar FM960BR showed significantly higher levels of Sd compared to the other two genotypes. There was no significant cultivar x BM86 interaction two weeks after the first application. BM86 had a significant effect on Put compared to the control (Fig. 2A). In addition, there was a significant cultivar effect on Put and Sp. FM960BR had significantly higher Put compared to the other genotypes (Fig. 2B). One week after the second application of BM86 Put and Sd levels were not significantly affected by BM96 while Sp was not detected (Fig. 3A). There was a significant cultivar x BM86 interaction, shown in Fig. 3B. The polyamine content of FM960BR and ST5599BR was increased numerically after the BM86 application, while in DP444BR the polyamine content was significantly decreased.

Finally, a significant increase in seed set efficiency was observed in the PGR-treated plants when the total number of seeds (mature and undeveloped) was determined at harvest (Fig 4). However, this result was not observed when only mature, harvestable seeds were counted and seed set efficiency was recalculated. The cultivar effect was not significant.

PRACTICAL APPLICATION

It is obvious that the application of BM86 had a significant positive effect on cotton ovary polyamine content, specifically on putrescine and spermidine. In addition the number of total seeds (mature and undeveloped) was significantly increased on the treated plants, but the number of harvestable seeds was not affected. Therefore, we can say that application of BM86 can increase significantly cotton seed number, but we need to improve cotton in order to capitalize on the potential seed number increase.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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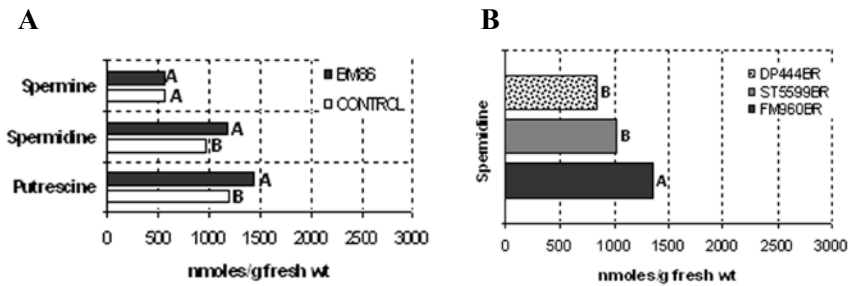


Fig. 1. The effect of (A) the plant growth regulator BM86 and (B) cultivars on polyamine content of cotton ovaries. Pairs of columns with the same letter are not significantly different ($P\leq0.05$).

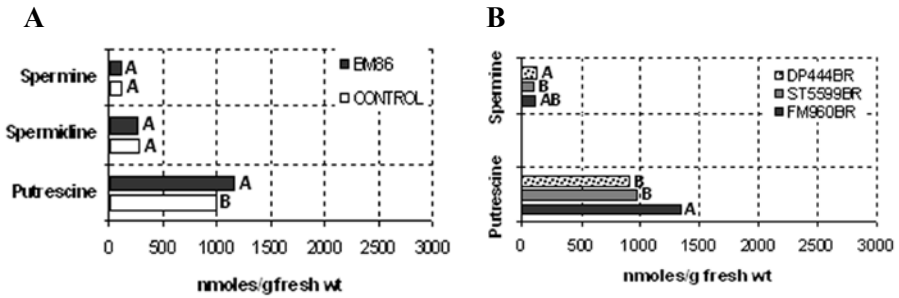


Fig. 2. Effect of (A) the plant growth regulator BM86, and (B) cultivar on the polyamine content of cotton ovaries two weeks after the first BM86 application. Pairs of columns with the same letter are not significantly different ($P \leq 0.05$).

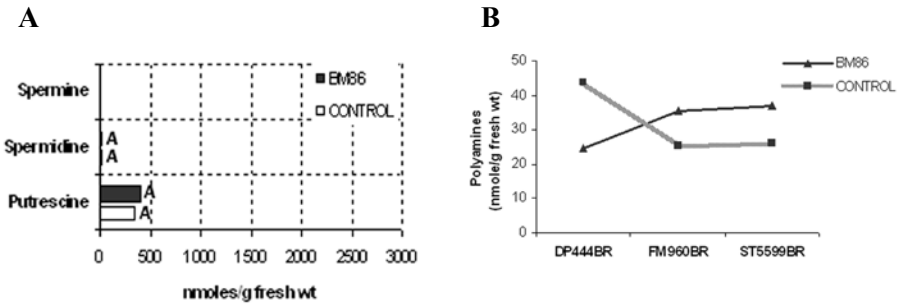


Fig. 3. The effect of the PGR BM86 (one week after the second spraying) on polyamine content of cotton ovaries (A). The significant cultivar x BM86 interaction on Sd concentration of three cotton genotypes (B). Pairs of columns with the same letter are not significantly different ($P \leq 0.05$).

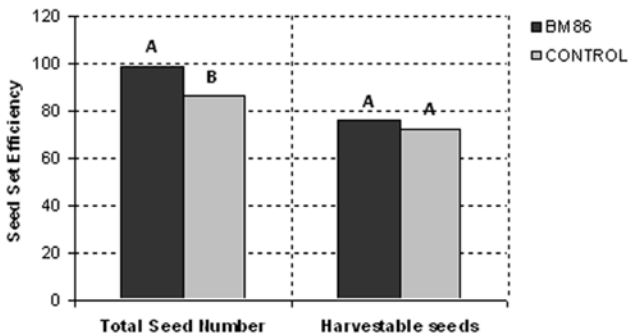


Fig. 4. The effect of Goemar BM86 on seed set efficiency of cotton. Pairs of columns with the same letter are not significantly different ($P \leq 0.05$).

Polyamines in Cotton Ovaries as Affected by Nodal Position and Canopy Temperature

Androniki C. Bibi, Derrick M. Oosterhuis, and Evangelos D. Gonias¹

RESEARCH PROBLEM

Polyamines have been associated with a large number of plant growth and developmental processes. In particular, they have been associated with floral initiation with increased polyamines concentration occurring during flowering in horticulture plants. However, there is limited information about polyamines in cotton (*Gossypium hirsutum* L.) and how they are distributed in the cotton plant. In addition, little is known about the effect of canopy temperature on cotton ovary polyamine content.

BACKGROUND INFORMATION

The response of a cotton plant to environment in the square stage is of particular interest because of the close relationship of square and flower production to earliness of a crop (Stewart, 1986). Past experience and recent research has indicated that high temperature is a major factor adversely affecting cotton yields (Bibi, 2005; Oosterhuis, 2002). Previous research has indicated that *Gossypium hirsutum* plants maintained at a constant high temperature (29.4°C) had very low fruit set, even when pollinated with pollen of known viability (Stewart, 1986). The influence of temperature on the number of ovules per flower has not been determined directly. However there is an indication that extreme high temperatures can result in a lower number of ovules per locule (Hughes, 1966).

Plant growth substances play a controlling role in the process of reproduction. Polyamines are substances that are naturally present in plants and act as promoters of growth. They are involved in cellular multiplication and also in cellular differentiation during organogenesis, and they also play an important role at the time of flowering, pollination, and early fruit development (Costa et al., 1984). Generally, it appears that polyamines are growth regulators indispensable to plants at the time of flowering, as well as during early fruit development (Kloareg et al., 1986). To the knowledge of the

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authors, no reports on polyamine content in cotton ovaries exist. Therefore the objective of this study was firstly to investigate how the polyamines are distributed in the cotton plant, and secondly to determine the correlation of canopy temperature and cotton ovarian polyamine content.

RESEARCH DESCRIPTION

A field study was conducted in 2006 at the Cotton Branch Station in Marianna, eastern Arkansas. The cultivars used in this study were DP444BR, ST5599BR, and FM960BR. The soil was a Captina silt loam (Typic fragidault). The experimental design was a randomized complete block with five replications, while the treatment design was a split-block design. The main factor was cultivars, and the sub-factor nodal position. The experimental plot size was four rows by 15 m. The study was furrow-irrigated based on an irrigation scheduler program. The fertilization program was determined by preseason soil tests and recommended values for cotton. Weed and insect control were conducted according to Arkansas recommendations.

At first flower, the flowering node was determined and 10 first-position white flowers were collected from each plot. Thereafter, sampling was performed weekly with first-position flowers two nodes higher than the previous position, for a total of four weeks. Watch-dog temperature data loggers (Spectrum Technologies Inc., Ill.) were placed on each of the nodes from which flowers were collected. Each time flowers were collected, half were used to determine the number of ovules per ovary and the remaining flowers were stored at -80°C for subsequent polyamines determination. Polyamines were measured with HPLC and included putrescine, spermine, and spermidine (Davies and Smith, 1985). The final number of seeds was determined from hand-picked bolls from the same nodal positions from which flowers had been previously collected. The seed set efficiency was calculated using the equation:

$$\text{Seed set efficiency} = (\# \text{ of seeds harvested} / \# \text{ of ovules initially collected}) \times 100$$

RESULTS AND DISCUSSION

The results from the statistical analysis showed that there was no significant interaction between nodal position and cultivars. The main effects, the cultivars, had no significant effect on any of the polyamines measured. However, this was not the case for the nodal position. Putrescine content in cotton decreased significantly up the main stem (Fig. 1). Putrescine in node 7 was significantly higher compared to nodes 9 and 11, and even higher than at node 13. Spermidine and spermine showed similar trends (Fig. 2 and Fig. 3). The node effect was significant and the content of both spermidine and spermine decreased up the main stem. However, node 9 had statistically the highest concentration compared to the other nodes. Correlating the temperature data from the data loggers with the polyamine content up the main stem, we observed that there was a negative correlation of temperature and polyamines (Fig. 4). Polyamine content in cotton ovaries decreased with increased canopy temperature.

PRACTICAL APPLICATION

Polyamines play a critical role in reproductive development. Therefore, knowledge of their distribution in the cotton plant and how they are affected by high temperature will allow the formulation of strategies to counteract high temperature stress for yield improvement and stabilization.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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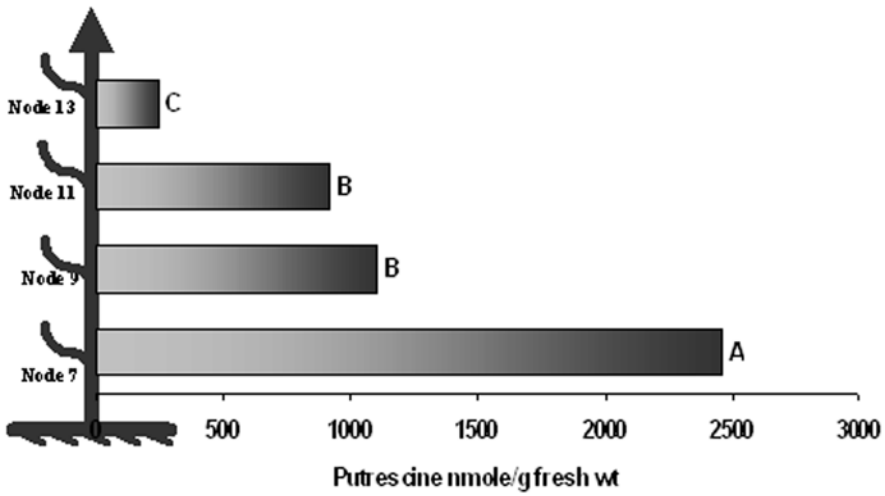


Fig. 1. Effect of nodal position on putrescine content in cotton ovaries. Columns with the same letter are not significantly different ($P \leq 0.05$).

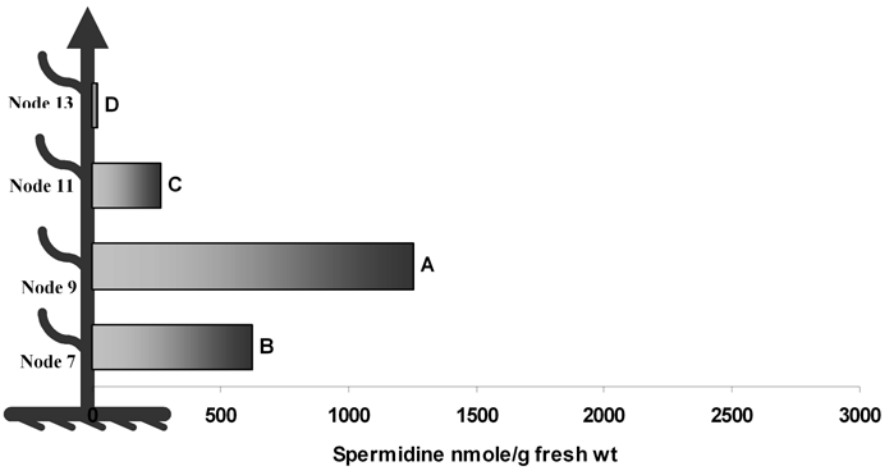


Fig. 2. Effect of nodal position on spermidine content in cotton ovaries. Columns with the same letter are not significantly different ($P \leq 0.05$).

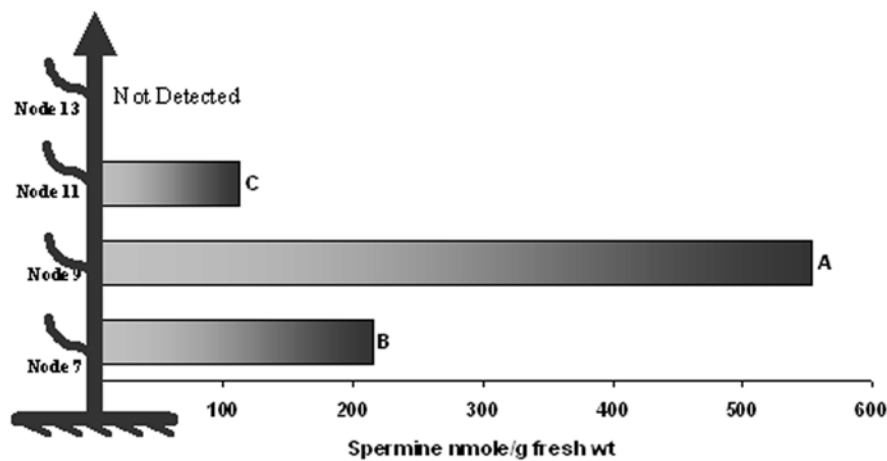


Fig. 3. Effect of nodal position on spermine content in cotton ovaries. Columns with the same letter are not significantly different ($P \leq 0.05$).

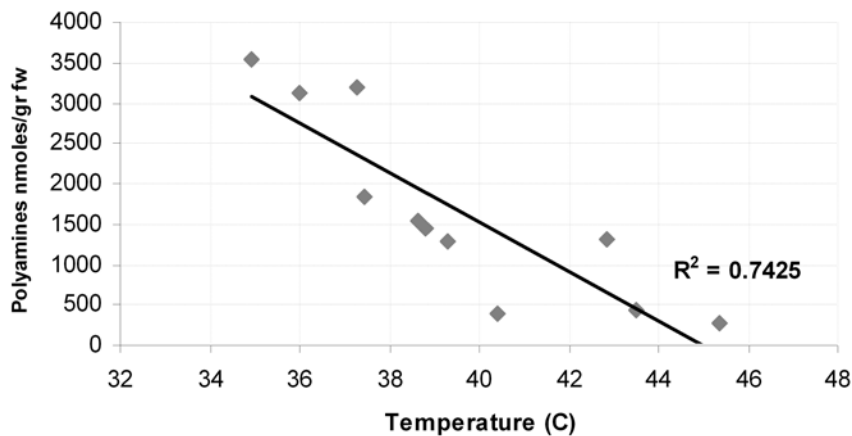


Fig. 4. Effect of canopy temperature on polyamine content in cotton ovaries.

Exogenous Application of Putrescine on Cotton Ovaries under Two Temperature Regimes

Androniki C. Bibi, Derrick M. Oosterhuis, and Evangelos D. Gonias¹

RESEARCH PROBLEM

Polyamines are organic polycations that have been associated with a large number of plant growth and developmental processes, such as pollination and fruit set. Most of the research has been done in horticulture plants with limited information existing for cotton. Numerous studies have correlated increased fruit set with increased polyamines concentration during flowering. Therefore in this study it was hypothesized that exogenous putrescine application in cotton ovaries might have a positive effect in cotton seed set, under two temperature regimes.

BACKGROUND INFORMATION

Past experience and recent research has indicated that high temperature is a major factor adversely affecting cotton yields (Bibi, 2004; Oosterhuis, 2002). The ideal day/night temperature range in cotton has been reported to be 30/20°C (Reddy et al., 1991), although cotton physiological growth is not significantly affected up to 35 to 36°C (Bibi et al., 2004). The influence of temperature on the number of ovules per flower has not been determined directly, although there is an indication that extreme high temperatures can result in a lower number of ovules per locule (Hughes, 1966).

Plant growth substances play a controlling role in the process of reproduction. Polyamines (PAs) are substances that are naturally present in plants and act as promoters of growth. They play an important role at the time of flowering, pollination, and early fruit development (Costa et al., 1984). In addition, polyamines have been associated with plant response to abiotic stress (Kumar et al., 1997). To our knowledge, no evidence exists on the effect of exogenous PAs on polyamine content of cotton ovaries. Also, no information exists on how PAs affect seed set of cotton in normal and high temperatures. Therefore, the objective of this study was to investigate the effect of exogenous putrescine application on seed set of cotton under two temperature regimes.

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RESEARCH DESCRIPTION

In December 2006 a growth chamber study was conducted in the Altheimer Laboratory, Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) cultivar DP444BR was planted in 80 2-L pots filled with Sunshine growing media. Two growth chambers were used, one was used as control with a day/night temperature regime of 30/20°C, while the second chamber was the high temperature treatment with a day/night temperature regime of 38/20°C. The plants were maintained at the control temperature until they reached the flowering stage (5 weeks after planting). Following that 40 pots were placed in each growth chamber. The 40 pots in each chamber were split in two sets; half were used as control and half were used for the exogenous application of putrescine. Putrescine at 10mM plus 0.5% Tween 20 was applied 2 days after the plants were placed in temperature treatment. Putrescine was applied to 20 tagged “candles” of the same main stem node. In addition, 20 more candles were tagged from the control plants in each untreated growth chamber. At anthesis (24 hours later), 4 treated white flowers and 4 “control” white flowers were collected for polyamines analysis. This procedure was repeated for 3 days. After 3 weeks the remaining bolls were collected in order to determine the number of seeds. The treatment design was split-plot with the main factor temperature and the sub-factor putrescine application. For the statistical analysis, JMP 6 software was used (SAS Institute Inc., Cary, N.C.).

RESULTS AND DISCUSSION

The statistical analysis of the data revealed that there was no significant temperature x exogenous putrescine application interaction. Because of the lack of interaction, we focused on the main effects of the exogenous putrescine application and the main effect of temperature. The results showed that the exogenous putrescine application significantly increased the putrescine content of cotton ovaries at both temperature regimes (Fig. 1). However, spermidine and spermine concentration in cotton ovaries was not significantly affected. Subjecting the plants to temperatures above the 35°C physiological optimum (Bibi et al., 2005) significantly decreased the spermidine and spermine levels, but not the putrescine, probably due to the exogenous application (Fig. 2).

The results of seed set showed again that there was no significant temperature x exogenous Putrescine application interaction. Analyzing the main effects showed that seed set of cotton was significantly decreased from the high temperature (Fig. 3). In addition, seed set was significantly increased by exogenous putrescine application (Fig. 4).

PRACTICAL APPLICATIONS

Polyamines play an important role in flowers and seed induction and have been shown to decrease under high temperature stress. Exogenous application of putrescine increased the level of putrescine in flowers and this was associated with increased seed set. Therefore the possibility exists of ameliorating high temperature stress in cotton flowers through exogenous application of putrescine.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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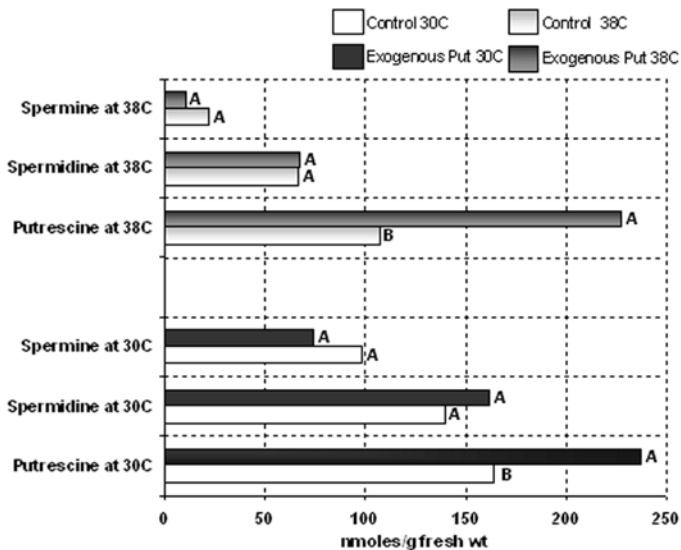


Fig. 1. Effect of exogenous putrescine application on putrescine, spermidine, and spermine content of cotton ovaries at 30 and 38°C. Pairs of columns with the same letter are not significantly different ($P=0.05$).

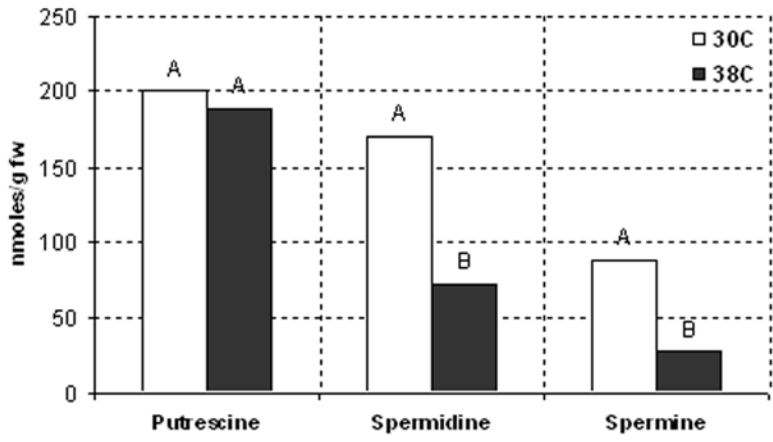


Fig. 2. Effect of high temperature on putrescine, spermidine, and spermine content of cotton ovaries. Pairs of columns with the same letter are not significantly different (P=0.05).

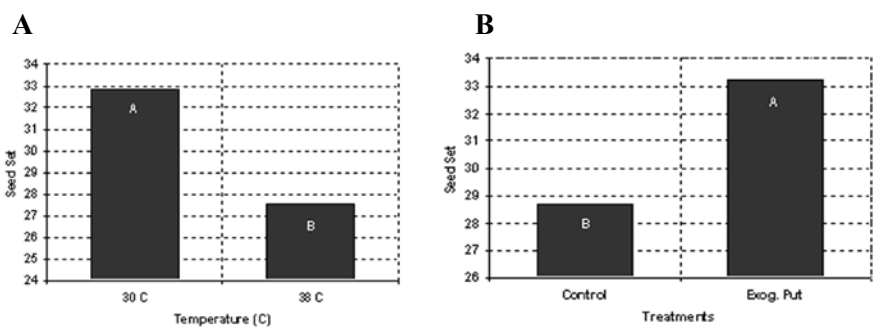


Fig. 3. Effect of (A) temperature and (B) exogenous putrescine application on seed set of cotton. Columns with the same letter are not significantly different (P=0.05).

Effect of 1-MCP on the Growth and Yield of Cotton

*Eduardo M. Kawakami, Derrick M. Oosterhuis,
Evangelos D. Gonias, and Androniki C. Bibi¹*

RESEARCH PROBLEM

One of the major concerns of cotton farmers and the cotton industry is extreme year-to-year variability in yield (Lewis et al., 2000). Variability in cotton yield is mainly associated with environmental stress factors, in which temperature and drought appear to play a major role. When plants are stressed they produce ethylene, which normally acts as an endogenous senescence phytohormone. Also ethylene is well known for its role in the regulation of the fruit abscission process in cotton fruits (Guinn, 1982). The current project was designed to evaluate the possible use of 1-methylcyclopropene (1-MCP) to alleviate the adverse effects of environmental stresses on square and bolls set, and thereby reduce year-to-year yield variability, and allow the cotton crop to yield closer to its potential.

BACKGROUND INFORMATION

1-Methylcyclopropene (1-MCP) is an inhibitor of ethylene action that has been widely used to improve shelf life and quality of agricultural products. Also, this inhibitor has been used by scientists to make advances in understanding the role of ethylene in plants. Since its discovery, over one hundred studies have tested its action, application, and effects on ethylene inhibition (Blankenship and Dole, 2003).

At room temperature and pressure, the 1-MCP molecule is a gas with a weight of 54 g and a formula of C_4H_6 . 1-Methylcyclopropene has been known to occupy ethylene receptors such that ethylene cannot bind and initiate action (Sisler and Serek, 1999, Blankenship, 2001). The affinity of 1-MCP for the receptors is approximately 10 times greater than that of ethylene. In addition, compared with ethylene, 1-MCP is active at much lower concentrations. 1-MCP was also reported, in some species, to decrease ethylene biosynthesis through feedback inhibition (Blankenship and Dole, 2003).

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The objective of this study was to determine the effect of the anti-ethylene action compound 1-methylcyclopropene on the growth and yield of cotton in field conditions.

RESEARCH DESCRIPTION

The field study was conducted at the University of Arkansas Cotton Branch Station at Marianna, Ark., in a Captina silt loam (Typic fragidult) soil. The cotton (*Gossypium hirsutum* L.), cultivar DP444 BR was planted on 21 May 2006. Fertilization was according to preseason soil tests and recommended rates. Weed and insect control were performed according to state recommendations. The plot size was 4 rows by 15 m, with a row spacing of 0.96 m and plant density of 10 plants/m. The experiment was arranged in a randomized complete block design with five replications. Treatments consisted of: (T1) Untreated control; (T2) 1-MCP at 10 g ai/ha applied at first flower (FF), (T3) 1-MCP at 10 g ai/ha applied at FF and at FF+2 weeks, (T4) 1-MCP at 10 g ai/ha applied at FF, FF+1, FF+2, FF+3 weeks, and (T5) 1-MCP at 10 g ai/ha + 0.584 l PIX/ha (8 oz/acre) applied at FF. All 1-MCP treatments were sprayed with a backpack CO₂ sprayer calibrated to deliver 20 gal/acre. The adjuvant AF-400 was added to the spraying solution at a rate of 0.375% v/v.

The yield parameters, number of bolls, seedcotton yield, lint yield, and boll size, were calculated from a one-meter length of row, hand-picked cotton. Glutathione reductase was measured using the fourth main-stem leaf from the terminal.

RESULTS AND DISCUSSION

Overall, in this field study, the 1-MCP treatments did not have statistically significant ($P=0.05$) effects on yield. However, the numerical data indicated that the best treatment was “1-MCP applied at First Flower + 2 weeks later.” In this treatment all yield variables were higher than the control, with the exception of boll number in which the untreated control was higher (Table 1). The explanation of these results is that treatments with 1-MCP had bigger bolls when compared with the untreated control treatment. The treatments 1-MCP applied at first flower and 1-MCP applied at FF + (FF+2 weeks) had significantly bigger bolls than the untreated control treatment (Fig. 1). Measurements of the antioxidant enzyme glutathione reductase (an indication of the stress level of the plants) at 2 weeks after first spraying showed positive effects in all 1-MCP treatments compared with untreated control treatment. In this case, 1-MCP applied at first flower had significantly lower ($P\text{-value}=0.0376$) glutathione reductase levels compared with the untreated control treatment (Fig. 2). In addition, when the four 1-MCP treatments were combined and compared with the untreated control, glutathione reductase enzyme activity was significantly lower in the 1-MCP treatments with a $P\text{-value}$ of 0.0336 (data not shown).

PRACTICAL APPLICATION

In conclusion, 1-MCP did not have an effect on the yield of field-grown cotton, but positively affected cotton boll size and the activity of the antioxidant enzyme

glutathione reductase. Future research will further elucidate the mechanism and best method of use for 1-MCP to positively impact yields.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Effect of 1-MCP treatments on number of bolls, seedcotton yield, and lint yield.

Treatment	Number of bolls (bolls/ha)	Seedcotton yield ----- (kg/ha)-----	Lint yield
Untreated control	746000 a ^z	2522 a	1132 a
1-MCP First Flower (FF)	672000 a	2504 a	1140 a
1-MCP FF + (FF+2 weeks)	736000 a	2770 a	1256 a
1-MCP FF + (FF+1 weeks) + (FF+2 weeks) + (FF+3 weeks)	658000 a	2376 a	1074 a
1-MCP FF + PIX	674000 a	2412 a	1088 a

^z Rows with the same letters are not significant different (P=0.05).

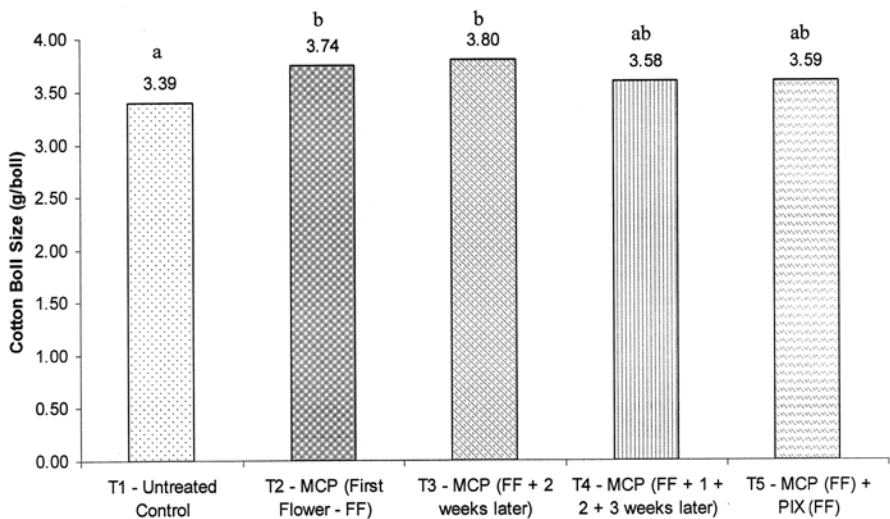


Fig. 1. Effect of 1-MCP treatments on cotton boll size. Columns with the same letters are not significantly different ($P=0.05$).

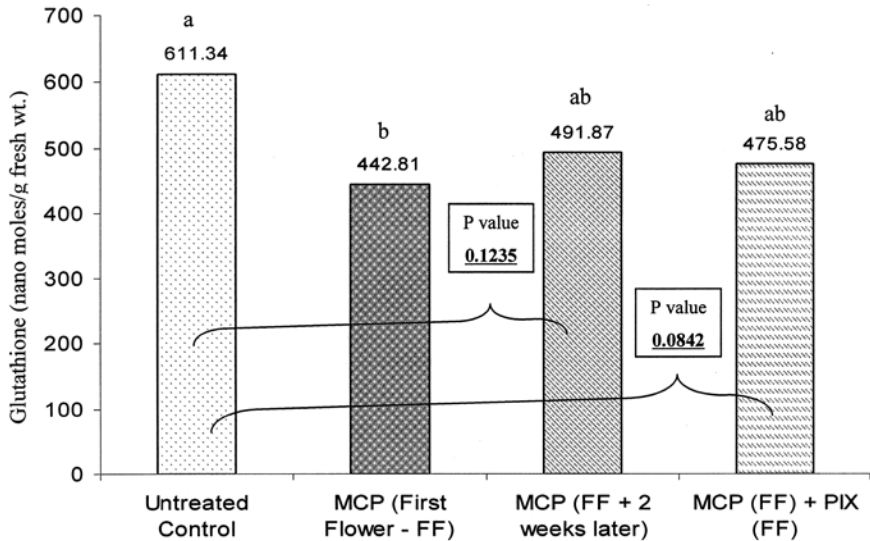


Fig. 2. Effect of 1-MCP treatments on the antioxidant enzyme glutathione, 2 weeks after first application of 1-MCP. Columns with the same letters are not significant different ($P=0.05$).

Effect of 1-MCP on the Physiology and Growth of Drought-Stressed Cotton Plants

Eduardo M. Kawakami and Derrick M. Oosterhuis¹

RESEARCH PROBLEM

Among all abiotic stress factors, drought is the major environmental constraint to crop productivity worldwide (Sharp et al., 2004). According to Bot et al. (2000), 45% of the world's agricultural lands are subject to continuous or frequent drought conditions. In cotton production, higher yields are limited in many regions of the U.S. Cotton Belt by inadequate amounts or inadequate distribution of rainfall (Basal et al., 2005). Even in irrigated or high rainfall areas, short periods of interruption of the water supply can increase fruit shed and decrease yield. Alleviation of plant stress during dry periods could prevent yield loss and increase profits.

BACKGROUND INFORMATION

1-Methylcyclopropene (1-MCP) is a biopesticide approved for use in fruits and vegetables by the EPA. The product works by decreasing or delaying the effect of ethylene which normally acts as an endogenous stress and senescence phytohormone. In essence, 1-MCP occupies ethylene receptors such that ethylene cannot bind and elicit action (Blankenship and Dole, 2003). There have been anecdotal reports of 1-MCP decreasing fruit shed in cotton under elevated temperature conditions in the growth chamber, thereby increasing the number of flowers and bolls set and increasing yield. If 1-MCP functions in horticultural fruit-growing to enhance the development of flowers, pollination, and the first stage in the formation of fruit, it could have a major impact in cotton production where excessive fruit shed in response to stress is a primary cause of yield reduction. The objective of this study was to investigate the effect of the plant growth regulator 1-MCP on the physiology and growth of cotton plants under stress-watered and well-watered condition.

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RESEARCH DESCRIPTION

A growth chamber study was conducted in the Altheimer Laboratory, Arkansas Agricultural Research and Extension Center, to determine the effect of 1-MCP on drought-stressed cotton plants. In October 2006, cotton (*Gossypium hirsutum* L.) cultivar DP444 BR was planted in one-liter pots filled with Sunshine potting mix (Sun Gro Horticultural Distribution Inc., Bellevue, Wash.). Pots were arranged in a large growth chamber with a day/night temperature regime of 30/20°C, 12-hour photoperiod and relative humidity of 60%. After four weeks, 1-MCP was sprayed according to the treatments. The pots were wrapped with plastic bags to avoid water evaporation from the soil and to confine water loss to transpiration only. Half of the pots (10 pots) were carried through a water-stress regime. The stress regime was established for five days, after which the stressed plants were re-watered. This process was repeated three times, giving a total of three water-stress cycles at the end of the experiment. The experiment was arranged in a completely randomized design with five replications. The treatments consisted of: (T1) untreated control well-watered, (T2) 1-MCP at 10 g ai/ha well-watered, (T3) untreated control water-stressed, and (T4) 1-MCP at 10 g ai/ha water-stressed. The 1-MCP was applied with a CO₂ backpack sprayer calibrated to deliver 20 gal/acre. All 1-MCP treatments were applied with the adjuvant AF-400 at 0.375% v/v.

Transpiration and stomatal conductance were recorded daily using a LICOR 6200 porometer and measurements of fluorescence were made using a Modulate Fluorometer (OS1-FL). In order to calculate water-use efficiency (g/ml), pots were weighed daily to estimate water use and at the end of the experiment values of total dry matter (g) were divided by the total amount of water used (ml).

RESULTS AND DISCUSSION

All data collected showed that cotton under conditions of water stress had inferior performance when compared with well-watered plants. It was also apparent that 1-MCP-treated plants performed better under water-deficit conditions.

Plants treated with 1-MCP in stress condition had a higher stomatal resistance (Fig. 1) and lower values of transpiration (data not shown). Calculations of water-use efficiency (Fig. 2) showed a slightly higher efficiency in both 1-MCP treatments compared with the untreated controls, but the values were not statistically significant ($P=0.05$).

The number of main-stem nodes gained was calculated by subtracting the total number of main-stem-nodes at the end of the experiment by the number of main stem nodes at the time of 1-MCP application. In both, well-watered and water-stressed conditions, the number of main-stem nodes gained was slightly higher in 1-MCP treatments when compared with the untreated control treatments (Table 1). A higher number of squares was observed in the 1-MCP treatment under water stress compared with the untreated control in the same stress regime, with a P -value of 0.13 (Table 1).

Chlorophyll fluorescence measurements showed numerically lower values of fluorescence in the 1-MCP-treated plants within each water regime (Table 2). Significant differences at $P=0.05$ were observed only between the 1-MCP in the well-watered treatment and the untreated water-stressed control (Table 2). The same results were

detected in the membrane integrity measurements. The 1-MCP treatments exhibited lower values of electrical conductivity than the untreated controls within each water regime. In addition, 1-MCP in the well-watered treatment had values significantly lower compared with the untreated water-stressed controls (Table 2).

PRACTICAL APPLICATION

The growth chamber study showed that 1-MCP increased cotton stomatal resistance, number of nodes, and number of squares in water-stressed plants. In addition, 1-MCP had positive effects on chlorophyll fluorescence and membrane integrity. These results indicated that application of 1-MCP to water-stressed cotton may be beneficial, but the study needs to be continued.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Effect of 1-MCP on gain of main-stem nodes and number of squares per plant, with and without water deficit. Squares collected at 6 weeks after planting.

Treatment	Gain of main-stem nodes ^z	No. of squares per plant
1-MCP well-watered	2.6 a ^y	10.0 a
Control well-watered	2.2 a	9.8 a
1-MCP water-stressed	1.4 b	7.8 b
Control water-stressed	1.0 b	6.4 b

^z Number of main-stem nodes at the end of the experiment minus number of main-stem nodes at the day of 1-MCP application.

^y Rows with the same letters are not significantly different (P=0.05).

Table 2. Effect of 1-MCP on chlorophyll fluorescence and membrane leakage, with and without water deficit.

Treatment	Chlorophyll fluorescence (Fms-Fm)/Fm	Membrane leakage (μ A/cm ²)
1-MCP well-watered	0.428 b ^z	33.01 b
Control well-watered	0.454 ab	58.41 ab
1-MCP water-stressed	0.455 ab	66.66 ab
Control water-stressed	0.471 a	74.28 a

^z Rows with the same letters are not significantly different (P=0.05).

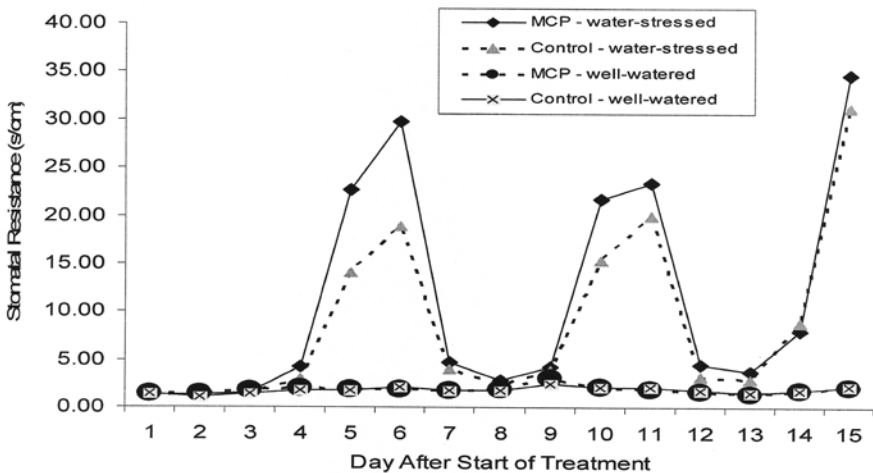


Fig. 1. Effect of 1-MCP on cotton stomatal resistance, with and without water deficit, measured at midday. 1-MCP was sprayed at day 1. Note that the two well-watered treatments' stomatal resistance were similar (overlapped).

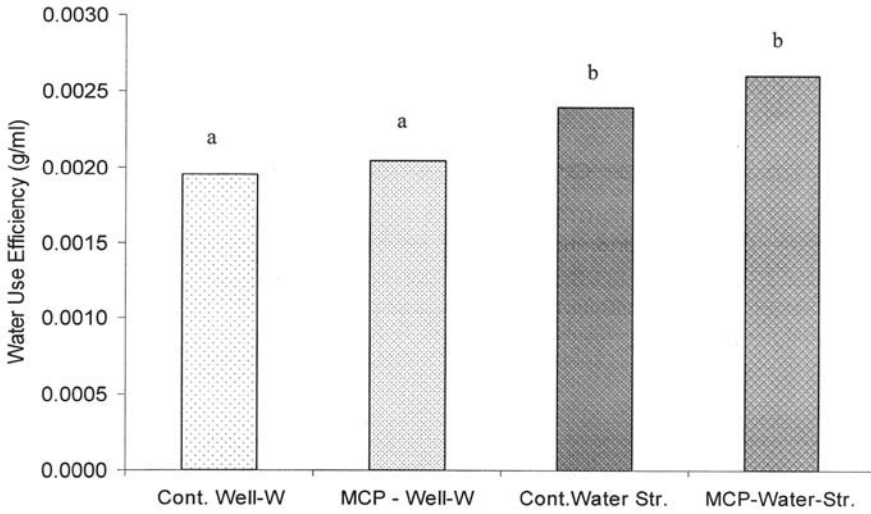


Fig. 2. Effect of 1-MCP on cotton water use efficiency (g/ml), with and without water deficit. Column with the same letters are not significantly different ($P=0.05$).

Management of Late-Planted Cotton

William C. Robertson, Frank E. Groves, and Robert Hogan, Jr.¹

RESEARCH PROBLEM

The ideal planting date for cotton in Arkansas varies with location, but is generally around 1 May. However, planting is sometimes delayed until as late as early- to mid-June for reasons such as double-cropping behind wheat, replanting poor stands, or unfavorable weather. Specific recommendations for irrigation initiation, fertilization, and plant growth regulator (PGR) applications are not currently available for late-planted cotton.

BACKGROUND INFORMATION

Managing late-planted cotton can present additional challenges to the producer. The ideal planting date for cotton in Arkansas varies with location, but is generally around 1 May. However, planting is sometimes delayed until as late as June for reasons such as double-cropping behind wheat, replanting poor stands, or unfavorable weather. Specific recommendations for irrigation initiation, fertilization, and plant growth regulator (PGR) applications are not currently available for late-planted cotton. All of these cultural practices have been shown to result in maturity delays when misapplied to cotton planted at normal planting dates. A three-year study was conducted at Marianna, Ark., to determine best management practices related to irrigation initiation, fertilization, and mequiat chloride (PGR) applications for late-planted cotton.

RESEARCH DESCRIPTION

The cotton (*Gossypium hirsutum* L.) variety PM 1218BG/RR was planted on 3 June 2004 while DP 444BG/RR was planted 2 June in 2005 and 2006 on the Cotton Branch Experiment Station in Marianna, Ark. Treatments consisted of two irrigation initiations (timely and delayed), three fertilization levels (40, 80, and 120 lb N/acre),

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and two mepiquat chloride PGR regimes (typical and aggressive). Treatments were arranged in a split-plot design with four replications. Plots under timely irrigation initiation were irrigated timely throughout the growing season as determined by the University of Arkansas Irrigation Scheduling Program. The delayed irrigation treatment was identical to the timely treatment with the exception of the first irrigation, which was omitted. All nitrogen fertilization treatments were applied just prior to squaring. End-of-season plant heights and number of main-stem nodes were recorded. Yield was determined using a plot picker equipped with load cells.

RESULTS AND DISCUSSION

Lint yield was greater under delayed irrigation. Delayed initiation of irrigation led to numerically higher lint yields when compared to those under timely irrigation, 936 lb lint/acre and 919 lb lint/acre, respectively. An average lint yield of 959 lb lint/acre was achieved with 80 lb N/acre across all other main effects compared to 926 lb lint for 120 lb N/ac and 897 lb lint/ac for 40 lb N/acre. As expected, plant height increased numerically with additional nitrogen; plants in the 120 lb N/acre treatment (37.2 in.) were taller than those that received either 40 or 80 lb N/acre, respectively (34.5 in. and 34.9 in.). A two-way, irrigation x PGR regime interaction occurred for plant height. Plants were taller when timely irrigation was combined with the typical PGR regime (Fig. 1). As expected, height-to-node ratio was greater when PGR application was less aggressive (Fig. 2).

PRACTICAL APPLICATION

It was hypothesized that timely irrigation initiation and a more aggressive PGR regime would be needed for late-planted cotton to be successful. Results of this three-year study did not support this hypothesis. It appears that timely irrigation initiation for late-planted cotton is not as critical as that for timely-planted cotton. A delay in the initial irrigation resulted in numerically greater yields, while eliminating the cost of the first irrigation. A reduction in nitrogen to 80 lb N/acre from a standard of 120 lb N/acre resulted in numerically greater yields and lower costs compared to the 120 lb N/acre rate. Mepiquat chloride treatment regimes had little impact in final lint yields. It appears that the lost yield potential associated with late-planted cotton may be overcome to some degree with reduced production costs through reduced inputs without sacrificing additional yield potential.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

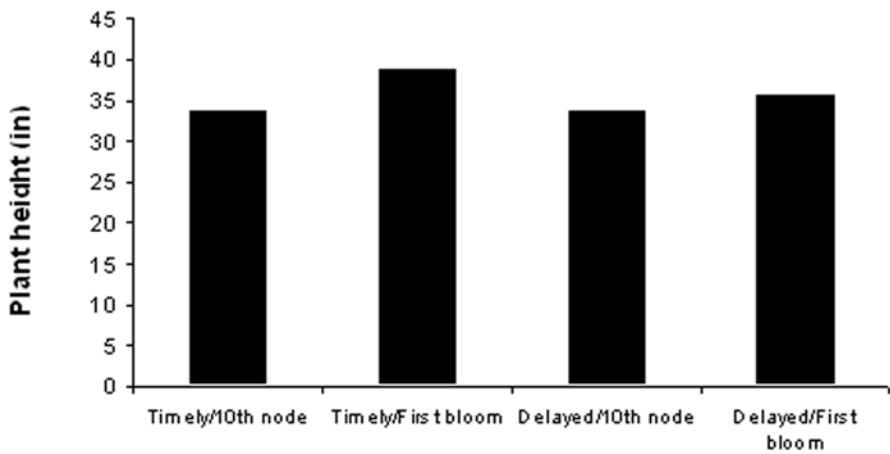


Fig. 1. Effect of irrigation x PGR regime interaction on plant height.

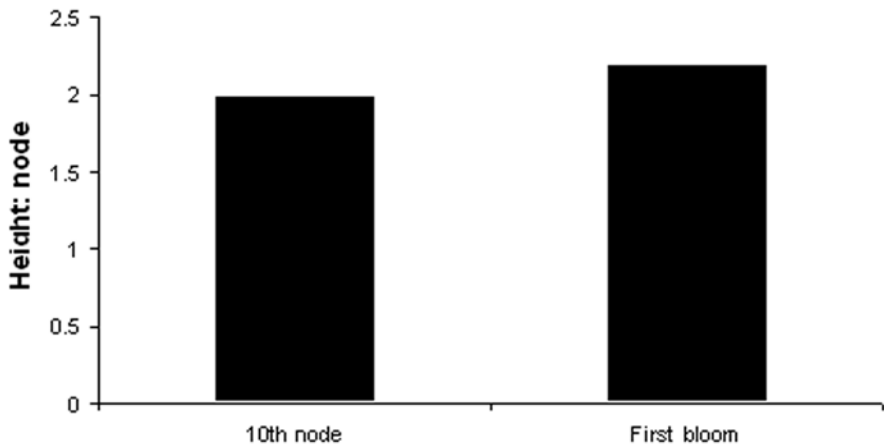


Fig. 2. Effect of PGR regime on height-to-node ratio.

Optimizing Revenue Through Defoliation Timing Using COTMAN

William C. Robertson, Frank E. Groves, and Robert Hogan, Jr.¹

RESEARCH PROBLEM

Timing of harvest aids continues to be a difficult decision for producers. 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. The objective of this study was to evaluate the heat unit-based concept for defoliation timing with traditional methods.

BACKGROUND INFORMATION

Producers and crop advisors often are tempted to wait as long as possible on young immature bolls in the top of the plant before making the decision to defoliate. These bolls are often insect damaged, small, of low fiber quality, and account for little additional gain but the perception of additional lint gain is difficult to overcome. Any delay in defoliation application is often enhanced as deteriorating weather increased time from defoliation application to harvest. Validation of the heat unit (HU) concept (NAWF5 + 850 HU) for 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. Traditional timings for defoliation include nodes above cracked boll (NACB) 4 or less and open bolls at 60% to 65%. The crop status at the different timings in these studies indicates this optimal complement to occur near 950 HU. However, in practice grower standards tend to approximate 1050 HU.

RESEARCH DESCRIPTION

The defoliation timing study was conducted over six consecutive years, 2001 to 2006, with sites in northeast, central, and southeast Arkansas. Replicated strips ran the

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length of the field and standard defoliation treatments were used at all locations. Defoliation timings were scheduled at 850, 950, and 1050 HU beyond cutout. The replicated strips were harvested with the producer's picker as each treatment became harvest-ready 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 AND DISCUSSION

Yields were similar for the 850 HU, 950 HU, and 1050 HU timings with 1234 lb lint/acre, 1223 lb lint/acre, and 1235 lb lint/acre, respectively. Harvest losses due to rainfall events were primarily responsible for the similar yields. Traditional timings for defoliation include NACB 4 or less and open bolls at 60% to 70%. The crop status at the different timings indicates this complement to occur near 950 HU. However, in practice grower standards tend to approximate 1000 to 1050 HU (Table 1). Yield penalties have been observed with defoliation prior to 850 HU. As a result, defoliation timings at 750 HU beyond cutout were not included in this evaluation.

Loan values were greatest at the 850 HU timing (\$0.5358/lb lint) and decreased numerically as defoliation was delayed from the 950 HU (\$0.5348/lb lint) and 1050 HU (\$0.5204/lb lint) timings. Average delays in defoliation from timing of 850 HU to a standard of 1050 HU were 12 to 14 days. This delay was often enhanced as deteriorating weather increased time from defoliation application to harvest.

In low-rainfall environments, reported yields generally improve with delayed defoliation. However, harvest losses due to rainfall events, which commonly occur in the Mid-South, were responsible for the similar yields in this study. The impact of earlier defoliation on reducing micronaire and avoiding quality deterioration as a result of delayed harvest in a wet environment, resulted in greater gross revenues (pounds lint $\times$ loan price) generated per acre.

PRACTICAL APPLICATION

Yields were similar for the three defoliation timings. Loan values were greatest at the 850 HU timing (\$0.5358/lb lint) and decreased as defoliation was delayed to the 950 HU (\$0.5348/lb lint) and 1050 HU (\$0.5204/lb lint) timings. Defoliation at 850 HU did not result in lower returns per acre and allowed for an earlier harvest. A 12- to 14-day harvest advantage, in environments where rainfall can result in harvest losses and fiber quality deterioration (commonly experienced in the Mid-South) can reap valuable rewards.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

Table 1. The effect of defoliation timing on plant maturity status, yield, and lint value.

Timing	Open bolls	NACB	Lint yield	Total revenue
(HU beyond cutout) ^z	(%)	(#)	(lb/acre)	(\$/acre)
850	43	4.5	1234	661.22
950	57	3.3	1223	654.02
1050	70	2.0	1235	642.76

^z Cutout defined at 5 nodes above the uppermost white flower.

Evaluation of Drip Irrigation for Cotton in Arkansas

*William C. Robertson, Frank E. Groves, Robert Hogan, Jr.,
Leo Espinoza, M. Ismanov, and Robin Franks¹*

RESEARCH PROBLEM

Drip irrigation of cotton is increasing throughout the United States particularly in the West. A major benefit of drip is the ability to apply small amounts of water at high frequency intervals. This provides the opportunity to maintain the soil moisture at a specified moisture deficit. This is particularly beneficial in areas of the Mid-South with soils that have shallow rooting potentials. However, significant rainfall and cloudy days received in the Mid-South present challenges for cotton production using drip irrigation that are not experienced in the West. Limited information is available concerning drip irrigation in the Mid-South.

BACKGROUND INFORMATION

Drip systems provide not only the potential to irrigate more frequently but also the ability to more readily maintain specific moisture deficits at a level below field capacity either for part or all of the irrigation season. Irrigating to maintain a specified root-zone soil-moisture deficit provides the opportunity for increased soil moisture storage from rainfall during the irrigation season. Timely delivery of nutrients through the system is another benefit.

Drip irrigation systems are more plentiful in the western United States. Low rainfall and the occurrence of few cloudy days contribute to the success of drip systems in the West. Significant rainfall and cloudy days received in the Mid-South present challenges for cotton production using drip irrigation that are not experienced in the West. The objectives of this study were to evaluate the growth and development of cotton grown under

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dryland, furrow, and low-pressure drip irrigation systems in Arkansas and to compare revenue and expenses associated with each system using partial budget analysis.

RESEARCH DESCRIPTION

A thirteen-acre field located on the Cotton Branch Experiment Station near Marianna, Ark., was utilized for this study. NetaFim USA sponsored this study by installing a low-pressure system on approximately five acres of this field. The drip irrigation, furrow irrigation, and dryland plots were arranged in a complete randomized design with four replications. The drip tape was installed to the side of each row. Poor water infiltration rates dictated installation on every row, as opposed to every other row as commonly installed for cotton in the western United States.

The cotton (*Gossypium hirsutum* L.) variety DP444BG/RR was planted 16 May 2006 into the silt loam study area utilizing no-till best management practices. The University of Arkansas irrigation scheduling program was used to schedule furrow irrigations. Daily evapotranspiration and crop coefficients were used to schedule drip timings and rates. Cultural practices were followed throughout the season. Partial budget analysis was utilized to compare differences in expenses for both irrigated methods compared to the dryland plots.

RESULTS AND DISCUSSION

Plant Growth and Development

COTMAN growth curves in Fig. 1 illustrate distinct differences prior to flowering for the dryland compared to either of the irrigation treatments. Different growth curves were observed from flowering to cutout for the furrow- and drip-irrigated plots.

Date of cutout as well as basic reproductive and vegetative growth parameters collected at cutout for each irrigation treatment, respectively, are included in Table 1. The drip-irrigated plots cutout five days later than the furrow-irrigated plots. This should not present a problem for cotton producers in the upper Mid-South where the length of growing season is a concern.

Irrigation rates and timings varied. Furrow irrigation timings were established using the University of Arkansas Irrigation Scheduling Program. Pan evaporation rates and soil moisture served as the basis for irrigation rates and timings in the drip. Irrigation rates were adjusted to achieve a six-inch depth average soil moisture of 25% to 30%. A total of 9.54 inches of water was applied to the furrow-irrigated plots in 6 events. The drip received a total of 8.2 inches of water in 32 irrigation events.

Fertilizer applications for the dryland consisted of 70-0-0 in the form of UAN32 in a single knife application just prior to squaring. The furrow-irrigated plots received 120-0-0 in the same manner as the dryland. The fertility program for the drip consisted of 130-0-120 applied through the drip system in the form of UAN32 and a liquid 15% potassium solution. Nitrogen applications were made during a period of 6 weeks beginning just prior to squaring to two weeks after first flower. Potassium applications were made during a period of four weeks beginning at first flower.

Mepiquat chloride (MC) needs differed in this study. No MC was applied in the dryland. A total of 46 oz/acre of MC was applied in three applications to the furrow-irrigated plots. A total of 41 oz/acre was applied to the drip.

Yield and Fiber Quality

Outstanding yields were observed in 2006. A lint yield advantage of 216 lb/acre was observed with the furrow irrigation over that of the dryland. An additional 561 lb lint/acre was produced with the drip over that of the furrow irrigation (Table 2). Fiber quality did not differ significantly between irrigation treatments.

Partial Budget Analysis

Revenues and expenses are included in Table 3 to reflect differences in yield for the irrigation systems and additional inputs beyond that used for the dryland system, which serves as the base for this analysis. Fixed costs are also included that basically reflect ownership costs associated with each of the irrigation systems. Although the fixed costs for the drip exceeded that of the furrow irrigation, land leveling costs often associated with furrow irrigation are not included. As a comparison, fixed costs of a center pivot are \$69.24/acre.

A cost of \$400/acre was used for the low-pressure drip irrigation system with a life of six years. Costs for the system and labor involved in its use and system life vary by location and according to water quality. An expected cost of this system can range from \$400 to \$600/acre with an expected system life of three to eight years.

PRACTICAL APPLICATION

Although this system was small, challenges were encountered similar to those that could be expected in a production situation. Learning curves such as dealing with the calculation of effective rainfall accumulation as well as having a good understanding of dealing with water quality issues are the most noted differences in the low-pressure drip system compared to furrow irrigation. In this, the second full year of this project, we have been able to improve yields of the drip as well as lower the drip production costs.

When comparing the net of partial total expenses, the drip is at an advantage over both the dryland and furrow-irrigated treatments. The ability to consistently replicate these results will likely result in an increase in utilization of drip-irrigation in the Mid-South, as seen in other areas of the Cotton Belt.

Water conservation is an additional benefit of drip not included in this budget analysis. A 14% reduction of water on an acre basis was observed in this study comparing drip to furrow. However, this savings is 39% when calculated on a per-unit production of lint.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

Table 1. Effect of irrigation on SquareMap data collected at cutout.

Irrigation	Retention	Retained fruit	Height	Nodes	H:N	Cutout	Cutout
	(% 1 st position)	(#/plant)	(in.)	(#)		(Date)	(DAP)
Dryland	93.3	9.4	40	17.0	2.4	1 Aug	77
Furrow	76.8	10.6	52	18.8	2.8	9 Aug	85
Drip	78.7	12.6	58	21.0	2.8	14 Aug	90

Table 2. Effect of irrigation treatment on yield and fiber quality parameters.

Irrigation	Turnout	Lint	Mic	Length	Strength	Uniformity	Color	Loan
	(%)	(lb/acre)		(in)	(g/tex)	(%)		(\$/lb lint)
Dryland	43.1	1184	4.8	1.15	32.5	83.8	41-1	0.5610
Furrow	44.3	1400	4.2	1.15	28.2	83.4	41-2	0.5570
Drip	43.0	1961	3.6	1.16	30.1	84.3	41-1	0.5595

Table 3. Partial budget analysis (\$/acre) for the three irrigation treatments.

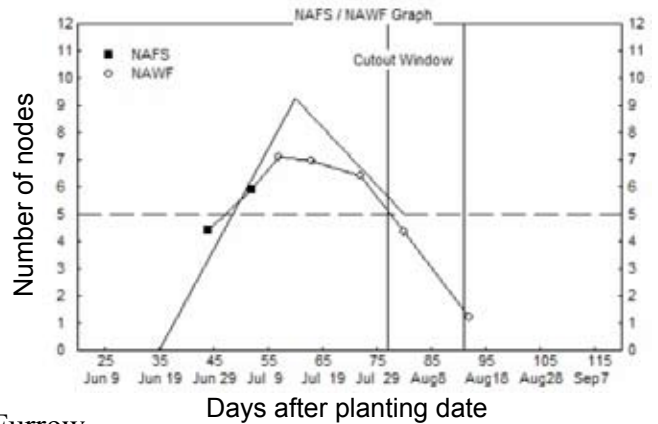
Parameter	Dryland	Furrow	Drip
Yield	1184 lb/acre	1400 lb/acre	1961 lb/acre
Loan (\$/lb lint)	\$0.5610	\$0.5570	\$0.5595
Lint revenue	\$664.22	\$783.30	\$1,097.18
Change in direct costs		\$59.13 (irr) ^z	\$206.82 (irr)
		\$12.84 (fert) ^y	\$58.00 (fert)
		\$7.39 (mc) ^x	\$6.59 (mc)
Net of partial direct expenses	\$664.22	\$703.94	\$825.77
Change in fixed costs		\$24.43 (irr)	\$89.94 (irr)
Net of partial total expenses	\$664.22	\$679.51	\$735.83

^z Actual expenses for acid and chlorine were used in this analysis. A cost savings of \$62.34 would be expected in a production-scale situation.

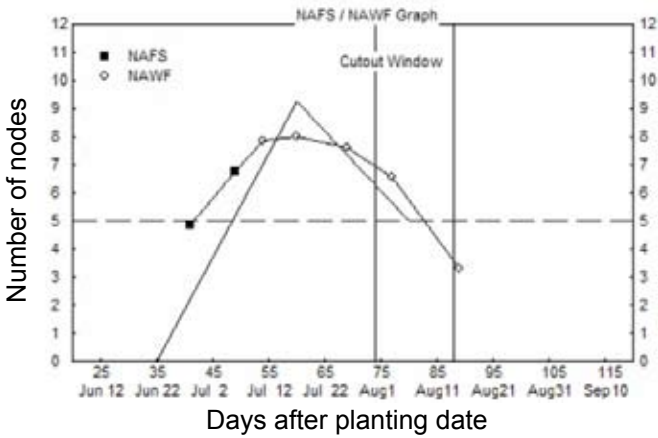
^y Irrigation.

^x Mepiquat chloride.

Dryland



Furrow



Drip

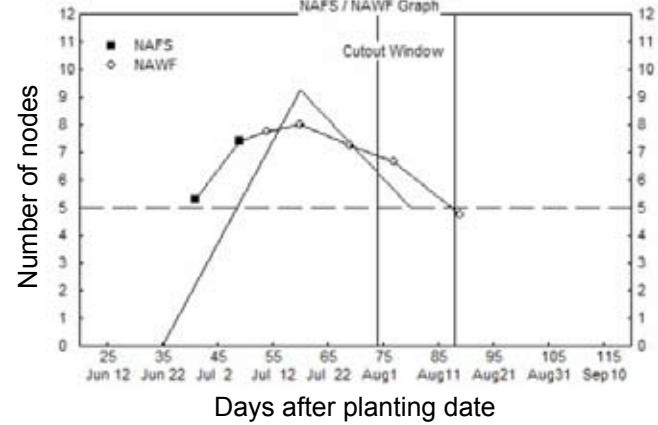


Fig. 1. COTMAN growth curves for dryland, furrow-, and drip-irrigated plots.

Effect of Potassium Fertilization on Seedcotton Yield

*Morteza Mozaffari, Nathan A. Slaton, Edwin E. Evans,
J. Varvil, Fred M. Bourland, and Claude Kennedy¹*

BACKGROUND INFORMATION AND RESEARCH PROBLEM

In 2005 more than one million acres of cotton (*Gossypium hirsutum* L.) were harvested in Arkansas. When needed, supplemental application of potassium (K) is essential for producing high yield and quality lint. During the past two decades, cotton-production systems have changed by advances in technology and introduction of new fast-fruited cultivars. Information on cotton response to K fertilization under current production practices will aid in developing agronomically sound K-fertilizer recommendations. The objective of this research was to evaluate the effect of K-fertilization rate on lint yield of modern cotton cultivars.

RESEARCH DESCRIPTION

In 2006, five replicated field experiments were established on soils commonly used for cotton production in Arkansas. Information on the soil series, previous crop, cotton cultivar(s), and agronomically important dates is provided in Table 1. Prior to application of any soil amendments, a composite soil sample consisting of 10 to 12 soil cores was collected from the 0-to 6-in. soil depth of each replication at all sites except site LEG67 where composite soil samples were collected from each plot. Soil samples were oven-dried at 65°C, crushed, and extracted with Mehlich-3 solution and the elemental concentrations were measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Potassium fertilizer (KCl) was applied in one single application at rates of 0, 30, 60, 90, 120, and 150 lb K₂O/acre at all sites except MSG62,

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which received rates of 0, 35, 70, 105, and 140 lb K₂O/acre. Each experimental treatment was replicated four times. Individual plots were 45-ft long and 12.5-ft wide allowing for four rows of cotton with 38-in. wide row spacings. All other cultural practices including fertilization closely followed the University of Arkansas recommendations for irrigated cotton production. Analysis of variance (ANOVA) was performed using the GLM procedure of SAS. Sites were analyzed separately. Mean separations were performed by the Waller Duncan minimum significant difference (MSD) test at a significance level of 0.05 and 0.10.

RESULTS AND DISCUSSION

Preplant mean soil-test K ranged from 90 to 286 ppm among sites (Table 2), relative to an optimum K level of 131 to 175 ppm for cotton production in Arkansas. Seedcotton yields were not affected by cultivar or the cultivar $\times$ annual K rate interaction at any of the sites, but were significantly ($P=0.05$) affected by K rate, averaged across cultivars, at LEG67, LEG69, and MSG64A ($P<0.1$, Table 4). Compared with the unfertilized control, application of >60 lb K₂O/acre significantly ($P=0.1$) increased seedcotton yields on the silt loam soils at LEG67 and LG69.

PRACTICAL APPLICATION

Potassium fertilizer rate significantly ($P=0.05$) increased seedcotton yields at two sites with silt loam soils. The need for K fertilization was accurately predicted by soil test-based cotton fertilization guidelines for the silt loam soils where near maximum seedcotton yields were produced with 90 to 150 lb K₂O/acre.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

Table 1. Selected agronomic information for cotton K fertilization experiments conducted in Arkansas during 2006.

Site	Soil series	Previous crop	Cultivar(s)	K ₂ O applied	Planting	First square	Bloom date	Cutout date	Harvest date
LEG67	Convent silt loam	cotton	ST5599 DP445	10 April	22 May	20 June	17 July	27 July	14 Oct
LEG69	Loring silt loam	corn	ST5599 DP445	11 April	22 May	20 June	17 July	27 July	19 Oct
LEGO61	Grenada silt loam	cotton	DP444	9 May	1 May	8 June	26 June	23 July	22 Sep
MSG62	Sharkey Steele Complex	cotton	ST4892 DP444	3 May	3 May	14 June	10 July	30 July	9 Oct
MSG64-A	Sharkey silty clay	soybean	DP445	3 May	3 May	14 June	10 July	29 July	9 Oct

Table 2. Selected soil chemical property means (0- to 6-in. depth) from samples taken before planting of cotton K-fertilization trials conducted at Agricultural Experiment Stations and a commercial farm in Arkansas during 2006.

Site	Soil pH ^z	Soil NO ₃ -N ^y	Mehlich-3 extractable nutrients										Clay	Texture
			P	K	Ca	Mg	Mn	Cu	Zn	B	Sand	Silt		
LEG67	6.0	3	39	125	1293	272	168	1.3	1.7	3.4	11	64	25	silt loam
LEG69	6.9	7	49	96	1057	280	124	1.1	1.9	0.5	15	67	19	silt loam
LEGO61	6.2	6	26	162	1428	467	222	1.4	2.2	0.9	-	-	-	-
MSG62	6.0	9	70	146	972	212	233	1.0	2.6	1.6	57	18	25	sandy clay loam
MSG64-A	6.1	8	61	286	1063	263	231	1.1	2.6	1.5	27	22	51	clay

^z Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.

^y NO₃-N measured by ion-specific electrode.

Table 3. Effect of K-fertilizer rate on seedcotton yield in trials conducted in Arkansas during 2006.

K ₂ O rate (lb/acre)	LEG67	LEG69	LEGO61	MSG64-B	K ₂ O rate (lb/acre)	MSG62
	[seedcotton yield (lb/acre)]					[seedcotton yield (lb/acre)]
0	2658	2347	2704	1360	0	1840
30	2675	2793	2496	1496	35	1840
60	2773	2855	2678	1521	70	1775
90	2965	2965	2987	1548	105	1838
120	3031	3171	2855	1536	140	1977
150	3109	3261	2777	1500	---	---
P value	0.0074	0.0416	0.4373	0.9058	---	0.4980
MSD at 0.05 ^z	274	645	---	---	---	---
MSD at 0.10 ^y	231	539	---	---	---	---

^{z, y} Minimum significant difference at P=0.05 and P=0.1 as determined by Waller-Duncan Test.

Effect of Phosphorus Fertilization and Cultivar on Seedcotton Yield at Multiple Locations

Morteza Mozaffari, Nathan A. Slaton, Fred M. Bourland, and Claude Kennedy¹

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Phosphorus (P) availability is important for balanced nutrition and producing an optimal cotton (*Gossypium hirsutum* L.) yield. Improved P-fertility recommendations will enable the growers to get a sound return on their fertilizer investment and reduce the risk of potential environmental concerns over eutrophication of water supplies. In 2006 the University of Arkansas changed its soil-test method from a modified Mehlich-3 to the standard Mehlich-3 method, which extracts slightly more P from soil. Because of these changes, the soil-test calibration data that support current P fertilization recommendations need to be updated. The objectives of this study were to evaluate the effect of P-fertilizer rate and cotton cultivar on seedcotton yield at multiple locations in Arkansas.

RESEARCH DESCRIPTION

A total of four replicated field experiments were conducted on the University of Arkansas Lonnn Mann Cotton Experiment Station (LMCRS) and two commercial farms in 2006. Information on soil series, previous crop, cotton cultivar(s), and agronomically important dates are provided in Table 1. Prior to application of any soil amendments, 10 to 12 soil cores were collected and composited from the 0- to 6-in. soil depth of each replication at all sites. Soil samples were extracted with Mehlich-3 solution and the elemental concentrations were measured. Selected soil properties for each site are listed in Tables 2. Phosphorus was applied at rates of 0, 30, 60, 90, and 120 lb P_2O_5 /acre at LEG610 and LEGO61; 0, 30, 60, and 90 lb P_2O_5 /acre at LEG65; and 0, 30, and 60 lb P_2O_5 /acre at PHG64. Each treatment was replicated four times. Individual plots were 45-ft long and 12.5-ft wide, allowing for four rows of cotton with 38-in. wide row spac-

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ings. All other cultural practices including fertilization closely followed the University of Arkansas recommendations for irrigated cotton production.

Analysis of variance (ANOVA) was performed using the GLM procedure of SAS. Sites were analyzed separately. Mean separations were performed by the Waller Duncan minimum significant difference (MSD) test at a significance level of 0.05.

RESULTS AND DISCUSSION

Preplant mean Mehlich-3-extractable P ranged from 30 to 374 ppm, and the soil-test P was classified as Medium (26-35 ppm) or Optimum (36-50 ppm) (Table 2). Based on the soil-test P levels little or no significant yield responses from P fertilization were expected.

There was no significant cultivar or cultivar $\times$ P rate effect. Seedcotton yield was not significantly ($P \leq 0.1$) affected by cultivar, P rate, or the cultivar $\times$ P rate interaction for any of the four sites (Table 3). The data support the current University of Arkansas cotton P-fertility recommendations.

PRACTICAL APPLICATION

Cotton yield did not respond to P fertilization at four sites with soils having preplant Mehlich-3-extractable P that ranged from 30 to 37 ppm. Similar yield results have been observed from 2003 to 2005, which suggests that additional research with a wider range of soils is needed to develop improved P-fertilizer recommendations for cotton production in Arkansas.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees and the Division of Agriculture, University of Arkansas..

Table 1. Selected agronomic information for cotton P fertilization experiments conducted at four sites in Arkansas during 2006.

Site	Soil series	Previous crop	Cultivar(s)	P ₂ O ₅ application date	Planting date	First square	Bloom date	Cutout date	Harvest date
LEG610	Loring silt loam	Corn	DP444	11 April	18 May	20 June	17 July	27 July	19 Oct
LEG65	Convent silt loam	Cotton	DP444 ST4892	10 April	20 May	20 June	17 July	27 July	14 Oct
LEGO62	Grenada silt loam	Cotton	DP444	9 May	1 May	8 June	26 June	23 July	22 Sept
PHG64	Grenada silt loam	Cotton	DP444	6 June	24 April	8 June	26 June	21 July	20 Sept

**Table 2. Selected soil chemical property means (0- to 6-in. depth)
from samples taken before planting in cotton
P-fertilization trials conducted at four sites in Arkansas during 2006.**

Location	Soil	Mehlich-3 extractable nutrients						
	pH	P	K	Ca	Mg	Mn	Cu	Zn
		----- (ppm) -----						
LEG65	5.6	35	129	1064	208	165	0.96	1.7
LEG610	6.7	34	104	1134	319	106	1.1	1.7
LEGO62	6.4	30	123	1365	440	248	1.7	2.3
PHG64	6.8	37	144	1905	241	123	1.3	3.3

**Table 3. Effect of soil applied P-fertilizer rate on seed-
cotton yield in four trials conducted in Arkansas during 2006.**

P rate	LEG65	LEG610	LEGO62	PHG64
(lb P ₂ O ₅ /acre)	----- [seedcotton yield (lb/acre)] -----			
0	2870	2905	3427	2932
30	2802	3009	3382	2980
60	2961	3377	3441	3303
90	2875	2765	4003	---
120	---	2799	3114	---
150	---	---	3268	---
P value	0.8688	0.3029	0.1634	0.3092

Sidedress Application of Nitrogen and Pre-Sidedress Soil Nitrate Test Can Improve Nitrogen Management for Cotton

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Supplemental application of N is needed to produce optimally economic cotton (*Gossypium hirsutum* L.) yields. Denitrification and leaching losses of N may occur between the preplant soil sampling time and the period of high N demand by cotton (i.e., first square). Therefore, there is a potential to improve N-fertilizer recommendations by basing N rates on analysis of soil samples collected immediately before the first square from deeper soil samples (e.g., top 12 in.). This approach is referred to as the presidedress soil NO₃-N test (PSNT). Evaluation of PSNT is a timely topic, given the high price of N fertilizers and increasing environmental concern over water quality. The objectives of this study were to 1) evaluate the effect of sidedressed N-fertilizer rate on seedcotton yield, and 2) identify soil PSNT levels beyond which no agronomic yield response to N fertilizer will be expected.

RESEARCH DESCRIPTION

In 2007, eight replicated field experiments were conducted at multiple locations on soils commonly used for cotton production in Arkansas (Table 1). Prior to fertilizer application and planting, composite soil samples were collected from the 0- to 6-in. soil depth of each replication. Selected soil property averages for each site are listed in Table 2. Each experimental plot was 45-ft long and 4-rows wide. Nitrogen fertilizer was applied in split applications at total-N rates of 0, 30, 60, 90, 120, and 150 lb N/acre or 0, 35, 70, 105, and 140 lb N/acre (LEG66 and MSG61 sites). Prior to or at planting,

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20 lb N/acre as ammonium sulfate was side-dressed at all sites to all treatments except the 0 lb N/acre treatment. The balance of each total-N rate was sidedressed as urea by hand at first-square stage. Prior to the application of sidedressed N, soil samples were collected by replication from the 0- to 12-in. soil depth, composited by replication, and analyzed for $\text{NO}_3\text{-N}$.

RESULTS AND DISCUSSION

Preplant soil samples showed that the soil texture among sites ranged from clay to loam and soil pH ranged from 6.1 to 6.7 (Table 2). The PSNT levels ranged from 8 to 51 ppm and were >30 ppm at two sites (Table 3). For sites with two cultivars, the main effect of cultivar or the interaction between cultivar and N rate were not significant ($P>0.10$), therefore, seedcotton yields were averaged across cultivar. Sidedressed N-fertilizer rate significantly ($P\leq 0.05$) increased seedcotton yields at all sites except the POG63 site (Table 4) where the PSNT level was 42 ppm (Table 3). Seedcotton yields ranged from 1278 to 3501 lb/acre for 0 lb N/acre and 2407 to 3658 lb/acre for the greatest applied N rate. The N rate that produced the statistically ($\text{MSD}=0.10$) greatest seedcotton yield varied among sites including 0 lb N/acre for POG63, 30 lb N/acre for PHG62, 60 lb N/acre for GRG61 and MSG63A, 105 lb N/acre for LEG66 and MSG61, and 150 lb N/acre for LEG64 and MSG63B (Table 4). The N rate required to produce the statistically greatest seedcotton yield at each site generally increased as the PSNT soil $\text{NO}_3\text{-N}$ concentration decreased (Table 3), suggesting that the PSNT shows great promise in refining N rates for cotton.

PRACTICAL APPLICATION

Sidedress application of N significantly increased seedcotton yields at 7 of 8 sites. However, when PSNT was >21 ppm, we observed minimal or no response to N-fertilizer. When PSNT was ≤ 21 ppm, near maximal seedcotton yields were produced by application of 60 to 120 lb N/acre.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fees and the Division of Agriculture, University of Arkansas.

Table 1. Selected agronomic information for cotton N-fertilization experiments conducted at agricultural experiment stations and commercial fields in Arkansas during 2006.

Site	Soil series	Previous crop	Cultivar(s)	Planting date	Seedling emergence	First square	Bloom date	Cutout date	N Application dates		Harvest date
									First	Second	
GRG61	Lafe silt loam	Cotton	ST4554	13 May	21 May	30 June	10 July	5 Aug	17 May	12 June	25 Oct
LEG64	Convent silt loam	Cotton	DP445	20 May	27 May	20 June	17 July	7 Aug	10 April	29 June	14 Oct
LEG66	Convent silt loam	Cotton	ST5599								
			Dyna-Grow	20 May	27 May	20 June	17 July	7 Aug	10 April	29 June	14 Oct
			2520								
MSG61	Sharkey-Steele complex	Soybean	DP444	3 May	12 May	14 June	10 July	30 July	4 May	27 June	9 Oct
			ST4892								
MSG63-A	Sharkey silty clay	Cotton	DP445	3 May	11 May	14 June	10 July	29 July	4 May	27 June	9 Oct
MSG63-B	Sharkey silty clay	Cotton	ST5599	16 May	22 May	21 June	17 July	11 Aug	4 May	27 June	9 Oct
PHG62	Dubbs silt loam	Cotton	ST5599	16 May	22 May	14 June	10 July	1 Aug	16 April	22 June	10 Oct
POG63	Dundee silt loam	Cotton	DP444	19 May	25 May	14 June	10 July	3 Aug	28 April	13 June	2 Oct
			ST5599								

Table 2. Selected soil chemical property means (0- to 6-in. depth) from samples taken before planting in cotton N-fertilization trials conducted at agricultural experiment stations and commercial fields in Arkansas during 2006.

Site	Soil pH ^z	Soil NO ₃ -N ^y	Mehlich-3-extractable nutrients							Textural analysis			
			P	K	Ca	Mg	Mn	Cu	Zn	Sand	Silt	Clay	Texture
			----- (ppm) -----							----- (%) -----			
GRG61	6.6	19	97	236	1256	226	202	1.1	3.3	4	75	21	silt loam
LEG64	6.1	3	32	104	1170	224	191	1.1	2.1	8	69	22	silt loam
LEG66	6.4	3	44	115	1311	259	161	1.6	2.9	5	70	25	silt loam
MSG61	6.0	15	172	2455	431	84	2.8	4.4	5.4	48	21	32	sandy clay loam
MSG63-A	6.6	9	72	235	3743	664	57	4.1	5.4	34	24	42	clay
MSG63-B	6.6	9	72	235	3743	664	57	4.1	5.4	34	24	42	clay
PHG62	6.2	51	80	250	1295	132	408	1.7	4.3	12	65	23	silt loam
POG63	6.7	19	40	121	1772	206	95	1.2	2.9	39	38	23	loam

^z Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.^y NO₃-N measured by ion-specific electrode.

Table 3. Soil NO₃-N concentration and pH means (0- to 12-in. depth) from samples taken shortly before sidedress N application in cotton N-fertilization trials conducted at agricultural experiment stations and commercial fields in Arkansas during 2006.

Site	Soil pH	NO ₃ -N ^z (ppm)
GRG61	6.1	21
LEG64	5.2	13
LEG66	5.1	20
MSG61	6.1	16
MSG63-A	6.5	8
MSG63-B	6.5	8
PHG62	6.2	51
POG63	5.4	42

Table 4. Effect of soil-applied, N-fertilizer rate on seedcotton yield from eight trials conducted at agricultural experiment stations and commercial fields in Arkansas during 2006.

N rate (lb/acre)	GRG61	LEG64	MSG63-A	MSG63-B	PHG62	POG63	N rate (lb/acre)	LEG66	MSG61
0	2684	1315	1581	1278	3501	2441	0	1479	1547
30	3553	1900	1922	1569	3993	2587	35	1733	1865
60	3816	2526	2357	1674	3737	2485	70	2083	2208
90	4294	2673	2304	2058	3580	2743	105	2216	2274
120	4166	3025	1940	1992	3364	2467	140	2584	2407
150	2585	3115	2483	2428	3658	2552	---	---	---
P value	0.0018	<0.0001	0.0389	0.0002	0.0193	0.2659		0.0022	<0.0001
MSD at 0.05 ^z	706	312	650	376	372	---		464	212
MSD at 0.10 ^y	589	289	542	318	310	---		389	181

^{z, y} Minimum significant difference at $P=0.05$ and 0.10 as determined by Waller-Duncan Test.

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

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Economically successful cotton (*Gossypium hirsutum* L.) production must incorporate rigorous nitrogen (N)-fertilization management and water-management practices. Research examining the interaction between N-fertilizer rates and irrigation methods is scant. This is especially true for the humid production conditions of southeast Arkansas (McConnell et al., 1988). The objectives of these studies were to evaluate the growth, development, and yield of intensively managed cotton as a function of N-fertilization and soil-N dynamics under different irrigation methods.

Mismanagement of N may have detrimental consequences in cotton production. Oversupply of N to a developing cotton crop may delay maturity and cause 'rank' growth (Maples and Keogh, 1971). Reductions in yield and lint quality due to N deficiency may reduce the value of the crop and have adverse economic consequences for producers (Bondada et al., 1996; Radin and Mauney, 1984).

Cotton yields have typically increased with increasing N fertilization throughout previous years of this test (McConnell et al., 1988; McConnell and Baker, 1998). The N treatments that usually produced the greatest yields were applications of 60 to 150 lb N/acre, depending upon the irrigation treatment and year. The yields of the center-pivot irrigation 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.

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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 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 seasonal rainfall resulted in standing water that delayed maturity of 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.

PROCEDURES

An experiment to examine the interactions of N-fertilization strategy (N-rate and application times) and irrigation method was initiated at the Southeast Branch Experiment Station on an Hebert silt loam soil in 1982. This test, the McConnell-Mitchell Plots, is the oldest continuous field experiment 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). Phosphorus and potassium fertilizer were applied preplant annually to all plots at rates of 46 lb P_2O_5 /acre and 60 lb K_2O /acre. Nitrogen fertilization was discontinued for the 2000 through 2003 growing seasons to examine the effects of residual soil nitrate-nitrogen (NO_3 -N) on cotton development. Nitrogen treatments were resumed in 2004 after 2003 yield results indicated minimal yield response from residual N. Soil samples were taken from the plots and analyzed for residual NO_3 -N to a depth of five feet in 2000 and 2004 (Tables 3 and 4).

The McConnell-Mitchell Plots were planted on 12 May 2003, 11 May 2004, and 6 May 2005. The 2003 crop was influenced by cool, wet conditions early in the growing season. Timely rainfall throughout June and July precluded most irrigation in 2005. Just prior to harvest, intense rainfall and wind from Hurricane Katrina struck the test from 23 to 26 September 2005. Yield loss to the hurricane was estimated to be 20%.

The experimental design was a randomized complete block with seedcotton yield data analyzed by year. All data were analyzed using the Statistical Analysis System (SAS). F-tests and least significant differences (LSD) were calculated at the $\alpha=0.05$ level of probability. Only yield responses of cotton to N-fertilization and soil NO_3 -N concentrations are presented in this report.

RESULTS AND DISCUSSION

Residual soil-N was largely depleted under furrow-flow and center-pivot irrigation after four years of cotton production without N fertilization in 2004 (Tables 3 and 4). Residual N under dryland production conditions was also substantially less in 2004 than

in 2000. Additionally, the zone of accumulation of residual N appeared to be deeper in the soil profile in 2004 than in 2000, under dryland production conditions. The effects of residual soil-N were last tested during the 2003 growing season. Nitrogen fertilization was resumed in 2004 after soil sampling.

Some of the worst early-season growing conditions during the span of the McConnell-Mitchell Plots occurred in 2003 (Table 5). Cool, wet weather persisted from early May through June and delayed the growth, development, and squaring of the seedlings. The impaired plants of 2003 produced the lowest mean yields during the last three years of this study. The supplemental water applied in the irrigated blocks increased plant height (data not shown) and probably total plant weight but delayed maturity of the crop and reduced yields compared to the dryland block. Cotton yield response to residual soil- $\text{NO}_3\text{-N}$ was not significant in either the high-frequency or furrow-flow irrigation methods. The lack of yield response in these two blocks indicates that the residual soil $\text{NO}_3\text{-N}$ was depleted. Cotton yields were significantly affected by residual $\text{NO}_3\text{-N}$ in the dryland block. The greatest yielding treatments were those testing highest in residual $\text{NO}_3\text{-N}$ in 2000, which had previously received 120 to 150 lb N/acre (Table 3). These results indicate that substantial residual soil $\text{NO}_3\text{-N}$ still influenced cotton development under dryland production conditions.

Nitrogen fertilization treatments were resumed in spring 2004. The 2004 growing season was more moderate than the previous two years, thereby producing generally greater yields than in 2003 (Table 6). The interaction of N-treatment with irrigation method significantly affected seedcotton yield. The greatest yields in 2004 were associated with furrow-flow irrigation. Center-pivot irrigation tended to delay maturity of the crop, resulting in the lowest yields. Dryland cotton was earliest in maturity and averaged only 14.2% less than the furrow-flow irrigated cotton.

Yield increases were observed under all irrigation methods with increasing N rate, though not all differences were significant. The unfertilized control plots produced the lowest yields within each irrigation method. The greatest yielding N treatments received the maximum, 150 lb N/acre, as a two-way split under center-pivot irrigation and as three-way splits under furrow-flow irrigation and dryland production conditions. Plant height and plant maturity were also significantly affected by N-fertilization treatments (data not shown).

The 2005 growing season was moderate with respect to early-season rainfall and temperatures. Further, timely rainfall in the summer months between first square and first flower reduced the requirement for supplemental irrigation. The 2005 growing season was moving toward a high-yielding conclusion when wind storms and heavy rainfall from Hurricane Katrina struck the test just prior to harvest. Yield loss due to Hurricane Katrina was estimated to be 20% (Table 7). Furrow-flow-irrigated cotton produced the greatest overall yields but averaged only 251 lb seedcotton/acre more than dryland cotton, the lowest yielding irrigation method.

The impact of N treatments on seedcotton yield was not as dramatic as observed in 2004 (Table 7). Irregular increases with increasing N rate occurred under all irrigation methods, but many differences were insignificant. Maximum yields were found with 90, 150, and 120 lb N/acre with center-pivot irrigation, furrow-flow irrigation, and dryland production, respectively. The lowest mean yields were produced by the

unfertilized controls within the center-pivot and furrow-flow irrigation methods. The 30 lb N/acre was the lowest yielding treatment under dryland conditions but was not significantly less than the unfertilized control.

Yields were at historical lows on the McConnell-Mitchell Plots in 2006 (Table 8), and the coefficient of variation at a historical high at 36.07. The mean yield for all three irrigation blocs was only 1121 lb seedcotton/acre, less than a bale of lint per acre. Main effect differences in N-treatments and among irrigation blocks were observed, but there were no significant interaction effects between irrigation method and N fertilization. Yield response of the cotton to N-fertilization and irrigation methods should be suspect, compared with other years.

PRACTICAL APPLICATIONS

Irrigated cotton generally produced higher yields than cotton grown under dryland conditions, but the highest yielding irrigation method depended on the annual agronomic and climatic conditions.

Cotton yield response to residual soil-N from previous N-fertilization treatments tended to decline with time. Residual soil-N was sufficient the first year (2002) to produce relatively high yields when previous N-fertilization rates were high and cotton was irrigated. After three growing seasons (2000, 2002, and 2003) and one fallow season (2001), cotton yield response in 2003 to residual soil-NO₃-N was negligible for irrigated cotton, with only the dryland irrigation producing seedcotton yields that increased as previous N rate increased.

Resumption of N fertilization treatments in 2004 immediately resulted in significant yield differences due to N rates and the interactions of N treatment with irrigation methods. Similar results were observed in 2005 despite the impact of Hurricane Katrina on the test. Generally, greater yields were produced by greater N-rate treatments under all irrigation methods. Yield results observed in 2006 were abnormal and should not be considered in the overall evaluation of N-fertilization and irrigation methods.

ACKNOWLEDGMENTS

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Table 1. Duration, tensiometer thresholds and depths, and water application rates for three irrigation methods used in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark., since 1993.

Irrigation method	Duration	Tensiometer		Water applied ^z
		Threshold (cbar)	Depth (in.)	
High-frequency	Planting to P.B. ^y	35	6	0.75
center-pivot	P.B. to Aug. 15	35	6	1.00
Furrow-flow	Until Aug. 15	55	12	Not precise
Dryland	Not irrigated	--	--	--

^z Water application rate per irrigation.

^y P.B. = peak bloom.

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

Total-N rate	N-fertilizer application rates and timing		
	After emergence	First square	First flower
	(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 (NO₃-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split applied, half preplant, and half at first square) under three irrigation methods in the McConnell-Mitchell study in spring 2000.

Soil depth (in.)	Irrigation method and total N-fertilizer rate (lb N/acre)																	
	Furrow-irrigated						Dryland (non-irrigated)						High-frequency center-pivot					
	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
----- (lb residual-NO ₃ -N/acre) -----																		
0 - 6	2	2	2	2	3	3	6	6	6	29	87	65	1	1	3	3	2	2
6 - 12	2	2	1	2	2	2	5	9	6	33	108	102	1	1	2	3	3	5
12 - 18	2	3	3	2	3	4	4	6	5	35	138	135	2	1	3	3	3	11
18 - 24	3	3	3	2	4	7	4	5	6	36	125	111	2	1	2	1	2	20
24 - 30	3	3	3	3	4	7	4	4	6	31	91	104	2	3	2	2	3	18
30 - 36	2	3	3	3	5	6	3	3	5	22	58	68	2	3	1	3	4	10
36 - 42	3	3	3	3	4	7	3	3	4	12	54	37	2	2	2	3	4	7
42 - 48	3	2	3	2	4	9	2	3	3	7	37	21	2	2	3	3	6	6
48 - 54	3	3	3	3	4	8	3	3	4	6	21	15	2	3	2	3	6	4
54 - 60	2	2	3	2	7	6	13	6	30	2	33	57	6	4	2	2	5	7
Mean	2	3	3	2	4	6	5	5	8	21	75	71	2	2	2	3	4	9

Table 4. Residual nitrate-nitrogen (NO₃-N) to a depth of five feet in six-inch increments from five N-fertilization rates (Table 1, split applied, half preplant, and half at first square) under three irrigation methods in the McConnell-Mitchell study in spring 2004.

Soil depth	Irrigation method and total N-fertilizer rate (lb N/acre)																	
	Furrow-irrigated						Dryland (non-irrigated)						High-frequency center-pivot					
	0	30	60	90	120	150	0	30	60	90	120	150	0	30	60	90	120	150
(in.)	----- (lb residual-NO ₃ -N/acre) -----																	
0 - 6	3	2	1	2	4	2	4	4	4	3	6	4	2	3	3	4	2	3
6 - 12	1	1	2	2	2	2	4	4	4	3	4	6	2	1	3	2	2	3
12 - 18	2	2	2	5	2	2	5	5	5	5	6	8	2	2	3	2	2	2
18 - 24	4	3	3	3	3	3	5	5	5	5	12	9	2	2	3	2	2	2
24 - 30	3	2	3	4	3	3	5	5	6	6	13	41	2	2	3	2	3	2
30 - 36	3	3	3	3	3	3	5	4	6	9	19	52	2	2	3	2	3	2
36 - 42	3	2	3	3	3	3	5	4	6	12	37	80	3	2	3	2	3	2
42 - 48	2	2	3	3	2	3	5	5	7	17	54	89	3	2	3	3	3	3
48 - 54	2	2	3	3	3	3	5	5	7	17	64	89	3	2	3	3	3	3
54 - 60	2	2	2	3	3	3	5	6	7	10	41	79	2	3	3	3	3	3
Mean	3	2	2	3	3	3	5	5	6	9	26	45	3	2	3	2	3	3

Table 5. Seedcotton yield response to residual N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2003 in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N rate	N-rate and timing			Yield, by irrigation method			N-rate mean
	Preplant	First square	First flower	Center pivot	Furrow irrigated	Dryland	
	----- (lb N/acre) -----			----- (lb seedcotton yield/acre ²) -----			
150	75	75	0	1833	1406	2568	1936
150	50	50	50	1873	1463	2659	1998
150	30	60	60	2244	1412	2246	1967
120	60	60	0	2045	1646	2671	2120
120	40	40	40	2003	1271	2678	1983
90	45	45	0	1882	1353	1815	1677
90	30	30	30	1780	1426	2344	1852
60	30	30	0	1770	1493	1507	1593
30	15	15	0	1805	1381	1905	1697
0	0	0	0	1796	1284	1237	1439
To compare N-treatment means within irrigation method LSD(0.05) = 397							
To compare N-treatment means between irrigation methods LSD(0.05) = 472							
Irrigation method mean yield				1904	1413	2169	

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

Table 6. Seedcotton yield response to N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2004 in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N rate	N-rate and timing			Yield, by irrigation method			N-rate mean
	Preplant	First square	First flower	Center pivot	Furrow irrigated	Dryland	
	----- (lb N/acre) -----			----- (lb seedcotton yield/acre ²) -----			
150	75	75	0	3320	3870	3277	3476
150	50	50	50	3134	4042	3930	3690
150	30	60	60	3049	4467	3691	3710
120	60	60	0	2948	3829	3413	3396
120	40	40	40	3008	3888	3821	3562
90	45	45	0	2756	3761	3098	3205
90	30	30	30	2749	3697	3323	3241
60	30	30	0	2730	3037	2563	2777
30	15	15	0	2077	2974	2425	2475
0	0	0	0	1757	2224	1048	1676
To compare N-treatment means within irrigation method LSD(0.05) = 412							
To compare N-treatment means between irrigation methods LSD(0.05) = 663							
Irrigation method mean yield				2753	3563	3058	

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

Table 7. Seedcotton yield response to N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2005 in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N rate	N-rate and timing			Yield, by irrigation method			N-rate mean
	Preplant	First square	First flower	Center pivot	Furrow irrigated	Dryland	
	----- (lb N/acre) -----			----- (lb seedcotton yield/acre ²) -----			
150	75	75	0	2696	2856	2568	2707
150	50	50	50	2558	3124	2778	2820
150	30	60	60	2686	3185	2672	2853
120	60	60	0	2711	3156	2766	2878
120	40	40	40	2849	2856	2870	2858
90	45	45	0	2950	2986	2527	2817
90	30	30	30	2453	2815	2650	2645
60	30	30	0	2870	2655	2321	2615
30	15	15	0	2391	2195	2524	2370
0	0	0	0	2314	1784	1423	1840
To compare N-treatment means within irrigation method LSD(0.05) = 340							
To compare N-treatment means between irrigation methods LSD(0.05) = 596							
Irrigation method mean yield				2646	2761	2510	

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

Table 8. Seedcotton yield response to N from ten nitrogen (N)-fertilization treatments under three irrigation methods during 2006 in the McConnell-Mitchell Plots at the Southeast Branch Experiment Station near Rohwer, Ark.

Total N rate	N-rate and timing			Yield, by irrigation method			N-rate mean
	Preplant	First square	First flower	Center pivot	Furrow irrigated	Dryland	
	----- (lb N/acre) -----			----- (lb seedcotton yield/acre ²) -----			
150	75	75	0	1344	1611	241	1085
150	50	50	50	1650	1999	518	1419
150	30	60	60	1248	1861	351	1181
120	60	60	0	1379	1737	509	1249
120	40	40	40	1406	1592	498	1157
90	45	45	0	1545	1782	244	1199
90	30	30	30	1462	1563	399	1167
60	30	30	0	1145	1327	139	861
30	15	15	0	1653	1511	263	1106
0	0	0	0	990	1394	48	804
To compare N-treatment means LSD(0.05) = 212							
To compare irrigation methods means LSD(0.05) = 94							
Irrigation method mean yield							
				1380	1638	315	

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

Weed Management Needs in Arkansas Cotton

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RESEARCH PROBLEM

Because cotton (*Gossypium hirsutum* L.) consultants routinely scout fields, they are aware of the weed management problems and needs of cotton producers. Surveys can be used to document current problematic weeds and prevalent management practices, which will aid in developing weed management and weed biology research and educational efforts in cotton (Webster and Coble, 1997).

BACKGROUND INFORMATION

Weed management practices have changed dramatically since the release of glyphosate-resistant (Roundup Ready®) cotton in 1997 and cotton with enhanced resistance (Roundup Ready Flex®) in 2006 (Young, 2006). Enhanced glyphosate-resistant technology (Flex®) will result in even greater reliance on a single herbicide mode of action, which may increase the incidence of resistant weeds.

Shifts in the weed spectrum as a result of the widespread adoption of glyphosate-resistant crops and reliance on a single herbicide mode of action are believed to have already reached economic concern (Culpepper, 2006), and horseweed (marestail) and Palmer amaranth populations are continuing to develop resistance to glyphosate (Norsworthy et al., 2007). This paper presents the results of a survey targeting several aspects of cotton weed management in Arkansas so that our research and extension programs will be driven by real and immediate problems as well as long-range concerns.

RESEARCH DESCRIPTION

A direct mail survey (Tables 1 and 2) was sent to 265 certified crop advisors in Arkansas and crop consultants registered with the Arkansas Agricultural Consultants

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Association. The survey contained questions regarding a) current weed management practices, b) herbicide-resistant weeds, c) problematic weeds, and d) research and educational priorities. Respondents were also asked to describe research and educational priorities that will help improve cotton production.

RESULTS AND DISCUSSION

Response rate to the survey represented consultants scouting 34% of the 1,150,000 cotton acres grown in Arkansas. Tables 1 and 2 summarize responses concerning management practices and herbicide-resistant weeds. It is obvious that current management practices center around RoundupReady® (glyphosate-resistant) cotton and that the adoption of RoundupReady Flex® cotton (enhanced resistance) will probably increase the use of glyphosate. Limiting herbicide use to a single mode of action is a prescription for development of resistant weeds, and concern about resistance is reflected in the survey.

Horseweed, Palmer amaranth, and morningglories were the first, second, and third most problematic weeds of cotton, respectively. Most weeds that were ranked high in importance probably received the ratings because of greater tolerance to glyphosate compared to other more sensitive species (Norsworthy et al., 2001).

Table 3 lists areas of concerns that consultants think should be priorities for research and educational efforts. The survey leads us to conclude that consultants are aware of the problems associated with herbicide-resistant weeds and the consequences of routine glyphosate applications. Research and education concerning the preservation of new weed-management technologies in cotton must continue, especially considering the increasing occurrence of herbicide-resistant biotypes.

PRACTICAL APPLICATION

Based on the survey, most of our current weed-management research and educational endeavors are in line with the problems most frequently deemed of importance by cotton consultants; however, some weeds appear to need increased attention. Future research and educational efforts will continue to address weed-management issues and concerns identified through this survey.

ACKNOWLEDGMENTS

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Table 1. Response to questions regarding current weed management practices asked in a direct mail survey to cotton consultants in Arkansas, 2006.

Current weed management practices	
1.	Number of cotton acres you scouted this year. 400,900 acres (total scouted; 34% of Ark. cotton acres)
2.	How often do you scout for weeds? (Circle only one) a) Weekly (63%) b) Twice per month (9%) c) During peak periods (29%)
3.	Upon what do you base the need to apply a postemergence herbicide? (Circle all that apply) a) Weed size and density (95%) b) Crop stage (78%) c) Economic threshold (78%) d) Previous weed problems (57%) e) Other: environmental conditions and size of farm
4.	Classify the tillage type used on the farms you scout (percentage). 17% No-tillage 63% Minimum tillage (stale seedbed) 20% Conventional tillage involving disking
5.	What percentage of your cotton acreage is Roundup Ready? (80%)
6.	What percentage of your cotton acreage is Roundup Ready Flex? (18%)
7.	Do you think Roundup Ready Flex cotton acreage will increase, remain the same, or decrease over the next 5 years? a) Increase (95%) b) Remain the same (5%) c) Decrease (0%)
8.	What percentage of your cotton acreage is Liberty Link? (2%)
9.	Do you think Liberty Link cotton acreage will increase, remain the same, or decrease over the next 5 years? a) Increase (33%) b) Remain the same (53%) c) Decrease (14%)
10.	How many applications of glyphosate do you commonly recommend in Roundup Ready cotton, including burndown? a) One or two (5%) b) Three (55%) d) Four or more (40%)
11.	How many applications of glyphosate do you commonly recommend in Roundup Ready Flex cotton, including burndown? a) One or two (2%) c) Three (42%) d) Four or more (56%)
12.	How many applications of glufosinate do you commonly recommend in Liberty Link cotton, including burndown? a) One 14% b) Two 43% c) Three 36% d) Four or more (7%)

Table 2. Questions regarding herbicide-resistant weeds asked in a direct mail survey to cotton consultants in Arkansas in 2006.

Herbicide-resistant weeds	
1.	Rate your concern with herbicide-resistant weeds (Circle most appropriate) a) None (0%) b) Slight (0%) c) No opinion (0%) d) Moderate to high (100%)
2.	Do you think it is taking more herbicide to control weeds today than it did 5 years ago? a) Yes (55%) b) No (35%) c) Don't know (10%) If 'yes', what herbicides? Glyphosate
3.	Do you expect the number of herbicides needed for effective weed management in cotton to increase, remain the same, or decrease over the next 5 years. a) Increase (72%) b) Remain the same (8%) c) Decrease (28%)
4.	Do you suspect herbicide-resistant weeds in the cotton fields you scout? a) Yes (79%) If 'yes', what weed(s), herbicide(s), and approximate number of acres do you believe are infested? Glyphosate-resistant horseweed (23% of acres); glyphosate-resistant Palmer amaranth (2% of acres)
5.	Has resistance at these locations been confirmed by the University? a) Yes for horseweed; some for Palmer amaranth
6.	What are you doing to control each weed that you believe to be "resistant"? Tank-mix other herbicides with glyphosate; use combinations of herbicides (Clarity, 2,4-D, Direx, Valor, Dual Magnum, Ignite, and Envoke)
7.	How much more will it cost to farm cotton with herbicide-resistant weeds? \$25.44/acre.
8.	If glyphosate or glufosinate were used as the only means of weed control in cotton for consecutive years, how many applications do you perceive would be needed before resistance develops? 14.7 # of glyphosate applications 11.0 # of glufosinate applications

Table 3. Ratings of the importance of various research and educational topics related to weed management by cotton consultants in Arkansas.

Potential concerns or areas of needed research and education	Importance ^z
Control strategies for herbicide-resistant weeds	4.76
Performance of current herbicides	4.68
Strategies to prevent occurrence of herbicide-resistant weeds	4.65
Development of new herbicides	4.59
Economical weed control	4.54
Development of herbicide-tolerant cotton	4.41
Rate of spread of herbicide-resistant weeds	4.32
Cultural weed management practices	4.32
Weed control in conservation tillage	4.22
Herbicide drift	4.08
Anticipated shifts in the weed spectrum	4.05
Herbicide carryover	3.32

^z Importance was based on the rating scale: 1 = not important, 2 = rarely important, 3 = occasionally important, 4 = important, and 5 = very important.

Confirmation of Glyphosate-Resistant Palmer Amaranth in Arkansas

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RESEARCH PROBLEM

Palmer amaranth from a soybean field in Mississippi County, Ark., was reported to be resistant to glyphosate in April 2006 (Scott and Smith, 2006), becoming the third weed species in the state since 2003 to have developed resistance to glyphosate (Heap, 2007). Although the resistance of Palmer amaranth to glyphosate was confirmed earlier, the level of resistance compared to known susceptible populations that had never been exposed to glyphosate is unknown as well as the amount of glyphosate needed to control this resistant biotype.

BACKGROUND INFORMATION

Overreliance on glyphosate for weed control in glyphosate-resistant crops has resulted in the development of glyphosate-resistant species worldwide and in Arkansas (Heap, 2007). Mississippi County is the largest cotton-producing county in Arkansas, and the resistant site lies within the Mississippi River flood plain, causing a concern for movement of this resistant biotype to adjacent cotton fields.

RESEARCH DESCRIPTION

Palmer amaranth seeds collected from three locations in South Carolina (Clarendon County in 1986; Anderson County in 1997; and Richland County in 1997) were used as susceptible standards to determine the level of resistance in the Mississippi County biotype. The South Carolina biotypes were selected because it is believed that these biotypes were never exposed to glyphosate. Putative resistant plants evaluated in this experiment were grown from seeds collected from a single plant that had previously

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survived glyphosate at 8 lb ae/acre applied at the eight- to ten-leaf stage. Seeds from this resistant plant were sown in trays containing potting mix and, at the cotyledon to first-true leaf stage, were transplanted to 4-in.-diameter pots containing potting mix. The experimental design was completely randomized with 8 replications of 11 glyphosate rates ranging from 0.0117 to 12.0 lb/acre, and the experiment was repeated. The lowest rate corresponded to 1/64 of a recommended glyphosate rate of 0.75 lb/acre. Seedlings were treated with glyphosate (MON 78623) plus 0.25% v/v nonionic surfactant (NIS) at the six-leaf stage. A control that was treated with NIS only was included. The spray applications were made inside a stationary chamber with a two-nozzle boom calibrated to deliver 10 gal/acre. After treatment, plants were returned to a greenhouse and were supplied adequate nutrients and water for an additional 28 d. Plant death (live or dead) was recorded at 28 d after treatment (DAT). Palmer amaranth biomass was harvested and oven dried for 7 d at 66°C and then weighed. The lethal dosage needed to kill 50 and 95% of each population (LD_{50} and LD_{95}) was determined using Probit analysis. Regression analysis was used to estimate 50% growth reduction (GR_{50}) of the susceptible and resistant biotypes.

RESULTS AND DISCUSSION

The LD_{50} values were similar among the susceptible biotypes based on 95% confidence intervals, ranging from a low of 0.0218 to a high of 0.0317 lb/acre glyphosate. The resistant biotype had an LD_{50} of 2.517 lb/acre glyphosate, which was 79- to 115-fold greater than the susceptible biotypes (Fig. 1). The LD_{95} value for the resistant population was 11.16 lb/acre—almost 15X the normal use rate of glyphosate. A glyphosate rate of 1.0 lb/acre was needed to reduce the biomass production of the resistant biotype by 50%, whereas the GR_{50} for the susceptible populations was less than the lowest evaluated glyphosate rate. This research further confirms that a Palmer amaranth population in Mississippi County has developed resistance to glyphosate.

PRACTICAL APPLICATIONS

Glyphosate is not a viable option for control of the glyphosate-resistant Palmer amaranth biotype in Mississippi County. Although this biotype was found in a soybean field, it is likely that it also exists in adjacent cotton fields as a result of annual flooding of this area during winter months. Management of Palmer amaranth in cotton needs to be centered around the use of residual herbicides at planting and control of later escapes with residual, postemergence herbicides.

ACKNOWLEDGMENTS

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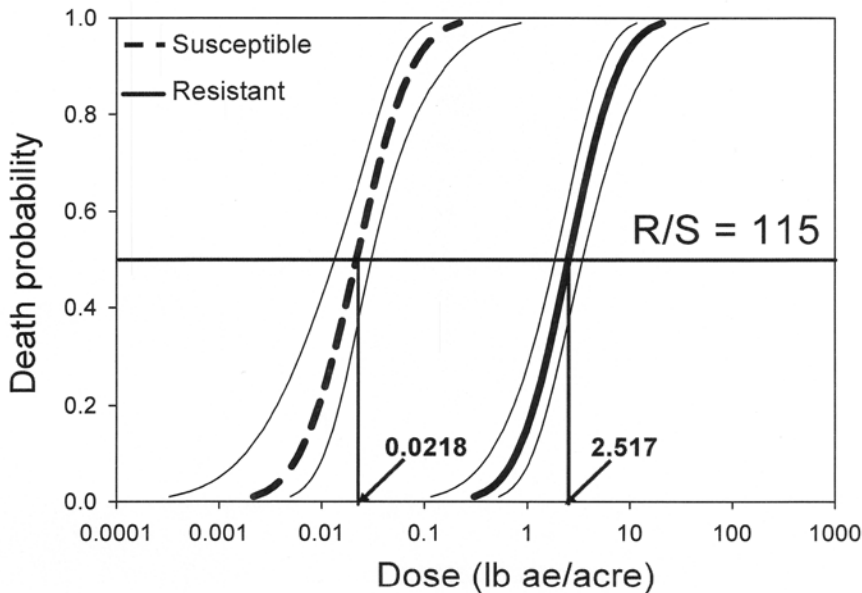


Fig. 1. Probit analysis with 95% confidence intervals to predict the lethal glyphosate dose needed to kill 50% of a susceptible and resistant Palmer amaranth population when treated at the six-leaf growth stage. The resistant population was from Mississippi County, Ark.

Managing Glyphosate-Resistant Horseweed in Conservation-Tillage Cotton Production: Final Summary and Recommendations

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RESEARCH PROBLEM

Glyphosate-resistant horseweed (*Conyza canadensis*), also called maretail, has been a significant problem for cotton producers in Arkansas since 2003. Without glyphosate to control horseweed populations and with the rapid spread of the resistant population, there was an urgent need to develop reliable, economical options to control the weed. Without economical alternatives for management of the resistant biotype, many farmers may have abandoned conservation-tillage practices, which would have increased labor and machinery costs and jeopardized soil conservation efforts.

BACKGROUND INFORMATION

Of the weeds that can cause a problem in Arkansas cotton fields, horseweed was not a concern until 2002-3 (Matthews et al., 2004; McClelland et al., 2004). Why is it only a recent problem? Before conservation-tillage practices became the norm on much of our cotton acreage, horseweed was controlled with tillage. Even with the elimination of primary tillage, horseweed was easily controlled with glyphosate (Roundup® and other trade names), the herbicide used extensively for burndown of winter and early spring weeds. However, failures of horseweed control with glyphosate were reported in Mississippi County in 2002; it was suspected that the biotype was resistant because Tennessee had confirmed resistance in 2001 in counties near the Mississippi River, and Bob Hayes, Tennessee weed scientist, predicted its spread to neighboring counties in Arkansas (Hayes et al., 2002; Mueller et al., 2003). Whether the glyphosate-resistant population came from Tennessee, just happened to evolve about the same time, or was a combination of the two, the population surged in 2003-4. Extension agents were fielding anxious calls from producers – “I have it; what do I do?” A united front of extension personnel, University of Arkansas researchers, producers, and Cotton Incorporated was

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established to evaluate horseweed samples sent by county agents for level of glyphosate resistance and to determine how to control horseweed without glyphosate in conservation-tillage systems in cotton.

RESEARCH DESCRIPTION

Horseweed plant and seed samples from fields suspected of having glyphosate-resistant horseweed were evaluated in greenhouse experiments at Fayetteville for level of glyphosate resistance. Glyphosate rates of 0, 0.375, 0.75 (labeled 1X rate), 1.5 (2X), 3 (4X), 6 (8X), and 12 (16X) lb ae/acre were evaluated.

Approximately 40 field experiments were conducted in Arkansas from 2004 through 2006 to evaluate herbicides that could replace or complement glyphosate for control of horseweed. Experiments were conducted at sites in Crittenden, Mississippi, Poinsett, Washington, Lee, Phillips, and Desha counties, most with a glyphosate-resistant population. Preplant, preemergence, and postemergence herbicides were evaluated. All experiments were conducted on a randomized complete block design with four replications, and standard small-plot procedures were used.

RESULTS AND DISCUSSION

The original Mississippi County population contained plants resistant to 3 lb/acre glyphosate, a resistance factor of 4X, and control was complete with 6 and 12 lb/acre. Plants that emerged and were collected and tested a few weeks later from that same population were susceptible to 6 lb/acre (58% control), and four out of six plants showed some resistance to 12 lb/acre (resistance factor = 16X). Plants from seed collected in another location in Mississippi County had a resistance factor of 16X, with control of only 59% from 12 lb/acre 27 days after treatment (DAT). Few samples were sent for evaluation in 2005 and 2006, probably because most producers were already aware of resistance in their fields.

An obvious choice to replace glyphosate as a burndown treatment was Ignite® (glufosinate) because it has a broad spectrum of activity and can be applied up to planting. However, horseweed control with Ignite alone was inconsistent across experiments. At early ratings, control with Ignite appeared to be good, but significant regrowth from the terminal bud occurred if any live tissue was present. Similar regrowth was seen with Gramoxone® (paraquat). However, whether due to environment or size of plants, control with both herbicides was sometimes >90%. Valor® (flumioxazin) and Aim® (carfentrazone) were of interest initially, but neither herbicide had postemergence activity on horseweed, and the soil activity reported for Valor to give residual horseweed control was not apparent in these experiments. In 2005 and 2006, herbicides were evaluated for residual control of horseweed and included Dual Magnum® (metolachlor), Cotoran® (fluometuron), Lorox® (linuron), Direx® (diuron), Staple® (pyrithiobac), Caparol® (prometryn), and Envoke® (trifloxysulfuron).

Clarity® (dicamba) and 2,4-D, especially Clarity®, consistently controlled emerged horseweed. Even with a 21-day preplant restriction, Clarity remained the most con-

sistent, effective herbicide and could be mixed with glyphosate, Gramoxone Inteon®, Ignite®, or residual herbicides that would aid in control of seedlings that might emerge between burndown and planting.

PRACTICAL APPLICATION

Recommendations Resulting from Project

Horseweed recommendations for Arkansas cotton in 2007 are: apply Clarity at 3 to 4 weeks before planting cotton (and after a 1-in. accumulation of rainfall or irrigation); Gramoxone Inteon® or Ignite® can be applied at planting to remove newly emerged horseweed seedlings if needed; Direx®, Caparol®, and Cotoran® provide residual horseweed control and should be applied at planting to maximize the length of in-crop control; if horseweed seedlings are a problem at planting, consider in subsequent years mixing a residual herbicide with Clarity at burndown, realizing that the length of in-crop residual control will be reduced; Envoke® can be applied over-the-top of cotton to control horseweed seedlings that emerge after the residual herbicides have dissipated.

A final result of this project was the significant and successful educational effort. The problem of glyphosate-resistant horseweed developed quickly, but the response of Arkansas extension, researchers, and Arkansas producers through Cotton Incorporated was also rapid and probably saved a number of cotton fields from the plow, allowing conservation-tillage systems to continue. These exceptional educational programs bode well for Arkansas producers as they face the problem of new resistant weeds.

ACKNOWLEDGMENTS

Cotton Incorporated provided funding for this research. Collaborative efforts of Dr. Bob Nichols, project director for Cotton Incorporated, are greatly appreciated. The authors also appreciate the efforts of extension service personnel and the producers who generously allowed research plots in their fields in the counties of testing; Susan Matthews (Scott), then Mississippi County agent; University of Arkansas experiment station personnel; industry personnel who provided herbicides for the project; and Drs. Ron Talbert and Jim Barrentine, who were instrumental in establishing the research project. Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Genetic Diversity of A-Genome Cotton

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RESEARCH PROBLEM

Since Upland cotton (*Gossypium hirsutum* L.) is known to have relatively low levels of genetic diversity, a better understanding of variation and relationships among possible sources of novel genes would be valuable. Therefore, analysis of genetic variation of the genus *Gossypium*, especially the diploids, could provide important information about the feasibility of using these genetic resources for cotton improvement. The A-genome cotton species, *G. arboreum* and *G. herbaceum*, are two of the closest living relatives of the cultivated tetraploids and, as such, can serve as a source of genetic diversity for cultivated tetraploid cottons (Stanton et al., 1994).

BACKGROUND INFORMATION

Genetic diversity is the basis for genetic improvement. By studying the genetic relationships between strains of diploid cotton in various ecological regions, it is possible not only to establish a theoretical basis for conserving diploid cotton germplasm resources, but also to target and improve certain ideal characteristics such as early maturity, resistance to stress, and fiber quality, and exploit this germplasm in modern cotton production (Guo et al., 2006). Developing superior cotton cultivars that combine the favorable qualities contributed by diverse germplasm resources requires an understanding of the genetic and genomic relationships of cotton species and cultivars (Iqbal et al., 2001). Several molecular technologies have been used to study the genetic diversity and systematic relationships of *Gossypium* species (Wendel et al., 1992; Abdalla et al., 2001) and these studies have shown that there is a low level of polymorphism within *G. hirsutum* cultivars. Transfer of desirable genes through introgression from germplasm resources of other *Gossypium* species could play an important role in increasing genetic variability in Upland cotton.

Molecular markers, especially PCR (Polymerase Chain Reaction)-based markers such as RAPDs (random amplified polymorphic DNA), AFLPs (amplified fragment

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length polymorphism), and SSRs (simple sequence repeats; also called microsatellites) have been extensively used to study genetic diversity, genetic relationships, and molecular phylogeny in *Gossypium* species. Recently, the SSR marker has received much attention in phylogenetic studies in cotton. The PCR-based, co-dominant microsatellite markers are highly polymorphic and preferentially associated with non-repetitive DNA in plant genomes. These features make the use of microsatellite markers ideal for genetic diversity studies and marker-assisted selection in cotton breeding (Abdalla et al., 2001; Iqbal et al., 2001).

RESEARCH DESCRIPTION

For evaluating genetic diversity, twelve *G. herbaceum* (A_1) and ten *G. arboreum* (A_2) accessions from different areas of origin (according to their passport data) were selected for analysis (Table 1). Total genomic DNA was isolated from leaf tissue of each accession with a DNeasy® Plant Mini Kit (Quiagen, Valencia, Calif.). PCR was performed on the DNA of each accession with each of 53 EST-derived SSR primer pairs (MUSS, MUCS). The products from each primer/sample PCR were separated by electrophoresis to develop the accession fingerprint. A dendrogram based on genetic distance of the fingerprints of each accession was drawn using the Neighbor Joining method (Saitou and Nei, 1987).

RESULTS AND DISCUSSION

Of the 53 primer pairs, only 36 gave polymorphic patterns within each species. These were used to assess genetic diversity in the twelve *G. herbaceum* (A_1) and ten *G. arboreum* (A_2) accessions. Eighty-seven different alleles were found among these accessions. The number of bands generated by an individual primer ranged from 1 to 6. For example, the microsatellite markers MUSS300 and MUCS113 detected six and four polymorphic loci, respectively, among the 22 accessions.

Based on the data from microsatellite analysis, genetic distance values among *G. herbaceum* accessions ranged from 0.11 to 0.50 whereas the values for *G. arboreum* ranged from 0.19 to 0.48, showing that intra-specific genetic variability in the two species is similar. The Neighbor Joining dendrograms generated from genetic dissimilarity coefficients are shown in Figures 1 and 2. This analysis classified accessions within each species into distinct sub-clusters. As shown in Fig. 1, within the A_1 genome group, accessions A_1 -9 (Turkey), A_1 -23 (India), and A_1 -24 (Iran) formed their own clusters. Within the A_2 genome cluster (Fig. 2) there were also several sub-clusters. The dendrogram shows that A_2 -171, with its passport data indicating The Netherlands as its origin, is distinct from the other accessions.

PRACTICAL APPLICATION

A-genome cotton is an invaluable gene pool for improving cotton cultivars. A systematic genetic assessment of the gene resources will help to decrease the redun-

dancy and to construct a core germplasm collection that is important for efficient use of these gene resources in cotton breeding. This research is in progress and the next objective of our work is to evaluate genomic SSR primer sets (BNL) from different series for polymorphisms and additional accessions of both A genome species in order to determine the putative diversity as extensively as possible.

ACKNOWLEDGMENTS

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Table 1. *Gossypium herbaceum* and *G. arboreum* accessions selected based on passport data.

Species	Genome	Passport origin	Accession no.
<i>G. herbaceum</i>	A ₁	India	5
		Turkey	9
		India	15
		Afghanistan	17
		Afghanistan	18
		Afghanistan	22
		India	23
		Iran	24
		China	40
		China	47
		Zimbabwe	79
		Switzerland	127
<i>G. arboreum</i>	A ₂	Russia	21
		India	50
		Pakistan	54
		USA	62
		USA	121
		China	142
		The Netherlands	171
		China	247
		India	753
		India	810

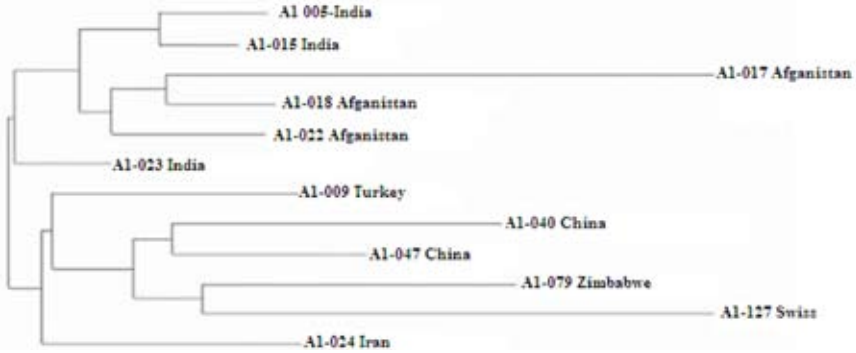


Fig. 1. Neighbour Joining dendrogram of 12 *Gossypium herbaceum* accessions based on SSR data.

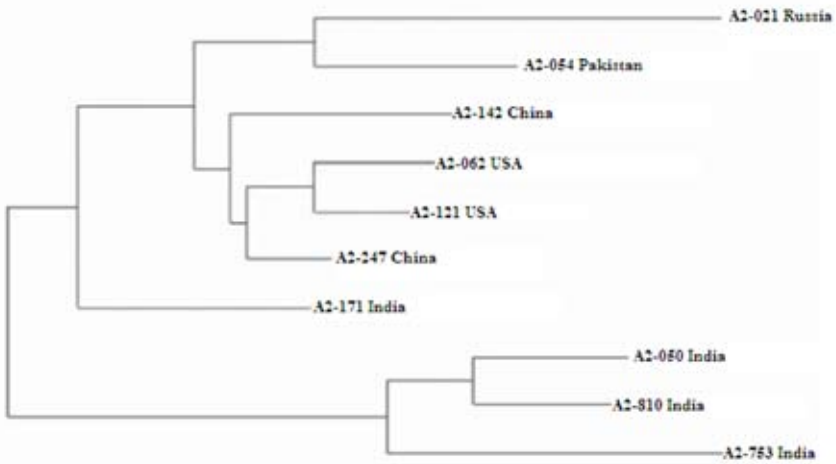


Fig. 2. Neighbour Joining dendrogram of 10 *G. arboreum* accessions based on SSR data.

Molecular Diversity and Determination of Possible Natural Hybridization among the Australian Arid-Zone *Gossypium* Species (*G. australe*, *G. bickii*, and *G. nelsonii*)

Rashmi Tiwari and James M. Stewart¹

RESEARCH PROBLEM

Ancient interspecific hybridization between diploid species of *Gossypium* had a major role in the formation of the current Australian species *G. bickii* (Wendel et al., 1991). Some modern collections of Australian *Gossypium* species in section *Hibiscoidea* show morphological evidence of interspecific hybridization. If hybridization and trait introgression are occurring today, this suggests that speciation may be continuing for the species involved. Also, a measure of molecular diversity among the many accessions of the species would be helpful in accession selection for cotton improvement to eliminate redundancy of effort.

BACKGROUND INFORMATION

Gossypium australe has the widest distribution of the Australian *Gossypium* species and is found from near the east coast in Queensland to the west coast of Western Australia and from south to north across the continent approximately north of the Tropic of Capricorn. It is also the most molecularly diverse species in section *Hibiscoidea* of the genus, *Gossypium*. *Gossypium bickii*, also classified with *G. australe* and *G. nelsonii* under section *Hibiscoidea*, shares a common nuclear ancestor with these two species. However, *G. bickii* appears to share an ancestor with *G. sturtianum* in as much as the chloroplast genome groups it with this latter species. *G. bickii* occurs primarily within central Northern Territory, and *G. nelsonii* is distributed in a band from central Northern Territory to central Queensland. All four species have overlapping geographical distribution and grow sympatrically in various combinations (Stewart et al., 1987; Office of the Gene Technology Regulator, 2002), hence they have the potential to intercross.

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RESEARCH DESCRIPTION

The species and accessions examined are listed in Table 1. The accessions are identified by their Plant Introduction (PI) number or by the Australian Plant Genetic Resources Information System designation. Plants from originally collected seeds were grown in a greenhouse in 6-in. pots. Total genomic DNA was isolated and purified for each accession according to the method of Zhang and Stewart (2000). For this project the method employed to determine diversity and species relatedness was a DNA fingerprinting technique called Amplified Fragment Length Polymorphism (AFLP). This technique is based on the selective polymerase chain reaction (PCR) amplification of restriction fragments from an endonuclease digest of genomic DNA from each accession. The technique involves three steps: (i) restriction of the DNA and ligation of oligonucleotide adapters, (ii) selective amplification of sets of restriction fragments, and (iii) gel analysis of the amplified fragments. Polyacrylamide gel electrophoresis was used to separate the amplified fragments. The gels were silver-stained to visualize fragment bands. Polymorphic fragments between accessions were scored as present (1) and absent (0). The standard operating procedure for AFLP is similar to the one reported by Vos et al. (1995). The protocol was modified by Bill Hendrix (unpublished), CBGD Lab, University of Arkansas, Fayetteville, Ark., from the Invitrogen AFLP Protocol® (<http://www.invitrogen.com/content/sfs/manuals/aflpii.pdf>) and Wendel AFLP Lab Protocol (<http://www.eeob.iastate.edu/faculty/WendelJ/home.htm>).

The data were analyzed by the computer software program Phylogenetic Analysis Using Parsimony (PAUP*) v.4.0b (Swafford, 2003). A dendrogram was constructed from the data by the Neighbor Joining method.

RESULTS AND DISCUSSION

Two primer combinations were used for selective amplification of DNA fragments from 153 selected genotypes representing the broad distribution of the species. Four *Gossypium* species and possible natural hybrids were included. A total of 55 major bands were obtained from the PCR reactions. The resulting dendrogram (Fig. 1) showed four groups (clades) corresponding to the four species. All accessions of *G. australe* fell in one group. However, a few accessions of *G. bickii* and *G. nelsonii* clustered with *G. australe*, suggesting that these accessions, although collected as the respective species, were possible hybrids with *G. australe*. The presence of accessions on the same clade (tree branch) that were collected as possible hybrids supports this statement. The presence of bands that appear to be primarily unique to *G. australe* in a few accessions of *G. nelsonii* and *G. bickii* strongly suggests that hybridization and introgression are occurring among the *G.* genome species. The data show that *G. australe*, the most widely distributed of the arid zone *Gossypium* species, is also the most molecularly diverse species in the group.

Molecular evidence shows that natural hybridization is occurring among the arid-zone species, and based on the *G. bickii* model, this implies that speciation is also occurring.

PRACTICAL APPLICATIONS

Classification of species is based on morphological characters and may not reflect the diversity of the species. On the other hand, molecular analyses allow direct comparison of species at the DNA level. With DNA methods we have obtained a snapshot of the evolution of Australian arid-zone *Gossypium* that suggests that speciation by hybridization and introgression is occurring today. The data also provide a measure of the molecular diversity of the Australian arid-zone *Gossypium*. This information helps eliminate redundancy in the selection of accessions for cotton improvement.

ACKNOWLEDGMENTS

Support by Cotton Incorporated of this research is gratefully acknowledged. The support by the Division of Agriculture, University of Arkansas is also gratefully acknowledged.

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Table 1. PI number and geographic origin of Australian *Gossypium* accessions studied.

Species	Code	Location
<i>G. australe</i>	1163	20.3 km E of Marqua Sta. , NT
	5041	Carawine Gorge, E of Marble Bar, WA
	5052	9-13 km W of Blackwater, along Landsboroug Hwy, Qld
	5053	95 km N of Clermont towards Charters Towers, Qld
	5056	251.3 km N of Clermont, S of Sardine Creek at Myrtna Station turn-off
	5142	1.5 km N of Peko Rd/Warrego-Nobles Nob bypass, 10km E Tenant Ck, NT
	5145	53.7 km E of Hughenden along Flinders Highway, Qld
	5148	2 km E of Black Elvire Creek, Duncan Highway, WA
	5152	3 km W of Burtawurta Crk, Buchanan Hwy. (347 km E Halls Crk), NT
	5154	~88 km W of Dunmarra Roadhouse along Buchanan Hwy, NT
	5291	Karand Station, Via Alpha, Qld
	5304	Town reserve, Qld
	5428	86.5 km S of Dajarra towards Boulia along Diamantina Dev. Rd., Qld
	5429	215.8 km E of Boulia towards Winton along Kennedy Dev. Rd., Qld
	5431	10.5 km W of Serpentine Gorge T/O along Namatjira Dr. to Ormiston Gorge, NT
	5434	N end of Ormiston Gorge, West MacDonnell Ranges, NT
	5436	213 km N of Alice Springs along the Stuart Highway, NT
	5437	Forster Range; 20 km S of Barrow Creek along Stuart Hwy, NT
	5439	45 km E of Kurundi HS; Davenport Ranges, NT
	5440	15 km N of Epenarra HS (road to Barkly Hwy) Davenport Ranges, NT
	5442	Old Police Station waterhole on Frew River, Davenport Ranges, NT
	5443	7 km from Old Police waterhole towards Epenarra/Murray Downs Rd, NT
	5444	41 km S of Old Police Station T/O along Epenarra/Murray Downs Rd, NT
	5452	Entr. To Bot. Park, S of Barcaldine on Landsborough Hwy, Qld
	5507	24.5 km NW Longreach, 153 km SE Winton, Qld.
	PI 499761	200 km W of Rabbit Flat, 77 km W of state line, W.A
	PI 499762	Crater slopes of Wolf Creek Crater, WA
	PI 499765	8 km W of Katherine, N.T, Great Norten HWY.
<i>G. bickii</i>	5412	16.7 km E along track to Ruby Gap National Park, NT
	5466	32 km S of Epenarra Homestead along Murray Downs & Old Police Station Rd, NT
	5470	~1 km W of Lake Nash Homestead, NT
	5464	45 km E of Kurundi Station, Davenport Ranges, NT
	5460	20.3 km E of Marqua Sta. turn-off along Plenty Hwy, NT
	5469	7 km E of Elkedra Station turnoff along Sandover Highway towards Lake Nash, NT
	5467	5 km S of Old police Station T/O along Epenarra/Murray Downs Rd, NT
	5468	18 km SE of Jct Epenarra and Murray Downs road, Davenport Range, NT
	5456	13.2 km W of Ambalindum Homestead T/O along Plenty Highway, W of Gem Tree, NT

continued

Table 1. Continued.

Species	Code	Location
	5159	42 km N of Tennant Creek, NT
	5454	25.7 km S of Arltunga Tour Drive T/O, 20.7km N of Alice Springs, NT
	5462	3 km S of John McDowell Stuart Cairn, ca 20 km S of Barrow Creek., NT
	PI 464843	40 km W of Supplejack Station Homestead, NT. Herbarium sheet seeds
	PI 499768	15 km S of Alice Springs, Saint Teresa Rd near airport, NT
<i>G. nelsonii</i>	5479	44 km E of Boulia towards Winton along the Kennedy Dev. Rd, Qld
	5397	22.2 km S of Dajarra towards Boulia along Diamantina Dev. Rd, Qld
	5471	11 km W of Ambalindum Station T/O along Plenty Highway, E of Gem Tree, NT
	5506	The Cascades, 6.5 km [by air] NE of Mt. Isa, Qld
	5475	13.5 km N of Urandangi towards Headingly Station, Qld
	5502	W side of Algamba Creek, 16.6 km E of Tarlton Downs Station, NT
	5478	Sybella Creek, S of Mt. Isa along the Diamantina Development Road, Qld
	5481	25.5 km W of Serpentine Gorge T/O along Namatjira Drive to Ormiston Gorge, NT
<i>G. sturtianum</i>	5489	10.5 km W of Serpentine Gorge turnoff towards Ormiston Gorge, NT
	5493	7 km from Old Police Station Waterhole to Epenarra/Murray Downs Rd, NT
Hybrid	9744	5 km S of Old police Station T/O along Epenarra/Murray Downs Rd., NT
	9838	W side of Algamba Creek, 16.6 km E of Tarlton Downs Station, Plenty Hwy, NT

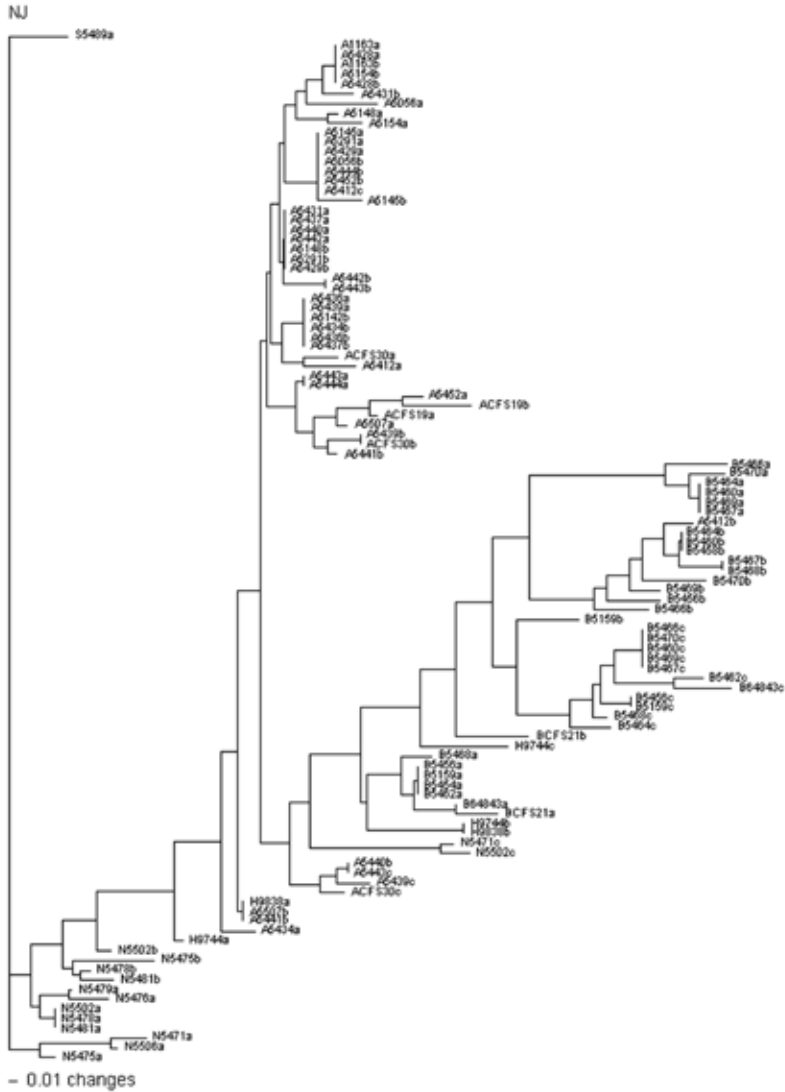


Fig. 1. Unrooted neighbor-joining dendrogram for *G. australe* (A), *G. bickii* (B), *G. nelsonii* (N), *G. sturtianum* (S), and possible hybrids (H) from Australia, based on AFLP markers, and a, b and c are different plants of the same accession.

Host Response to Reniform Nematode Infection in Resistant and Susceptible *Gossypium arboreum* Accessions

Carlos A. Avila and James M. Stewart¹

RESEARCH PROBLEM

The reniform nematode (RN), *Rotylenchulus reniformis* Lindford and Oliveira, is a serious threat to cotton production. In fields infested with RN, yield losses are estimated at 340 to 452 kg/ha (Robinson, 2001). Genetic resistance to RN has not been reported for any commercial cultivar of cotton (*Gossypium hirsutum* L.) (Robinson et al., 2004); however, it has been found in *G. arboreum* (Stewart and Robbins, 1994), but little is known about the resistance mechanism. The objectives of this study were 1) describe the response of cotton roots at the transcriptome level in response to RN infection as a tool for the potential development of rational strategies for nematode control and 2) to identify differential genes regulated in resistant and susceptible *G. arboreum* accessions.

BACKGROUND INFORMATION

Plants respond to pathogen infection via a complex and integrated set of defenses driven by constitutive and induced responses (Dowd et al., 2004). When a nematode enters the root and initiates feeding, remarkable physiological and morphological changes occur in the cells to accommodate the nematode with a feeding site (Hammond-Khosack and Parker, 2003). Physiological changes in the host can be analyzed through its transcriptome. Since penetration behavior of reniform nematode females in resistant and susceptible *Gossypium* spp. has been reported to be the same, the events that occur in the feeding site (syncytium) establishment may determine the degree of susceptibility of cotton (Carter, 1974; Agudelo, 2004).

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RESEARCH DESCRIPTION

Cotton seeds from *G. arboreum* resistant (A2-194) and susceptible (A2-128) accessions were surface sterilized in a 20% bleach solution, germinated, and transplanted into 500-cc clay pots filled with pasteurized fine sand. Plants were kept in a growth chamber with a 16 h photoperiod at 28°C day/24°C night. Four treatments with 3 reps were applied to 1-month old plants: 1) Resistant-inoculated (**RI**), 2) Resistant non-inoculated (**RNI**), 3) Susceptible-inoculated (**SI**), and 4) Susceptible non-inoculated (**SNI**). Inoculated treatments received 5,500 vermiform-stage nematodes per pot divided in 5 locations around the plant to cover the entire root system. After 16 days, roots for each treatment were harvested and immediately frozen in liquid nitrogen.

Total root RNA was extracted using a method similar to that reported by Wilkins and Smart (1996). Extracted RNA was cleaned using an RNeasy Plant Mini Kit (Qiagen, Calif.). After quantification, total RNA for each of the 3-reps was bulked to synthesize cDNA from mRNA using the SuperScript III First-Strand Super Mix (Invitrogen, Calif.). Polymerase Chain Reactions with AFLP primers were used to identify polymorphism between treatments. Selected polymorphic bands were cloned using the pGEM T-easy Vector (Promega, Wis.) and sequenced to identify the transcripts.

RESULTS AND DISCUSSION

After 9 days, roots of monitor plants were stained with Acid Fuchsin and observed under a light microscope for RN infection as originally planned. At that point, only a low level of infection was observed. This is thought to be due to the fact that immature vermiform were not infective until they reached maturity. After 16-days plants had a higher infection level and were harvested for RNA extraction.

AFLP analysis was performed using 48 primer combinations on the cDNA of each of the four treatments. Each combination yielded an average of 80 bands. Observed polymorphisms between accessions and between treatments were selected for further analysis.

Expression changes were classified according to their distribution between accession and inoculation. These are summarized in Table 1. Few expression changes were observed between treatments (62 per ~3,840 total bands). Most of the polymorphism observed was due to accession effect ($34/62 = 55\%$), and these may or may not be directly involved in the resistance mechanism.

After cloning and sequencing polymorphic bands, sequences were compared with the NCBI database (www.ncbi.nlm.nih.gov) using the translated query vs. protein database (BLASTx) to obtain a hint of their function. In order to have a better understanding of what was happening between accessions, differentially expressed transcripts were grouped according to their putative biological process involved (Fig. 1). Cellular transport, cell cycle, and DNA processing resulted in more transcripts in the susceptible accession than in the resistant one. It is hypothesized that those processes may be related to syncytia formation. On the other hand, processes that may be involved in resistance mechanism, as cellular rescue, defense, and transcription, had more transcripts in the resistant accession.

Surprisingly, so far no gene-specific expression has been detected in the resistant accession when infected by reniform nematode, suggesting that resistance may be related to a down-regulated gene during nematode feeding, but additional supporting data need to be obtained before the validity of this statement is verified. The only up-regulated transcript observed during nematode infection in A2-194 has similarity to the transcription factor bZIP35, expression of which is related to abiotic stresses in soybean (unpublished data). Similarly, another bZIP transcription family protein was expressed only in the susceptible accession when it was infected by the nematode. The function of transcripts specific to A2-194 expressed in both inoculated and non-inoculated treatments included genes involved in carbohydrate synthesis, protein kinases, carboxyl-terminal peptidases, senescence-associated proteins, transcription factors, mRNA degradation, and a nod-factor-like protein. If these transcripts are involved in resistance, they are expressed without the presence of the nematode (constitutive resistance), but possibly the level of expression could change during infection.

Susceptible inoculated plants showed expression of a transcript similar to Transparent Testa 12 protein (NP_191462) from *A. thaliana*, a multi-drug transporter-like membrane protein, similar to ripening regulated protein DDTR18 (*Lycopersicon esculentum*). It may be involved in formation of the nematode feeding site (syncytium), which involves the coalition of adjacent cells through cell wall dissolution in response to nematode infection. Likewise, a protein similar to P450 (ABE81447) from *Medicago truncatula*, that is also involved in secondary metabolite biosynthesis, transport, and catabolism, was found in susceptible inoculated plants. Additionally, several transcripts from susceptible inoculated plants had similarity to a protein (Accession NP_566322) from *A. thaliana* with unknown function.

PRACTICAL APPLICATIONS

Unveiling the RN resistance mechanism found in *G. arboreum* can be used as a tool for the potential development of rational strategies for nematode control as rotation and pyramiding resistance genes with different mechanisms in order to delay the appearance of nematodes that overcome host resistance. Alternatively, in the absence of markers linked to resistant genes, differentially expressed genes can be used to select for resistance in developing populations. Finally, putative genes involved in syncytia formation can be the targets for gene silencing so as to induce resistance.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Differential gene expression changes in resistant and susceptible genotypes of *G. arboreum*.

Gene expression	RI ^z	RNI	SI	SNI	No. of entries
Accession effect	X	X			18
			X	X	16
Infection effect	X		X		3
		X		X	1
Accession vs infection interaction		X			3
			X		3
				X	2
	x	X	x	x	1
		x	X	X	1
	X	X		X	1
	X	x	x	x	1
Down-regulated	x	x	X	X	4
Up-regulated	X	X	x	x	8

^z RI= Resistant inoculated, RNI= Resistant non-inoculated, SI= Susceptible inoculated, SNI= Susceptible non-inoculated, X=band present and x= low intensity band.

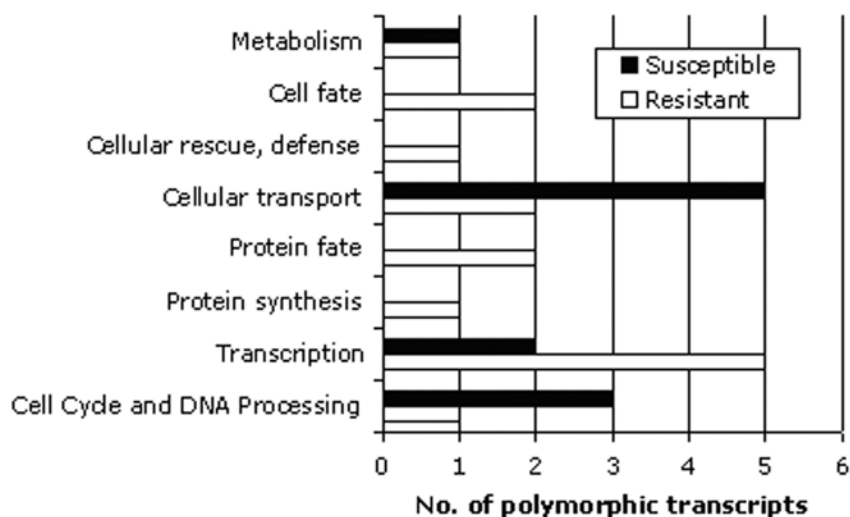


Fig. 1. Overview of cell biological processes differentially expressed in resistant and susceptible *G. arboreum* accessions.

Ecology and Over-Wintering Ability of *Rotylenchulus reniformis* on Cotton in Arkansas

Joshua A. Still and Terry L. Kirkpatrick¹

RESEARCH PROBLEM

Reniform nematode populations in cotton in northeastern Arkansas, although persisting from year to year, have not reached the high densities that are common in the central and southern parts of the state (T. Kirkpatrick, pers. comm.). Population densities in the spring in northeastern Arkansas are much lower than population densities in the more southern areas, implying that winter mortality may be higher in the north. However, soil temperature records from northern and southern Arkansas do not indicate sufficient difference to explain enhanced overwintering mortality due to cold temperatures. An experiment to evaluate the impact of soil texture on the temporal population dynamics and over-wintering survival of the reniform nematode on cotton in these two regions was initiated in 2005.

BACKGROUND INFORMATION

Cotton is one of the oldest and most important fiber crops worldwide (Stewart, 2001). Arkansas cotton growers produce approximately 1.9 million bales of cotton annually (National Agricultural Statistics Service, 2004). The reniform nematode was first discovered in the continental United States in Georgia in 1940 (Smith and Taylor, 1941) in cotton Fusarium wilt trials, and has since spread throughout much of the Cotton Belt. In Arkansas, the nematode was first reported in cotton in 1988 (Robbins et al., 1989), and was responsible for an estimated 4.3% yield loss in the crop in 2005 statewide (Blasingame and Patel, 2005). Reniform nematodes have generally been regarded as a primarily tropical nematode (Heald and Thames, 1982) due to their slightly higher temperature optima for infection and reproduction in relation to the southern root-knot nematode, and survival and reproduction have been linked to the silt or clay content of the soil. Nevertheless, the reniform nematode has been reported in relatively sandy soils recently at the northern fringe of the Cotton Belt in southeastern Missouri (Wrather et

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al., 1992), Virginia (Koenning et al., 2004), and extreme northeastern Arkansas (Batesman and Kirkpatrick, 2004).

RESEARCH DESCRIPTION

Two production cotton fields were chosen for this study. One field (MS) was located near Leachville, Ark. (35° 52' 31", 90° 14' 48"). The second field (MR) was in east-central Arkansas near St. Charles (34° 25' 52", 91° 4' 21"). Both fields have been planted with cotton each year for at least the past 10 years. In June 2005, 10 individual sampling points were established using a Global Positioning System in each of three distinctly different soil types in the MS field. Ten sampling points were also established in the MR field, which had a relatively uniform soil type throughout. The soil types in the MS field were: loamy sand (LS) (79% sand, 16% silt, 5% clay), sandy loam (SL; 63% sand, 27% silt, 10% clay), and sandy clay loam (SCL; 63% sand, 17% silt, 20% clay). The soil type in the MR field was a silt loam (19% sand, 70% silt, 11% clay). Monthly soil samples were collected from all sites from June 2005 through May 2006 by taking 20 cores (2.5 cm diameter) to a depth of 15 cm from the point and arbitrarily in a circular pattern approximately 1 meter from the point. In addition, single cores (5 cm diameter) were collected vertically to a depth of 120 cm from each sampling point in October 2005 and in February and April 2006. These vertical cores were divided into 20 cm sections and assayed separately for nematodes. Nematodes were extracted using a semi-automatic elutriator (Byrd et al., 1976) and sugar floatation (Jenkins, 1964).

RESULTS AND DISCUSSION

Reniform nematode population dynamics varied relatively little over time in the MS field, but were higher in the soil type that had the greatest clay content (Fig. 1). Population densities were much greater in the MR field than in any of the MS soils, although populations declined in September and October. The low nematode density recovered from samples in the fall in this field may have been due to the vertical stratification of the nematode population at that time. Vertical sampling indicated that most of the reniform population in the MR field during October was in the 20- to 40-cm depth range, considerably below the depth at which the monthly samples were collected (Fig. 2). In October, reniform nematodes were recovered at a depth of 120 cm in both the MS-SCL and MR sites (Fig. 2A). Populations were also higher throughout the soil profile in October than in February and April. Nematodes were detectable in the MR sites in February to a depth of 120 cm while the reniform in the MS soils was not detected below 60 cm. In April, most nematodes that were present in both fields were in the upper 60 cm, with the greatest numbers found at 0 to 20 cm.

PRACTICAL APPLICATIONS

Finer textured soils containing an appreciable clay percentage appear to support higher reniform populations throughout the growing season and may enhance survival

during the winter months. Controlled studies are currently underway to more thoroughly define the relationship between clay content, temperature, and over-winter survival. This research indicates that in a field setting, reniform nematodes will generally exist at higher populations in finer textured soils. This information could be useful to a grower who knows the soil texture throughout a production cotton field and could play a role in planning site-specific management strategies for the reniform nematode.

ACKNOWLEDEMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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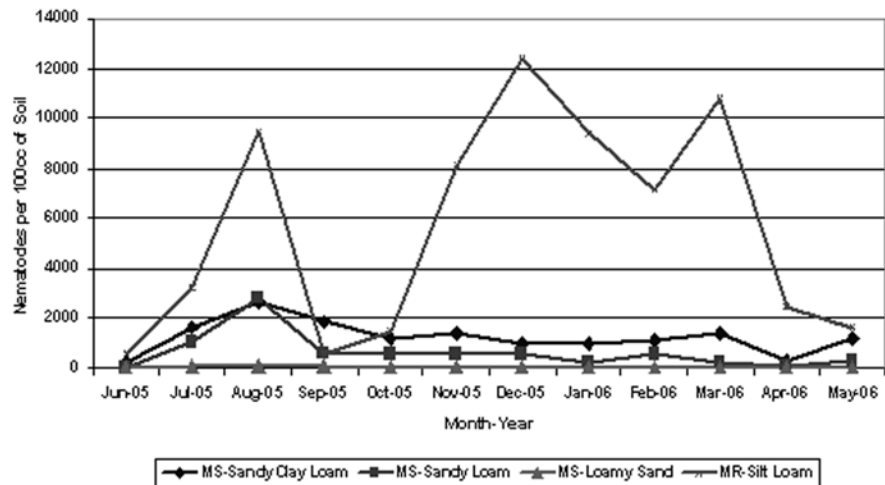


Fig. 1. Reniform nematode temporal population dynamics in Mississippi County (MS) and Monroe County (MR).

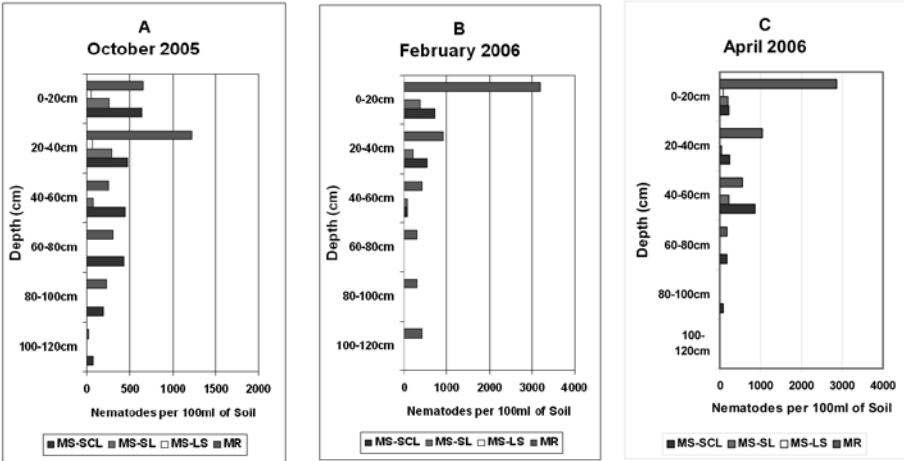


Fig. 2. Reniform nematode vertical distribution in MS and MR fields during (A) October 2005, (B) February 2006, and (C) April 2006.

Efficacy of At-planting Insecticides Against Thrips in Cotton in Northeast Arkansas

Glenn E. Studebaker¹

RESEARCH PROBLEM

Insecticides used at planting, either in-furrow or as seed treatments, are the recommended management option for control of thrips in cotton in Arkansas (Greene, 2006). However, in recent years the popularity of seed-treatment insecticides has increased. This is due in part to the convenience of having everything on the seed and the increased safety issues of not having to deal with more toxic granular in-furrow insecticides. As seed treatment technology has increased, more materials are being applied in-furrow as a seed treatment. Seed treatments are now available that include not just an insecticide, but also a fungicide as well as a nematocide for management of a complex of pests. The purpose of this trial was to evaluate the efficacy of new seed treatment technologies and utilize this information to enhance University recommendations to cotton growers in Arkansas.

BACKGROUND INFORMATION

Thrips are a common early-season pest of cotton in Arkansas (Leigh et al., 1996). Typically, damage from this pest results in reduced leaf area and stunted plants. This usually results in a delay in maturity at the end of the season. The recommended management practice for this pest in Arkansas has been the use of either in-furrow insecticides in the form of a granular or in-furrow spray, or seed-treatment insecticides at planting. Growers who do not follow this practice are encouraged to make a foliar application at first or second true-leaf stage. For many years aldicarb has been the standard to which other new insecticides for thrips control were compared. However, in recent years seed treatments have become the normal practice for thrips management in the south. Often multiple pesticides are applied to the seed to control not just one, but a complex of pests that may affect the cotton seed or seedling. It is not uncommon for one pesticide to have an effect upon another when used together. Sometimes this effect may increase efficacy (synergism) or may decrease efficacy (antagonism). As new seed-treatment insecticides become available, their efficacy should be compared to proven standards.

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RESEARCH DESCRIPTION

This test was conducted at the Northeast Research and Extension Center, Keiser, Ark. Test plots of cotton (*Gossypium hirsutum* L.) variety DP 444BG/RR were planted in a randomized complete block design with four replications on 17 May 2006. Plots were 4 rows wide by 50-ft long. Thrips counts were made by clipping 5 plants from each plot weekly for 5 weeks beginning 1 week after emergence, and placing the plants into jars of alcohol. The alcohol was then sieved through grid-lined filter paper, and the dislodged thrips counted under a dissecting microscope. Yields were taken at the end of the season by harvesting the center 4 rows of each plot. All data were analyzed using Agriculture Research Manager (ARM) version 6.0.

RESULTS AND DISCUSSION

Thrips populations were relatively low throughout the study. The untreated control had the highest thrips numbers throughout most of the study; however, it was only significantly higher on the first evaluation date (Table 1). The thiamethoxam/Avicta and imidacloprid/Avicta combinations had significantly fewer thrips than the untreated control or the aldicarb treatment on the first evaluation date (Table 1). There were no significant differences in yield between treatments (Table 1).

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Number of thrips per 5 plants and yield.

Treatment	Rate	Number of thrips (per 5 plants)				Lint yield (lb/acre)
Untreated						
Thiamethoxam 5FS	0.3 mg ai/seed	22.00 a ^z	6.75 ab	22.50 a	37.25 a	8.25 a
Avicta		2.75 c	2.75 b	14.00 a	27.75 a	5.00 a
Imidacloprid 5FS	0.375 mg ai/seed	2.00 c	3.50 b	15.50 a	46.25 a	7.00 a
Avicta						948.61 a
Thiamethoxam 5FS	0.34 mg ai/seed	2.75 c	1.75 b	13.00 a	52.00 a	11.25 a
Avicta						1033.09 a
Aldicarb 15G	5 lb/acre	13.25 b	11.50 a	21.00 a	43.25 a	19.50 a
						1046.46 a

^z Values within a column with the same letter are not significantly different (P = 0.05).

Performance of WideStrike Cotton in Arkansas, 2006

Gus M. Lorenz III, Kyle Colwell, Jarrod Hardke, and Craig Shelton¹

RESEARCH PROBLEM

WideStrike provides cotton producers with another effective tool for control of heliothines, tobacco budworm, *Heliothis virescens* F. and *Helicoverpa zea*, and other lepidopterous pests of cotton in Arkansas (Lorenz et al., 2002). In these studies, efficacy of WideStrike was compared against Bollgard II products. The purpose of this study was to examine the efficacy of WideStrike for control of lepidopterous pests.

BACKGROUND INFORMATION

The first caterpillar-resistant transgenic cotton varieties (Bollgard) were approved by the U.S. Environmental Protection Agency (EPA) in 1996. The Bollgard technology has successfully reduced the frequency of sprays for caterpillar pests by about half (Leonard et al., 2004). Dow AgroSciences has developed a similar multiple protein product (WideStrike) with efficacy against a wide range of lepidopterous pests. WideStrike cotton (*Gossypium hirsutum* L.) containing the Cry1Ac and Cry 1F endotoxin of *Bacillus thuringiensis*, became commercially available to cotton producers in 2005.

RESEARCH DESCRIPTION

Two trials were conducted in Jefferson County, Ark., in 2006. Trial 1 was a large block study in which varieties were planted 16 rows wide and 100 feet in length in a randomized complete block design with four replications. Insecticide applications are listed in the results (Table 1). PhytoGen varieties are lettered following the variety number; letters stand for the following; W = WideStrike, R = RoundupReady, and F = Flex. Data were collected on 18, 21, 24 July, 2 and 7 August using counts of 50 terminals, squares, 25 blooms, and 25 bolls.

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¹ Extension entomologist, seasonal agricultural technician, seasonal agricultural technician, and graduate assistant, Cooperative Extension Service, Little Rock.

Trial two was a small plot study in which varieties were planted 8 rows wide and 50 feet in length in a randomized complete block design with four replications. No insecticide applications targeting leps were made throughout the growing season. Data were collected on 19, 26, July, 2 and 9 August using counts of 50 terminals, squares, 25 blooms, and 25 bolls. In both trials, data were compared against each treatment and processed using Agriculture Research Manager Version 7. Bidrin at 0.6 lb a/acre was applied on 14 July for plant bug control on all plots. Zeal at 1 oz/acre was also applied on 17 August for control of spider mites in both trials.

RESULTS AND DISCUSSION

Variety PHY 425 RF had statistically more damage than all treatments in the large block trial (Fig. 1). DPL 117 BGII/RF showed significantly less damage than all other treatments, and fewer were larvae found than in PHY 425 RF. The small plot trial indicated that PHY 310 RF and PHY 425 RF had statistically more damage than the other treatments in the trial (Figs. 3 and 4). When seasonal total larvae were compared, PHY 370 WR, PHY 470 WR, and PHY 485 WRF had fewer total heliothines than the conventional varieties (Fig. 2). PHY 485 WRF, PHY 480 WR, and PHY 370 WR had significantly higher yields than all other treatments in the trial (Figs. 5 and 6).

PRACTICAL APPLICATION

Evaluating the efficacy of the new transgenic varieties will help us determine the applicability of this technology for Arkansas cotton producers.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. WideStrike large plots 2006 application history. Planting date: 17 May 2006

Variety	Treatment date	Treatment
PHY 485 WRF	18 Jul 06	Karate Z at 0.03 lb ai/acre
PHY 370 WR	No applications	
PHY 425 RF	18 Jul 06	Karate Z at 0.03 lb ai/acre
	31 Jul 06	Karate Z at 0.03 lb ai/acre
DPL 117	No applications	

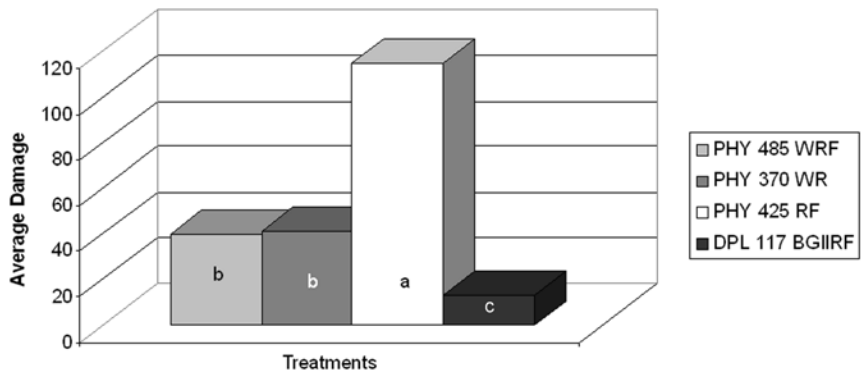


Fig. 1. WideStrike large plots seasonal damage.
Treatment means with the same letter do not significantly differ ($P=0.10$).

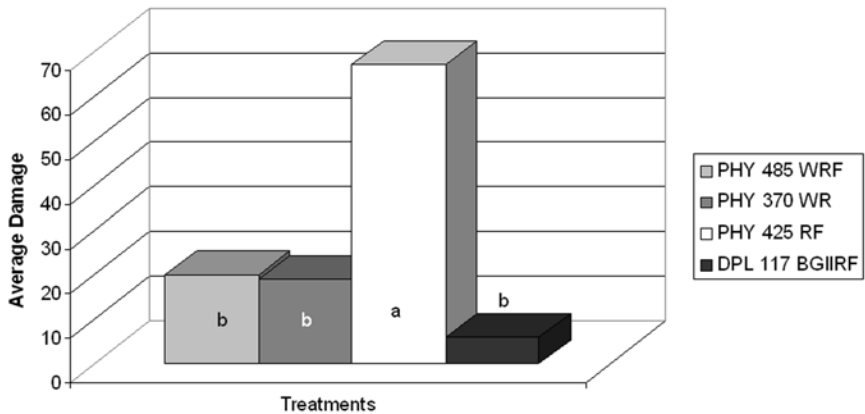


Fig. 2. WideStrike large plots average seasonal larvae found.
Treatment means with the same letter do not significantly differ ($P=0.10$).

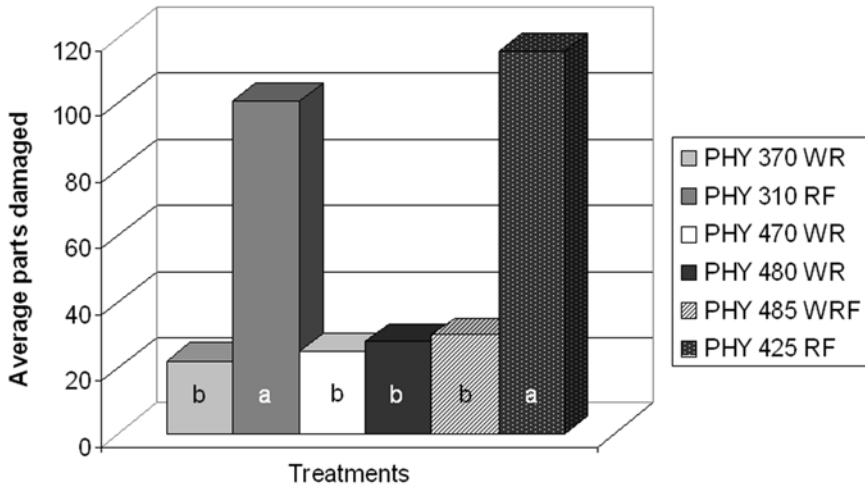


Fig. 3. WideStrike small plots seasonal damage.
Treatment means with the same letter do not significantly differ ($P=0.10$).

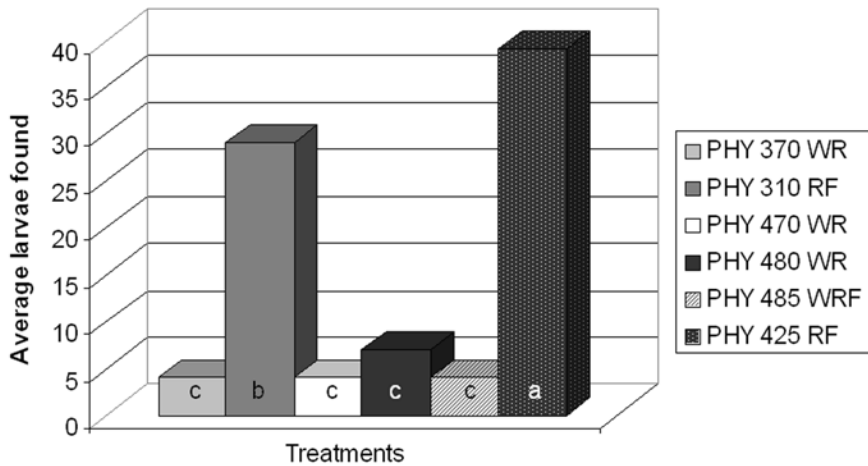


Fig. 4. WideStrike small plots seasonal total larvae.
Treatment means with the same letter do not significantly differ ($P=0.10$).

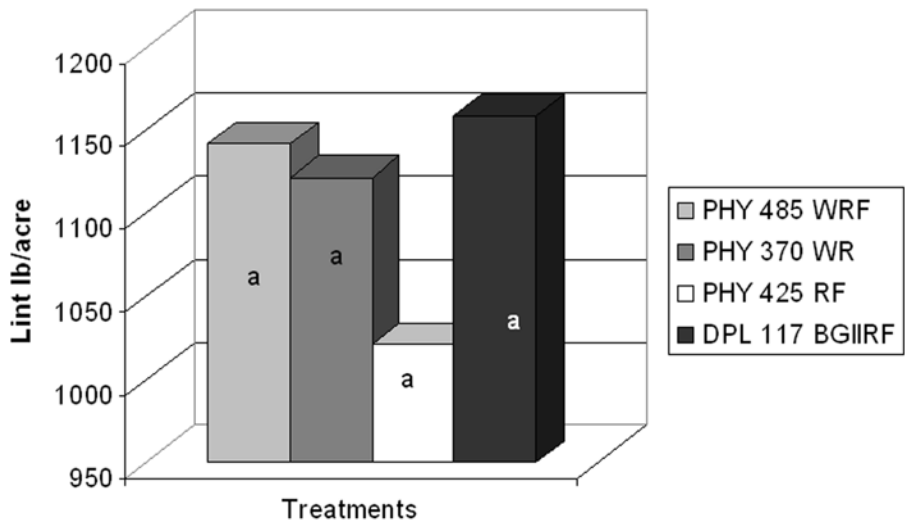


Fig. 5. WideStrike large plots harvest data.
Treatment means with the same letter do not significantly differ ($P=0.10$).

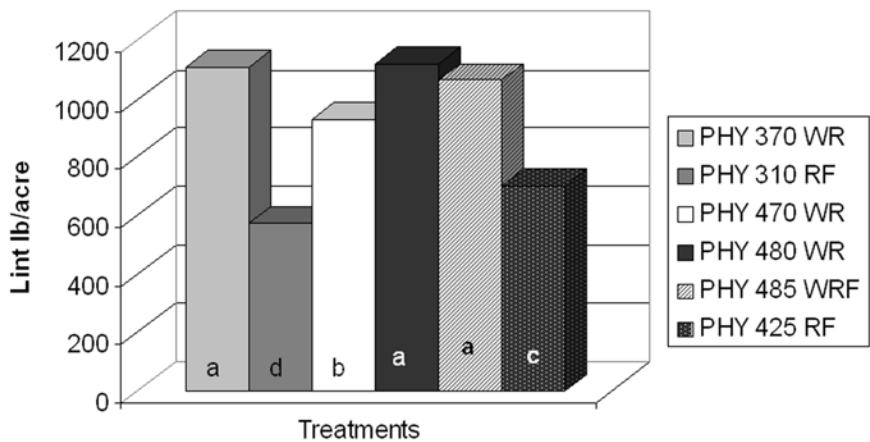


Fig. 6. WideStrike small plots harvest data.
Treatment means with the same letter do not significantly differ ($P=0.10$).

Mid-Season Plant Bug Thresholds in Arkansas, 2006

*Jarrod T. Hardke, Gus M. Lorenz, III, Kyle Colwell,
Craig Shelton, Chuck Farr, Bob Griffin, Eddie Cates, Chuck Capps¹*

RESEARCH PROBLEM

The tarnished plant bug (TPB) has become the primary target of foliar insecticides in cotton throughout the Mid-South over the last several years. This has prompted a re-evaluation of recommended sampling procedures and thresholds for this pest. Furthermore, scattered reports of TPB showing insecticide resistance and small profit margins prompt growers to become better stewards of the insecticides that are available. This research project was undertaken to identify sampling methods that are efficient and accurate throughout the Mid-South and then develop new thresholds for pre-bloom and blooming cotton with these sampling methods. Most people are comfortable with the recommended sweep net prior to bloom, so the focus of the sampling research was on blooming cotton.

BACKGROUND INFORMATION

Tarnished plant bugs are annual pests of cotton, most often damaging young flower buds (squares) (Johnson et al., 2001). Damage to young squares is a result of the piercing-sucking mouthparts of the plant bug puncturing the outer wall and feeding on the internal tissue. This feeding most often results in discoloration or “dirty squares,” and eventually abscission of the damaged structure. Feeding on blooms can also produce a “dirty” appearance, and feeding on bolls forms a wart inside the boll and damage to surrounding lint (Lorenz et al., 2005).

The increased use of transgenic *B.t.* cotton, as well as the success of the Boll Weevil Eradication Program, has led to a reduction in the use of insecticides, which

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previously controlled tarnished plant bugs (Greene et al., 2005). This shift in control measures has led to the evolution of the tarnished plant bug from a secondary pest to a major pest of cotton in the Mid-South. Since the emergence of the tarnished plant bug as a primary pest, there has been growing concern over the effectiveness of existing thresholds for tarnished plant control in the Mid-South.

RESEARCH DESCRIPTION

Trials for the evaluation of tarnished plant bug thresholds in mid-season Mid-South cotton were conducted in Lee, Desha, and Crittenden counties in Arkansas. Plot sizes were 24 rows (spaced on 38 inch rows) and 100 feet in length. All trials were arranged in a randomized complete block with four replications. All trials consisted of the same threshold treatments: an automatic treatment at first bloom and every seven days until cutout, a low threshold of 1 tarnished plants bug (TPB) per 5 row feet, a medium threshold of 3 TPB per 5 row feet, a high threshold of 5 TPB per 5 row feet, and a very high threshold of 10 TPB per 5 row feet. When a treatment threshold was reached, Bidrin (dicotophos) was applied at 8 oz/acre.

In the first trial, conducted in Lee County, the automatic treatment was applied with Bidrin five times, on 7 July, 17 July, 27 July, 29 July, and 8 August. The low-threshold treatment was applied with Bidrin three times, on 7 July, 17 July, and 27 July. The medium-threshold treatment and high-threshold treatment were each applied with Bidrin once, on 27 July. The very high-threshold treatment never received an application. In the second trial, conducted in Desha County, the automatic threshold treatment was applied with Bidrin four times, on 14 July, 20 July, 26 July, and 4 August. The low-threshold treatment was applied with Bidrin twice, on 14 July and 26 July. The medium-threshold treatment was applied with Bidrin twice, on 14 July and 4 August. The high- and very high-threshold treatments never received an application. In the third trial, also conducted in Desha County, the automatic threshold treatment was applied with Bidrin five times, on 26 June, 3 July, 10 July, 17 July, and 24 July. The low-threshold treatment was applied with Bidrin once, on 3 July. The medium-threshold treatment was applied with Bidrin once, on 10 July. The high- and very high-threshold treatments never received an application. In the fourth trial, conducted in Crittenden County, the automatic threshold treatment was applied with Bidrin three times, on 7 July, 17 July, and 8 August. The low-threshold treatment was applied with Bidrin once, on 17 July. No other thresholds reached treatment level. Tarnished plant bug density was determined by counting adult and nymph tarnished plant bugs in 2 drop cloth samples in each plot. Data were processed using Agricultural Research Manager Version 7. Analysis of variance was conducted and Duncan's New Multiple Range Test ($P=0.10$).

RESULTS AND DISCUSSION

In the first trial, conducted in Lee County, no significant differences ($P = 0.05$) were observed between treated and control which received no applications (Fig. 1). Results were similar to the Lee County trial and no differences between the low- and

high-threshold treatments were observed (Fig. 3). The high-threshold treatment showed the highest numerical yield of all treatments. In the second trial, conducted in Desha County, no significant differences were observed among treatments (Fig. 2). The very high-threshold treatment showed the highest numerical yield of all treatments. In the third trial, also conducted in Desha County, no significant differences were observed among treatments (Fig. 3). The medium-threshold treatment showed the highest numerical yield of all treatments. In the fourth trial, conducted in Crittenden County, no significant differences were observed among treatments (Fig. 4). The high-threshold treatment showed the highest numerical yield of all treatments. The effect of early season plant bug treatment on yield across all locations is shown in Fig. 5. Similarly, the effect of treatment for all locations indicates that early season applications in 2006 did not increase yields (Fig. 6). These trials indicate that treatments for plant bugs when threshold is not reached do not increase yield.

PRACTICAL APPLICATIONS

The results of this study provide growers and consultants with knowledge of the effectiveness of different treatment thresholds. Automatic applications from flowering through cutout for control of tarnished plant bugs had no significant effect on yield. Scheduled application of insecticides for control of tarnished plant bugs appears economically unwarranted in situations where recommended thresholds are not met.

ACKNOWLEDGMENTS

The researchers would like to thank Judd Hill, Steve Stevens, Larry McClendon, and Alan Helms for their cooperation in these studies and the Division of Agriculture, University of Arkansas.

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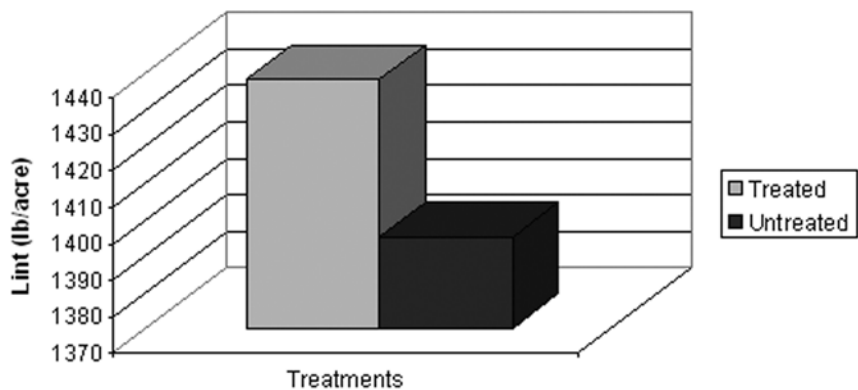


Fig. 1. Effect of mid-season plant bug treatment on yield, Lee Co.
Application dates: 7 July, 17 July, 27 July, 29 July, and 8 August.

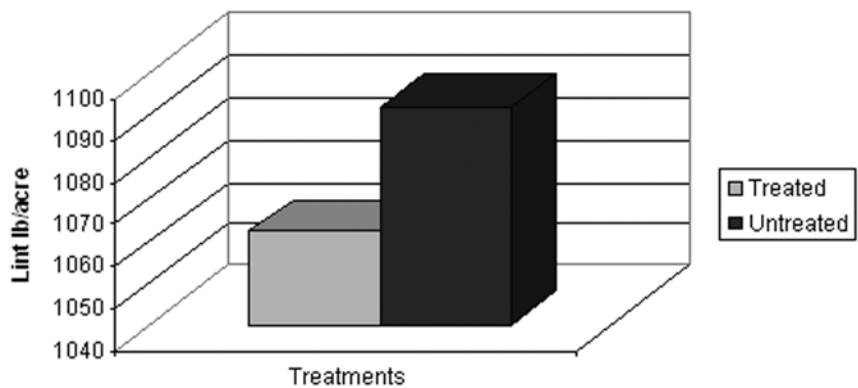


Fig. 2. Effect of mid-season plant bug treatment on yield, Desha Co. 1.
Application dates: 14 July, 20 July, 26 July, and 4 August.

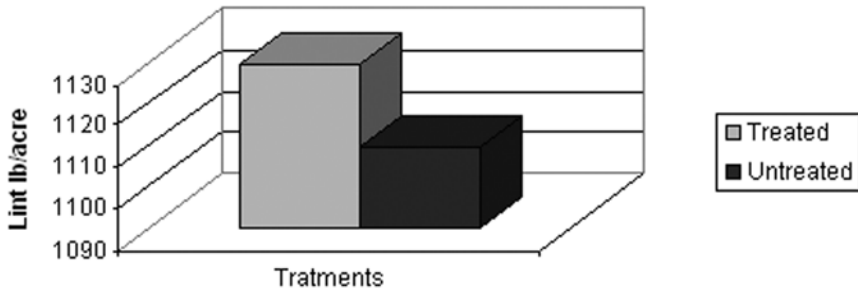


Fig. 3. Effect of mid-season plant bug treatment on yield, Desha Co. 2.
Application dates: 26 June, 3 July, 10 July, 17 July, and 24 July.

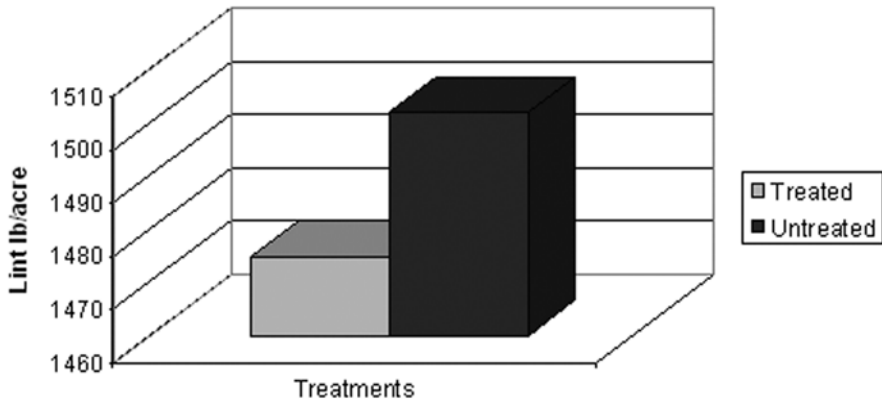


Fig. 4. Effect of mid-season plant bug treatment on yield, Crittenden Co.
Application dates: 26 June, 3 July, 10 July, 17 July, and 24 July.

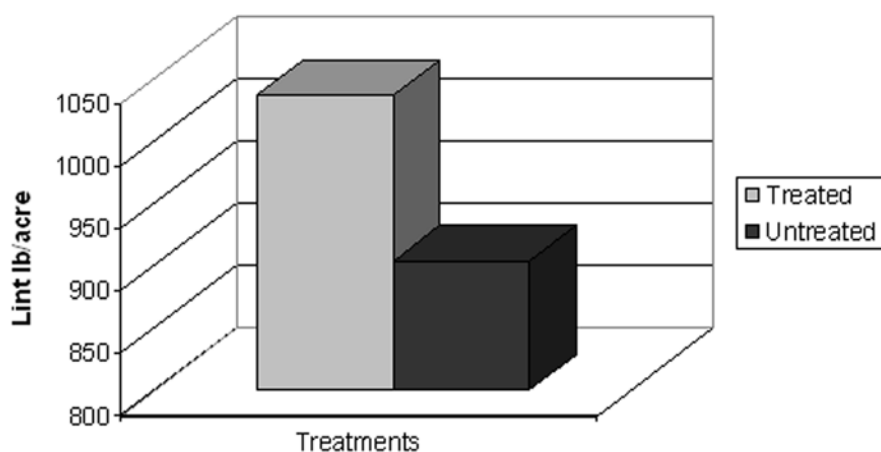


Fig. 5. Effect of early-season plant bug treatment on yield data across all locations.

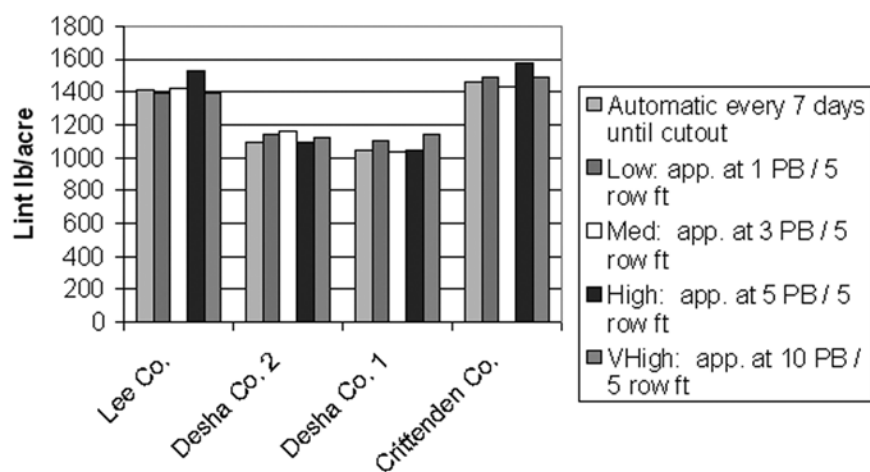


Fig. 6. Harvest data per treatment across all locations.

Early-Season Plant Bug Thresholds in Arkansas, 2006

*Jarrold T. Hardke, Gus M. Lorenz III, Kyle Colwell,
Craig Shelton, Chuck Farr, Bob Griffin, Eddie Cates, and Chuck Capps¹*

RESEARCH PROBLEM

The tarnished plant bug, *Lygus lineolaris*, is an important pest of cotton in the Mid-South (Layton, 2000). It has traditionally been considered an early-season pest. Insecticide applications targeting tarnished plant bugs were primarily made prior to the blooming period of cotton development (Black, 1973). However, the cotton-growing environment is rapidly evolving in the Mid-South because of new technologies. *Bt*-transgenic cotton is planted on over 80% of the acres because of the threat posed by insecticide-resistant tobacco budworm (*Heliothis virescens*) populations, and to a lesser extent, bollworm (*Helicoverpa zea*) and other caterpillar pests. Heavy adoption of *Bt* cultivars and boll weevil eradication has greatly reduced the number of “hard” insecticide applications targeting caterpillar pests and boll weevils. Concurrently, tarnished plant bug populations have developed resistance to commonly used insecticides, particularly the pyrethroids, in much of the region (Scott and Snodgrass, 2000). The tarnished plant bug, in particular, and other hemipteran pests such as the clouded plant bug and stink bugs have emerged as common mid- and late-season pests in this new environment.

Hemipteran pests have become the dominant mid-season pest complex in Mississippi, Louisiana, Arkansas, and Tennessee during the last five years. Crop losses associated with plant bugs and stink bugs, and associated control costs, have increased dramatically during the flowering period (Williams, 2004). In the Mid-South, 4 to 8 insecticide applications were commonly made specifically for tarnished plant bugs during the 2005 growing season (Williams, 2006). This trend is expected to increase or even worsen with the anticipated adoption of new *Bt* technologies (e.g., Bollgard II) that will further reduce the number of insecticide applications targeting caterpillar pests.

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The purpose of these experiments was to evaluate current treatment thresholds for the tarnished plant bug prior to flowering.

BACKGROUND INFORMATION

Tarnished plant bugs are annual pests of cotton, most often damaging young flower buds (squares) (Johnson et al., 2001). Damage to young squares is a result of the piercing-sucking mouthparts of the plant bug puncturing the outer wall and feeding on the internal tissue. This feeding most often results in discoloration or “dirty squares”, and eventually abscission of the damaged structure. Feeding on blooms can also produce a “dirty” appearance, and feeding on bolls forms a wart inside the boll and damage to surrounding lint (Lorenz et al., 2005).

The increased use of transgenic *Bt* cotton, as well as the success of the Boll Weevil Eradication Program, has led to a reduction in the use of insecticides, which previously controlled tarnished plant bugs (Greene et al., 2005). This shift in control measures has led to the evolution of the tarnished plant bug from a secondary pest to a major pest of cotton in the Mid-South. Since the emergence of the tarnished plant bug as a primary pest, there has been growing concern over the effectiveness of existing thresholds for tarnished plant bug control in the Mid-South.

RESEARCH DESCRIPTION

Trials for the evaluation of tarnished plant bug thresholds in early-season Mid-South cotton were conducted in Lee, Desha, Mississippi, and Crittenden counties in Arkansas. Plot sizes were 24 rows (spaced on 38-in.) and 100 feet in length. All trials were arranged in a randomized complete block with four replications. All trials consisted of the same threshold treatments: an automatic treatment at pinhead square and every seven days until bloom, a low threshold of 8 tarnished plants bugs (TPB) per 100 sweeps, a high threshold of 16 TPB per 100 sweeps, and an untreated control. When a treatment threshold was reached, Centric (thiomethoxam) was applied at 2 oz/acre.

In the first trial, conducted in Lee County, the automatic treatment was applied with Centric four times, on 8 June, 15 June, 21 June, and 29 June. No other thresholds reached treatment level. In the second trial, conducted in Desha County, the automatic treatment was applied with Centric four times, on 15 June, 22 June, 29 June, and 6 July. No other thresholds reached treatment level. In the third trial, also conducted in Desha County, the automatic treatment was applied with Centric four times, on 5 June, 12 June, 20 June, and 26 June. The low threshold was also treated once on 12 June. No other thresholds reached treatment level. In the fourth trial, conducted in Mississippi County, the automatic treatment was applied with Centric four times, on 21 June, 26 June, 29 June, and 3 July. No other thresholds reached treatment level. In the fifth trial, conducted in Crittenden County, the automatic treatment was applied with Centric two times, on 26 June and 7 July. Tarnished plant bug density was determined by counting adult and nymph tarnished plant bugs in 25 sweep-net samples in each plot. Data were processed using Agricultural Research Manager Version 7. Analysis of variance was conducted and Duncan’s New Multiple Range Test ($p=0.10$) was used.

RESULTS AND DISCUSSION

In the first trial, conducted in Lee County, no significant differences were observed among treatments (Fig. 1). The untreated control showed the highest numerical yield of all treatments. In the second trial, conducted in Desha County, no significant differences were observed among treatments (Fig. 2). The low-threshold treatment showed the highest numerical yield of all treatments. In the third trial, also conducted in Desha County, no significant differences were observed among treatments (Fig. 3). The high-threshold treatment showed the highest numerical yield of all treatments. In the fourth trial, conducted in Mississippi County, no significant differences were observed among treatments (Fig. 4). The automatic-treatment threshold showed the highest numerical yield of all treatments. In the fifth trial, conducted in Crittenden County, no significant differences were observed among treatments (Fig. 5). The low-treatment threshold and the untreated control showed the highest numerical yields of all treatments. The effect of early season plant bug treatments on yield across all locations is shown in Fig. 6. Similarly, the effect of plant bug treatments on yield across all locations is shown in Fig. 7.

PRACTICAL APPLICATIONS

The results of this study provide growers and consultants with knowledge of the effectiveness of different treatment thresholds. Automatic applications beginning at pinhead square for control of tarnished plant bugs had no significant effect on yield. Early-season application of insecticides for control of tarnished plant bugs appears economically unwarranted in situations where recommended thresholds are not met.

ACKNOWLEDGMENTS

The researchers would like to thank Judd Hill, Steve Stevens, Larry McClendon, and Alan Helms for their cooperation in these studies.

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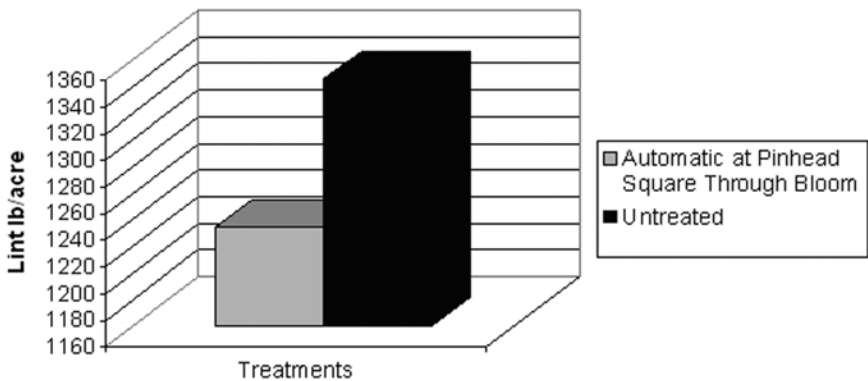


Fig. 1. Effect of early-season plant bug treatment on lint yield, Lee Co.
Application dates: 8 June, 15 June, 21 June, and 29 June, 2006.

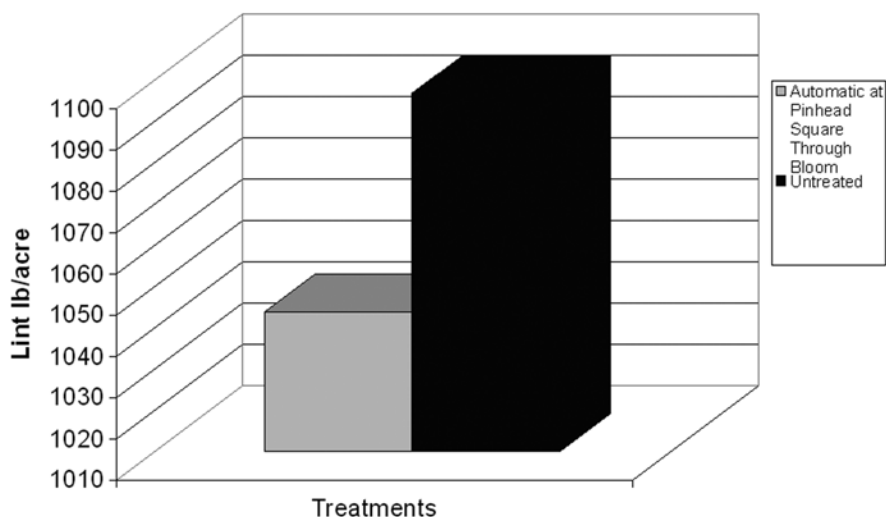


Fig. 2. Effect of early-season plant bug treatment on yield, Desha Co. 1.
Application dates: 15 June, 22 June, 29 June, and 6 July, 2006.

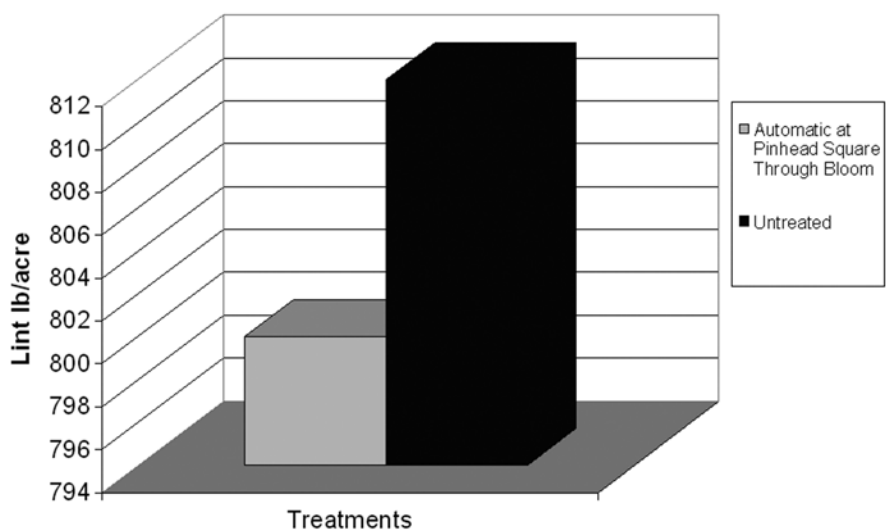


Fig. 3. Effect of early-season plant bug treatments on yield, Desha Co. 2.
Application dates: 15 June, 21 June, and 26 June, 2006.

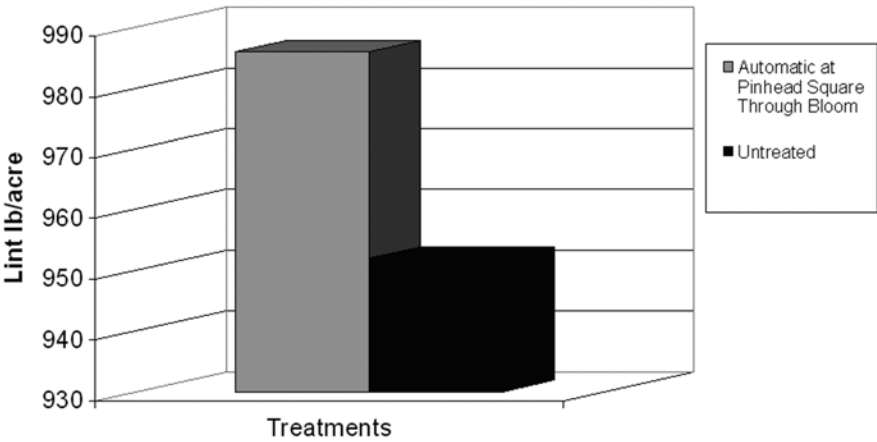


Fig. 4. Effect of early-season plant bug treatments on yield, Mississippi Co.
Application dates: 21 June, 26 June, 29 June, and 3 July, 2006.

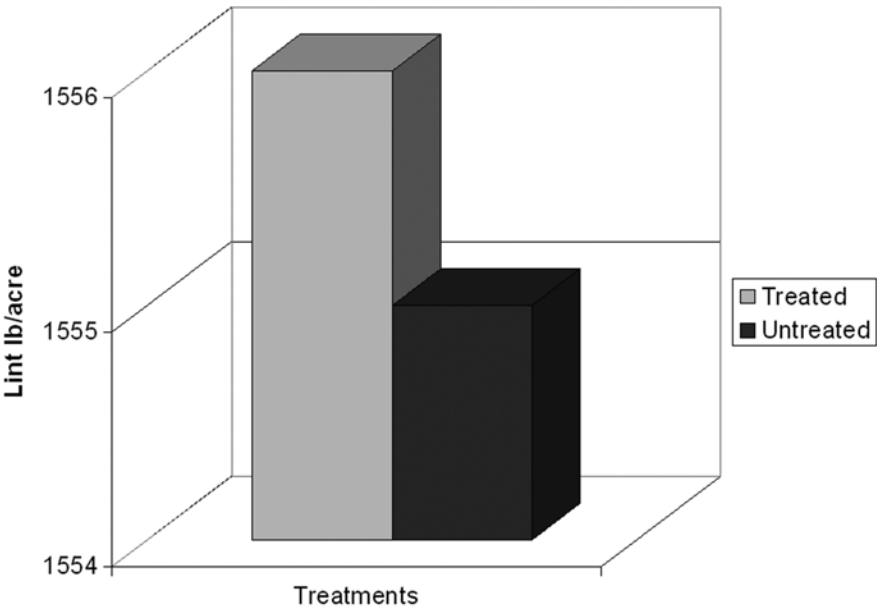


Fig. 5. Effect of early-season plant bug treatments on yield, Crittenden Co.
Application dates: 26 June and 7 July, 2006.

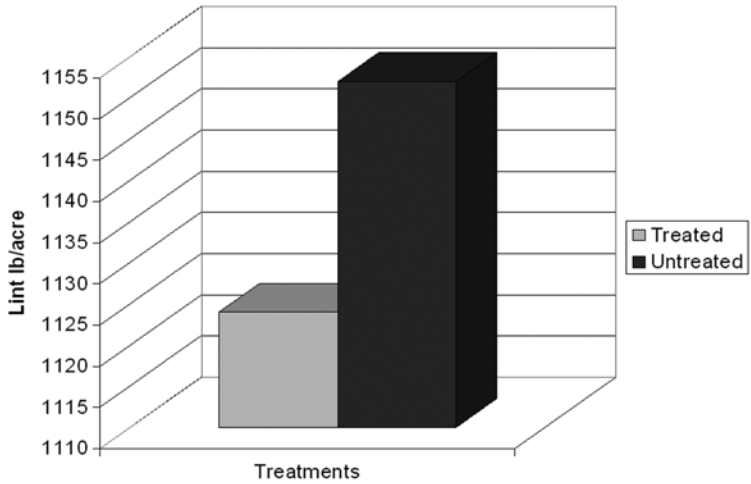


Fig. 6. Effect of early-season plant bug treatments on yield across all locations.

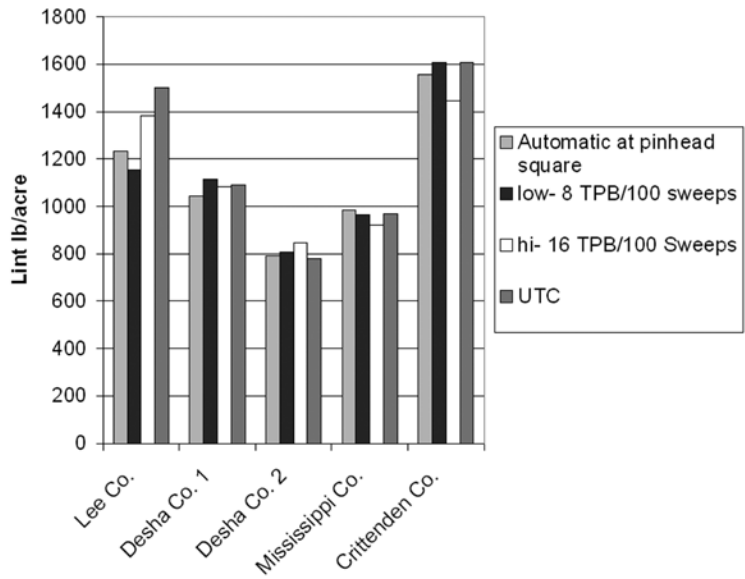


Fig. 7. Effect of plant bug treatments on yield across all locations.

Efficacy of Selected Compounds for Two-Spotted Spider Mite (*Tetranychus urticae*) Control in Arkansas, 2006

Kyle Colwell, Gus Lorenz, III, Craig Shelton, Jarrod Hardke, and Robert Goodson¹

RESEARCH PROBLEM

Two-spotted spider mites are becoming one of the most expensive pests to control in the Mid-South. Two-spotted spider mites, *Tetranychus urticae*, are occasional pests that can cause serious damage to cotton crops in the Mid-South (Bessin, 2004). Extended periods of hot, dry weather favor mite buildups. Spider mite populations in 2006 were responsible for yield loss across much of the Mid-South. Spider mites can cause premature defoliation resulting in yield loss.

BACKGROUND INFORMATION

In 2005, Arkansas growers spent on average \$13.62/acre for control of two-spotted spider mites. Continual evaluation of the performance of commercial miticides is necessary for prolonged two-spotted spider mite suppression. The purpose of the experiment was to assess the performance of selected miticides for two-spotted spider mite control.

RESEARCH DESCRIPTION

Test one was located in Lonoke County, Ark. (KEO). The variety of cotton was DPL 445. Data were collected on 12 [3 days after treatment DAT] and 15 (6 DAT) June. Treatments are listed Table 1. Test two and three were located adjacent to each other at Turner Farms, in Phillips County, Ark. The variety of cotton was DPL 444. Insecticide treatments were applied on 20 July with a hand boom. The boom was fitted with TX6 hollow-cone nozzles at 19-in. nozzle spacing. Spray volume was 10 gal/acre, at 45 psi. Plot size was 4 rows by 30 ft arranged in a randomized complete block design with

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four replications. Data were collected on 25 (5 DAT) and 27 (7 DAT) July. Treatments are listed in the results section. Spider mite density was determined by counting five leaves from the middle two rows from each plot and specimens were counted under a 1- × 1-in. hand lens. Data were compared against each treatment and were processed using Agriculture Research Manager Version 7.

RESULTS AND DISCUSSION

Kelthane at 1 qt/acre provided better control for spider mites than the untreated control (UTC) at three days after application in Keo, Arkansas. Five days after application, Kelthane provided better control than Acramite at 0.375 lb a/acre. Seasonal totals indicated Zeal at 1 oz/acre, and Kelthane at 1 qt/acre had significantly fewer two-spotted spider mites than the untreated check.

All treatments were statistically better for control of spider mites than the untreated check after five and seven days after application in Barton 1 (Table 2). Seasonal totals indicated Fujimite at 10 oz/acre + non-ionic surfactant at 0.25 % v/v provided statistically better control than Kelthane at 1 qt/acre and the UTC. In the second Barton study (Barton 2), all plots provided better control than the untreated control (Table 3). Abba at 6 oz/acre and Onager at 10 oz/acre had statistically fewer spider mites than Zephyr at 8 oz and the untreated control.

PRACTICAL APPLICATION

The results of this study provided growers and consultants with vital information for the changing efficacy of commercial miticides.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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Table 1. Efficacy of various insecticides for control of two-spotted spider mite at Keo, Ark.

Treatment name	Rate	Unit/acre	Total mites		Seasonal total spider mites
			3 DAT	6 DAT	
Untreated control			121 a ^z	49 a	170 a
Acramite	0.5	lb	77 ab	14 ab	92 abc
Acramite	0.375	lb	104 ab	48 a	151 ab
Kelthane MF	1	qt	20 b	6 b	26 c
Zephyr	4	oz	90 ab	12 ab	103 abc
Zeal	1	oz	61 ab	17 ab	78 bc

^z Means followed by same letter do not significantly differ (P=0.10).

Table 2. Efficacy of various insecticides for control of two-spotted spider mite at Barton (1).

Treatment name	Rate	Unit/acre	Total mites		Seasonal total spider mites
			5 DAT	7 DAT	
Untreated control			139 a ^z	128 a	267 a
Zeal 1	oz	45	b 57	b 102	bc
Oberon	6	oz	35 b	34 b	69 bc
Abba	6	oz	46 b	69 b	114 bc
Fujimite	10	oz	25 b	26 b	51 c
NIS ^y	0.25	% v/v			
Capture	6	oz	30 b	55 b	86 bc
COC ^x	0.25	% v/v			
Onager	10	oz	58 b	53 b	114 bc
Acramite	12	oz	36 b	53 b	89 bc
Kelthane	1	qt	77 b	65 b	142 b

^z Means followed by same letter do not significantly differ (P=0.10).

^y NIS = non-ionic surfactant.

^x COC = crop oil concentrate.

Table 3. Efficacy of various insecticides for control of two-spotted spider mite at Barton (2).

Treatment name	Rate	Unit/acre	Total mites		Seasonal total spider mites
			5 DAT	7 DAT	
Untreated control			99 a ^z	67 a	166 a
Zeal	1	oz	34 b	32 ab	65 bc
Oberon	4	oz	21 b	45 ab	66 bc
Oberon	6	oz	29 b	47 ab	75 bc
Oberon	8	oz	17 b	47 ab	64 bc
Zephyr	6	oz	33 b	26 b	59 bc
Zephyr	8	oz	42 b	67 a	109 b
Abba	6	oz	23 b	24 b	47 c
Abba	8	oz	31 b	44 ab	74 bc
Onager	6	oz	44 b	37 ab	81 bc
Onager	8	oz	33 b	32 ab	65 bc
Onager	10	oz	18 b	32 ab	50 c

^z Means followed by same letter do not significantly differ (P=0.10).

Rynaxypyr™: A Novel Insecticide for Control of Heliothines in Conventional and Bollgard Cotton

*Jarrold T. Hardke, Gus M. Lorenz, III,
Kyle Colwell, Craig Shelton, and Richard Edmund¹*

RESEARCH PROBLEM

In 2006, Rynaxypyr™ was evaluated in three studies in Jefferson County, Ark., for control of heliothines. This study represents an evaluation of a new class of insecticides.

BACKGROUND INFORMATION

Rynaxypyr 35 WG is a new foliar-applied insecticide being developed by DuPont to control lepidopteran pests in cotton, and to control pests in other major crops in the Mid-South including rice, soybeans, and sugarcane, as well as in fruits, nuts, and vegetables. Rynaxypyr's mode of action is activation of insect ryanodine receptors, which stimulates the release of calcium from internal stores of smooth and striated muscle, causing impaired muscle regulation, paralysis, and finally death. Rynaxypyr appears to have appreciable selectivity for insect ryanodine receptors over mammalian receptors.

RESEARCH DESCRIPTION

Three field experiments were conducted in 2006 in Jefferson County, Ark. All three trials were set up individually, using plot sizes of 8 rows (38-in. spacing) and 50 feet in length. A randomized complete block design with four replications was also used for each trial. Treatments were applied using a John Deere 6500 Hi-Cycle with an 8-row boom on 19-in. nozzle spacing. The nozzles used for application were Tee Jet TXVS-6. Operating pressure was 45 psi and 9.69 gal/acre of volume.

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The first trial compared Rynaxypyr and traditional insecticides in conventional non-*Bt* cotton to Bollgard II cotton. The cotton variety Delta Pine 434 was planted on 16 May 2006. Insecticide applications were made on 10 July and 2 August. Treatments included an untreated check, Rynaxypyr at 0.088 lb ai/acre followed by (FB) Rynaxypyr at 0.066 lb ai/acre, Rynaxypyr at 0.088 FB Rynaxypyr at 0.088 lb ai/acre, Tracer at 0.067 lb ai/acre, a Bollgard II variety that remained untreated, and Tracer at 0.033 lb ai/acre tank mixed with Capture at 0.1 lb ai/acre. Evaluations were made on 13 July [3 days after treatment (DAT)], 19 July (9 DAT), 26 July (15 DAT), 31 July (20 DAT), 2 August (22 DAT), and 7 August (5 DAT). Evaluations consisted of examining random samples of 25 terminals, squares, blooms, and bolls in each plot. Data were analyzed using Agricultural Research Manager Version 7 using Analysis of Variance and LSD ($P=0.10$, Student-Newman-Keuls).

The second trial compared Rynaxypyr and traditional insecticides in Bollgard cotton. Delta Pine 444 was planted on 16 May 2006. Insecticide applications were made on 31 July. Treatments included an untreated check, Rynaxypyr at 0.022 lb ai/acre, Rynaxypyr at 0.044 lb ai/acre Asana XL at 0.03 lb ai/acre, Capture at 0.046 lb ai/acre tank mixed with Orthene at 0.5 lb ai/acre, Capture alone at 0.046 lb ai/acre, and Tracer at 0.033 lb ai/acre tank mixed with Capture at 0.1 lb ai/acre. Evaluations were made on 3 August (3 DAT) and 7 August (7 DAT). Evaluations consisted of examining random samples of 25 terminals, squares, blooms, and bolls in each plot. Data were analyzed using Agricultural Research Manager Version 7 using Analysis of Variance and LSD ($P=0.10$, Student-Newman-Keuls).

The third trial evaluated Rynaxypyr in comparison to traditional and experimental insecticides in conventional non-*Bt* cotton. Delta Pine 434 was planted on 16 May 2006. Insecticide applications were made on 10 July, 20 July, and 31 July. Treatments included multiple rates of Experimental I, Experimental I tank mixed with Larvin at 0.12 lb ai/acre, Larvin alone at 0.12 lb ai/acre, Tracer at 0.078 lb ai/acre, Tracer at 0.0624 lb ai/acre tank mixed with Capture at 0.042 lb ai/acre, Denim at 0.01 lb ai/acre, Rynaxypyr at 0.088 lb ai/acre, and Steward at 0.1 lb ai/acre. Evaluations were made on 13 July (3 DAT), 17 July (7 DAT), 24 July (4 DAT), 31 July (11 DAT), 3 August (3 DAT), and 9 August (9 DAT). Evaluations consisted of examining random samples of 25 terminals, squares, blooms, and bolls in each plot. Data were analyzed using Agricultural Research Manager Version 7 using Analysis of Variance and LSD ($P=0.10$, Student-Newman-Keuls).

RESULTS AND DISCUSSION

In the first trial, both treatments of Rynaxypyr and Bollgard II displayed significantly less damage than the untreated check, Tracer, and Tracer tank mixed with Capture (Table 1). Both treatments of Rynaxypyr were significantly better than the untreated control. Tracer, and Tracer tank mixed with Capture for seasonal total larvae found. Bollgard II recorded fewer larvae than the untreated check and Tracer tank mixed with Capture.

In the second trial, all treatments had less seasonal damage and fewer seasonal larvae than the untreated control (Table 2). In the third trial, all treatments performed

statistically better than the untreated control in regard to seasonal total damage (Tables 3 and 4). Rynaxypyr and Tracer alone had less damage than a single Experimental I treatment, Experimental I tank mixed with Larvin, Larvin alone, Tracer tank mixed with Capture, Denim, and Steward (Tables 5 and 6). Three treatments of Experimental I performed statistically better than the remaining treatment of Experimental I and Steward. All treatments were better than the untreated check for seasonal total larvae found. Yields indicated that a single treatment of Experimental was better than Steward and Experimental I tank mixed with Larvin. No statistical differences were observed among any other treatments.

PRACTICAL APPLICATION

Rynaxypyr has been shown to perform statistically better than traditional insecticides for controlling heliothines in conventional non-*Bt* in regard to seasonal total damage and seasonal total larvae found. Rynaxypyr applied to conventional non-*Bt* cotton has also been shown to perform statistically similar to Bollgard II in terms of seasonal total damage and seasonal total larvae found. Rynaxypyr has also been shown to perform statistically similar to traditional insecticides in Bollgard cotton in regard to seasonal total damage, seasonal total larvae found, and yield. These studies show that Rynaxypyr has a place in Mid-South cotton production for controlling heliothines.

ACKNOWLEDGMENTS

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Table 1. Rynaxypyr on conventional cotton vs. BG II seasonal damage by sampling date.

Treatment		Total damage				Seasonal total
name	Rate	7/13/2006	7/19/2006	7/26/2006	8/2/2006	damage
(lb a/acre)						
Untreated control		4 a ^z	10 a	19 a	14 a	47 a
Ryanxypyr FB	0.088	1 a	4 a	4 c	4 b	14 b
Rynaxypyr	0.066					
Rynaxypyr FB	0.088	2 a	2 a	4 c	5 b	12 b
Rynaxypyr	0.088					
Tracer	0.067	2 a	8 a	13 b	12 a	34 a
BG II		1 a	6 a	4 c	6 b	17 b
Tracer +	0.033	3 a	6 a	12 b	13 a	33 a
Capture	0.1					

^z Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 2. Rynaxypyr on DPL 434 seasonal larvae found by sampling date.

Treatment		Total damage				Seasonal total
name	Rate	7/13/2006	7/19/2006	7/26/2006	8/2/2006	damage
(lb a/acre)						
Untreated control		1 a ^z	4 a	6 a	6 a	16 a
Rynaxypyr FB	0.088	0 a	0 a	1 b	1 b	2 d
Rynaxypyr	0.066					
Rynaxypyr FB	0.088	0 a	0 a	0 b	1 b	2 d
Rynaxypyr	0.088					
Tracer	0.067	0 a	1 a	4 ab	4 ab	9 bc
BG II		0 a	1 a	1 b	3 ab	5 cd
Tracer +	0.033	1 a	2 a	3 ab	5 ab	10 b
Capture	0.1					

^z Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 3. Rynaxypyr on DPL 444 total damage by date.

Treatment name	Rate	Rate unit	Total damage		Seasonal total damage
			8/3/2006	8/7/2006	
Untreated control			7 a ^z	17 a	24 a
Rynaxypyr	0.022	lb a/acre	3 a	5 b	8 b
Rynaxypyr	0.044	lb a/acre	6 a	4 b	10 b
Asana XL	0.03	lb a/acre	7 a	4 b	11 b
Capture +	0.046	lb a/acre	5 a	6 b	11 b
Orthene	0.5	lb/acre			
Capture	0.046	lb a/acre	5 a	6 b	10 b
Tracer +	0.033	lb a/acre	3 a	2 b	5 b
Capture	0.1	lb a/acre			

^z Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 4. Rynaxypyr on DPL 444 BG/RR total larvae by date.

Treatment name	Rate	Rate unit	Total damage		Seasonal total damage
			8/3/2006	8/7/2006	
Untreated control			3 a ^z	6 a	9 a
Rynaxypyr	0.022	lb a/acre	2 a	2 b	3 b
Rynaxypyr	0.044	lb a/acre	2 a	1 b	2 b
Asana XL	0.03	lb a/acre	2 a	1 b	3 b
Capture + Orthene	0.046	lb a/acre	1 a	2 b	3 b
	0.5	lb/acre			
Capture	0.046	lb a/acre	2 a	2 b	3 b
Tracer + Capture	0.033	lb a/acre	1 a	1 b	2 b
	0.1	lb a/acre			

^a Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 5. Rynaxypyr on DPL 434 (conventional) Trial 2 - total damage 2006.

Treatment name	Rate	Rate unit	Seasonal total damage
Untreated control			92 a ^z
Experimental I			24 cd
Experimental I			24 cd
Experimental I			28 cd
Experimental I			52 b
Experimental I + Larvin	5	oz/acre	42 bc
Larvin	5	oz/acre	44 bc
Tracer	2.5	fl oz/acre	19 d
Capture + Tracer	2.75 + 2	fl oz/acre	40 bc
Denim	8	oz/acre	46 bc
Rynaxypyr	0.088	lb a/acre	17 d
Steward	0.1	lb a/acre	53 b

^a Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 6. Rynaxypyr on DPL 434 (conventional) Trial 2 - total larvae, 2006.

Treatment name	Rate	Rate unit	Seasonal total damage
Untreated control			25 a
Experimental I			3 b
Experimental I			4 b
Experimental I			2 b
Experimental I			11 b
Experimental I + Larvin	5	oz/acre	8 b
Larvin	5	oz/acre	11 b
Tracer	2.5	fl oz/acre	3 b
Capture + Tracer	2.75 + 2	fl oz/acre	10 b
Denim	8	oz/acre	10 b
Rynaxypyr	0.088	lb a/acre	1 b
Steward	0.1	lb a/acre	12 b

^a Means followed by same letter do not significantly differ (P=.10, Student-Newman-Keuls). Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Economic Impacts of Termination Timing for Irrigation and Plant Bug Control

Juan J. Monge, Tina Gray Teague, Mark J. Cochran, and Diana M. Danforth¹

RESEARCH PROBLEM

An economic analysis was performed on a three-year irrigation/insecticide termination experiment conducted at the Lon Mann Cotton Research Station in Marianna with the objective of determining if longer periods of irrigation and plant-bug (*Lygus Lineolaris Palisot de Beauvois*) control reward producers through higher fiber attribute values and higher profits. It was hypothesized that an early termination of irrigation could decrease insect incidence and damage due to a reduction in plant lushness (Teague and Danforth, 2005). Hence, the problem posed was termination (irrigation and insect control) timing and its economic implications. The objectives of this study were the following:

1. Determine if longer periods of irrigation and insecticide treatment reward producers through higher yields, fiber attribute values (lint values), and profits.
2. Establish economically profitable termination guidelines based on crop maturity.

RESEARCH DESCRIPTION

Yield and fiber quality data were collected from experiments conducted at the University of Arkansas Lon Mann Cotton Research Station in Marianna in 2004, 2005, and 2006. The experiments were designed as a split plot with irrigation (5 levels) as the main plot and insecticide (4 levels) as the sub-plot. Due to late-season rains, two of the 5 irrigation termination treatments were dropped in 2005. In 2006, a one-in. rainfall occurred at NAWF=5 + 366 DD60s, confounding the irrigation termination treatment at 166 DD60s. More technical information about these experiments can be found in Teague et al. (2005) and Danforth et al. (2006). Nodes Above White Flower (NAWF) were monitored using the crop monitoring program COTMAN. Boll samples were sent to the International Textile Center at Texas Tech University for HVI fiber quality

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determinations. The 2004, 2005, and 2006 Commodity Credit Corporation (CCC) loan schedule of premiums and discounts for upland cotton were used to market adjust the price of cotton as a function of micronaire, color/leaf grade, fiber length, uniformity, and strength. A base loan rate of 0.52/lb was used to calculate prices for 2004 and 2005. For 2006, the base loan rate changed to 0.7977/lb. Irrigation and insect control costs were collected from the AG-896 budget for cotton grown on the Southeast/Central boll weevil eradication zone, published, and posted on the Cooperative Extension Service Web site of the University of Arkansas Division of Agriculture. Insect control costs are shown in Tables 1, 2, and 3 for 2004, 2005, and 2006, respectively. Irrigation cost in this study was estimated to be \$7.96/acre per application. Mean yields, lint values, and profits were analyzed using ANOVA for the different irrigation/insecticide treatments with mean separation factored using Fisher's Least Significant Difference (LSD).

RESULTS AND DISCUSSION

For the 2004 experiment's ANOVA analyses, there were no significant interactions and the interaction term was dropped from the models. Mean yields were significantly different ($p < 0.01$) for both irrigation and insecticide-termination treatment main effects as shown in Table 4. There was a 12% yield increase (lb/acre) when irrigation was continued to NAWF=5 + 360 DD60s compared to terminating at 100 DD60s. Continuing irrigation until 580 DD60s did not result in further yield increase. There was a 12% yield increase when insect control was continued to NAWF=5 + 240 DD60s compared to terminating at NAWF=5.6. Continuing until 450 DD60s did not result in further yield increase. Mean lint values were significantly different for the insecticide termination treatments ($p < 0.01$). There was a 6% lint value increase (\$/pound) when insect control was continued to NAWF=5 + 240 DD60s compared to terminating at NAWF=5.6. Continuing until 450 DD60s did not result in further lint value increase. Net returns were significantly different for the irrigation termination treatments ($p < 0.01$). There was a 16% profit increase (\$/acre) when irrigation was continued to NAWF=5 + 360 DD60s compared to terminating at 100 DD60s. Continuing until 580 DD60s caused profits to decrease.

For the 2005 experiment, mean yields, lint values, and profits did not show any significant differences for either irrigation or insecticide-termination main effects, as shown in Table 5.

For the 2006 experiment's ANOVA analyses, there were no significant interactions. Mean yields were significantly different ($p < 0.01$) for both irrigation and insecticide termination treatment main effects, as shown in Table 6. There was an 18% yield increase (lb/acre) when irrigation was continued to NAWF=5 + 166 DD60s (366 DD60s equivalent), compared to terminating at cutout. Continuing irrigation until 650 DD60s did not result in further yield increase. There was a 19% yield increase when insect control was continued to NAWF=5 + 280 DD60s compared to terminating 9 days prior to cutout. Continuing until 650 DD60s caused yields to decrease. Mean lint values were significantly different for the irrigation termination treatments ($p < 0.01$). There was a 5% lint value increase (\$/pound) when insect control was continued to NAWF=5 + 166 DD60s (366 DD60s equivalent) compared to terminating at cutout. Continuing until

650 DD60s did not result in further lint value increase. Net returns were significantly different for both irrigation and insecticide termination treatments ($p < 0.01$). There was a 26% profit increase (\$/acre) when irrigation was continued to NAWF=5 + 166 DD60s (366 DD60s equivalent) compared to terminating at cutout. Continuing until 650 DD60s did not result in further profit increase. There was a 22% profit increase when insecticide control was continued to 280 DD60s compared to terminating 9 days prior to cutout. Continuing until 650 DD60s caused profits to decrease.

PRACTICAL APPLICATION

Irrigations later than NAWF=5 + 360 DD60s did not pay in any year. Neither yield nor price increased, making continued irrigation economically unprofitable. It appears feasible to use COTMAN crop-termination guidelines for timing the final irrigation. On-farm field trials should be expanded to validate irrigation-termination guidelines based on crop maturity using the COTMAN system. Results from this three-year study indicate that neither yield nor profit was increased when control for tarnished plant bugs was extended beyond NAWF = 5+280 DD60s. The COTMAN guideline for terminating insect control at NAWF = 5+350 DD60s can economically be applied to tarnished plant bug. New infestations occurring after that time can be ignored.

ACKNOWLEDGMENTS

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- Teague, T.G. and D.M. Danforth. 2005. Final irrigation timing and late season crop susceptibility to tarnished plant bug [*Lygus lineolaris* (Palisot de Beauvois)] – using COTMAN to make crop termination decisions. pp. 1743-1753. *Proc. Beltwide Cotton Conf., National Cotton Council of America, Memphis, Tenn.*

Table 1. Insecticide and application costs (per acre) and schedule for the different insecticide termination treatments for 2004.

Termination treatment	Date	Insecticide	Rate	Unit	Price	Insecticide cost	Application cost ^z	Cost/application	Total cost
						-----(\$)-			
NAWF = 7.2	26 May	Bidrin	8.00	oz	0.71	5.68	1.04	6.72	37.19
	11 Jun	Centric	1.25	oz	4.59	5.74	1.04	6.78	
	18 Jun	Centric	1.25	oz	4.59	5.74	1.04	6.78	
	6 Jul	Centric	1.50	oz	4.59	6.89	1.04	7.93	
	16 Jul	Trimax	1.50	oz	5.30	7.95	1.04	8.99	
NAWF = 5.6	22 Jul	Bidrin	8.00	oz	0.71	5.68	1.04	6.72	43.91
NAWF = 5 + 240 DD60s	28 Jul	Orthene	0.75	lbs	9.00	6.75	1.04	41.97	110.53
		Fury	4.00	oz	1.23	4.92			
		Zephyr	5.90	oz	4.96	29.26			
	8 Aug	Trimax	1.50	oz	5.30	7.95	1.04	24.64	
		Capture	5.00	oz	3.13	15.65			
NAWF = 5 + 450 DD60s	17 Aug	Bidrin	8.00	oz	0.71	5.68	1.04	30.32	171.16
		Trimax	1.50	oz	5.30	7.95			
		Capture	5.00	oz	3.13	15.65			
	24 Aug	Bidrin	8.00	oz	0.71	5.68	1.04	30.32	
		Trimax	1.50	oz	5.30	7.95			
		Capture	5.00	oz	3.13	15.65			

^z Insecticides were applied with a 60-ft-wide John Deere Hi-Boy. Cost includes variable and fixed costs.

Table 4. Yields, lint values, and profits for each irrigation main effect and insecticide termination sub-plot effect in 2004 trial.

Treatment	Date of application	Crop maturity status at final application	Yield ^z (lb/acre)	Lint values ^z (\$/lb)	Profits ^z (\$/acre)
Irrigation ^y	14 Jul	NAWF = 7.2	1,357.77 a	0.47	534.84 a
	22 Jul	NAWF = 5.6	1,353.56 a	0.46	501.27 b
	30 Jul	NAWF = 5+100 DD60s	1,437.60 a	0.46	540.09 a
	18 Aug	NAWF = 5+360 DD60s	1,642.79 b	0.48	645.71 c
	31 Aug	NAWF = 5+580 DD60s	1,679.44 b	0.46	615.28 d
			LSD ₀₅ = 121.31	p>0.05	LSD ₀₅ = 25.80
Insecticide	16-Jul	NAWF = 7.2	1,388.26 a	0.45 b	532.04
	21-Jul	NAWF = 5.6	1,391.34 a	0.45 b	548.53
	8-Aug	NAWF = 5+240 DD60s	1,561.65 b	0.48 a	608.18
	24-Aug	NAWF = 5+450 DD60s	1,635.68 b	0.48 a	583.06
			LSD ₀₅ = 153.78	LSD ₀₅ = 0.02	p>0.05

^z Amounts with different letters are significantly different at the 5% significance level.

^y Irrigation dates: 14, 28, 30 July; 3, 9, 14, 19, 26 August; and 1 September.

Table 4. Yields, lint values, and profits for each irrigation main effect and insecticide termination sub-plot effect in 2004 trial.

Treatment	Date of application	Crop maturity status at final application	Yield ^z (lb/acre)	Lint values ^z (\$/lb)	Profits ^z (\$/acre)
Irrigation ^y	14 Jul	NAWF = 7.1	1,582.28	0.53	755.80
	22 Jul	NAWF = 5.0	1,591.58	0.55	780.75
	30 Jul	NAWF = 5+300 DD60s	1,691.93	0.55	815.77
Insecticide	8 Jul	NAWF = 8.6	1,599.01	0.54	787.33
	23 Jul	NAWS = 7.1	1,586.01	0.55	771.92
	4 Aug	NAWF = 5+95 DD60s	1,663.68	0.54	804.22
	19 Aug	NAWF = 5+413 DD60s	1,639.03	0.54	772.92

^z Amounts with different letters are significantly different at the 5% significance level.

^y Irrigation dates: 14, 28, 30 July; 3, 9, 14, 19, 26 August; and 1 September.

Table 6. Yields, lint values, and profits for each irrigation main effect and insecticide termination sub-plot effect in 2006 trial.

Treatment	Date of application	Crop maturity status at final application	Yield ^z (lb/acre)	Lint values ^z (\$/lb)	Profits ^z (\$/acre)
Irrigation ^y	9 Jul	1 wk prior to flowering	865.96 a	0.45 a	332.82 a
	20 Jul	NAWF = 7.3	944.01 ab	0.47 a	377.60 ab
	27 Jul	NAWF = 5	1103.71 b	0.48 a	451.72 b
	3 Aug	NAWF = 5+166 DD60s	1307.57 c	0.52 b	594.79 c
	24 Aug	NAWF = 5+650 DD60s	1452.58 c	0.54 b	674.70 c
			LSD ₀₅ = 189.87	LSD ₀₅ = 0.03	LSD ₀₅ = 105.21
Insecticide	13 Jul	1 wk prior to flowering	1035.53 a	0.48	439.48 a
	18 Jul	NAWF = 7.3	1042.62 a	0.48	442.12 a
	8 Aug	NAWF = 5+280 DD60s	1238.71 b	0.50	542.25 b
	24 Aug	NAWF = 5+650 DD60s	1222.19 b	0.50	522.24 b
			LSD ₀₅ = 116.13	p>0.05	LSD ₀₅ = 59.66

^z Amounts with different letters are significantly different at the 5% significance level.

^y Irrigation dates: 26, 11, 17 May; 11, 17 June 1, 9, 20, 27 July; and 3, 9, 18, and 24 August.

Control of the Tarnished Plant Bug (*Lygus lineolaris*) in Mid-South Cotton Using the Entomopathogenic Fungus (*Beauveria bassiana*) and the Insect Growth Regulator Diamond®

Jennifer Lund, Tina G. Teague, Donald C. Steinkraus,, and Jarrod E. Leland¹

RESEARCH PROBLEM

Throughout the Mid-South cotton region, insecticides are the sole control method for tarnished plant bug (TPB, *Lygus lineolaris* Palisot de Beauvois), a key insect pest in cotton. Resistance of TPB to commonly used insecticides has been noted, and the need for alternate control methods is apparent. Effective management alternatives are needed that include efficient, long-lasting, and specific biological control agents. During the 2006 field season, plant bug control using an experimental strain of the fungal pathogen, *Beauveria bassiana*, alone and in combination with the insect growth regulator novaluron (Diamond®) was tested.

BACKGROUND INFORMATION

The fungal entomopathogen, *Beauveria bassiana*, has been found naturally infecting *Lygus* spp. in Arkansas (Steinkraus and Tugwell, 1997), Mississippi (Leland and Snodgrass, 2004), and California (McGuire, 2002). Caged insect trials indicate that the *B. bassiana* can effectively kill 89 to 100% of adult insects compared to 7 to 11% in controls (Steinkraus and Tugwell, 1997). Nymph TPB are generally less vulnerable to *B. bassiana*, and therefore the use of a fungal pathogen alone might not provide adequate control of field populations. Diamond is an insect growth regulator that works by disrupting chitin development and molting. The product shows promise as a new management tool for plant bug nymphs (Barkley and Ellsworth, 2004; Smith et al., 2004).

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RESEARCH DESCRIPTION

Diamond and *Beauveria* applications were evaluated in cage studies conducted at the University Research Farm on the Judd Hill Plantation near Trumann in northeast Arkansas. Cotton (*Gossypium hirsutum* L.) cultivar Stoneville 5242 was planted 8 May 2006 in a Dundee silt loam soil. Plots were furrow irrigated. The experiment was arranged in a randomized complete block with 3 replications. Plots for each test were 30-ft long, 3 rows wide, and separated by 10-ft alleys; treatment plots were arranged in a RCB with 3 replications.

On the day prior to application, TPB were collected using sweep nets in blooming mustard or other wild plant hosts (primarily *Erigeron* spp.). Insects were held overnight at 27°C in cages with water and ears of fresh sweet corn. For each cage test, 10 organandy sleeve cages, 6-in. diameter by 18-in. long, with 1-mm × 2-mm openings were secured to randomly selected individual plants in the center row by tying with twist ties the lower end of each cage around the plant ca 1 ft from the terminal. After sunset, 5 TPB nymphs (3rd to 5th instar) or adults were placed into each cage. There were 5 cages each of TPB nymphs and adults in each plot. There were five treatments: (1) untreated control (UPB, water), (2) Centric™ (2 oz/acre), (3) Diamond (12 oz/acre), (4) *B. bassiana* (1 × 10¹³ conidia/acre), and (5) *B. bassiana* and Diamond. Applications were made using a 4-row CO₂-charged back pack sprayer calibrated to deliver 11 gpa at 60 psi with TX 10 hollow-cone nozzles on 19-in. spacing.

After 48 hrs plants were cut below the cage and taken to the laboratory where TPB were removed and sorted. Dead insects were placed in moist filter paper-lined chambers, and living insects were placed individually in 2-oz cups with a 0.5-in. cube of wet florist water foam and a kernel of canned corn. Living insects were held for ten days at 23°C and checked daily for death. Dead insects were checked for outward signs of fungal infection. Results from each of the two experiments were pooled together and ANOVA statistics were used to test the effects of lifestage and treatment on days to death (DTD). Differences in mean DTD were analyzed using Bonferroni adjusted comparisons.

RESULTS AND DISCUSSION

Percent Recovery

We recovered 92.1% of insects from the field cages 24 hours post application.

Average Days to Death (DTD)

Overall there was a significant effect of treatment, stage, and the interaction of the two on mean DTD (all $p < .0001$). When looking at each treatment separately, adults had a significantly higher mean DTD than nymphs for all treatments (Bonferroni Adjusted all $p < .0012$). Both untreated control (UTC) nymphs and adults had significantly higher DTDs than all other treatments (all $p < 0.0067$) (Fig. 1). Centric had significantly lower DTD than any other treatments (all $p < 0.0001$). There was no difference in the *Beauveria* or Diamond treatments singly or in combination.

Percent Mortality

Initial mortality (to day 2) ranged from 12.1 to 57.1% for adults and 11.6 to 59.8% for nymphs. Mortality from day 3 to 5 ranged from 18.1 to 37.7% for adults and 15.6 to 51.3% for nymphs. Mortality from day 6 to 10 ranged from 13.6 to 47.7% for adult insects and 16.4 to 34.7% for nymphs (see Table 1 for cumulative percent mortalities). When nymphs and adults are combined, initial mortality (to day 2) is highest in the Centric-treated insects (58.3%) and lowest in the untreated controls (11.8%). By day 5 fewer untreated-control TPB had died than in other treatments (35.2% for UTC, 51.3 to 76.1% for treated). By day 10, mortality was 75.2% in the UTC compared to 90.8 to 94.9% from Diamond and/or *Beauveria* treatments (see Fig. 2).

Percent Survival

Percent survival was highest in the untreated controls for both nymphs and adults (24.0% and 26.8%) (Table 1). Percent survival of nymphs was lowest in the *Beauveria* plus Diamond treatments (5.1 %) and highest in the *Beauveria* alone treatment (14.7%) while in adults the lowest percent survival was in the *Beauveria* only treatments (1.3%) and highest in the Centric treatments. An increase in adult percent survival (1.3% versus 6.0%) was measured when Diamond was added to *Beauveria*. Conversely, a decrease in nymph survival was measured when *Beauveria* and Diamond were paired (5.1%) versus treated separately (8.9% and 14.7%).

Percent Sporulation

There was higher percentage of sporulation in insects treated with *Beauveria* over UTC, Diamond only, and Centric-treated insects. Fungal treated insects averaged 41.5 to 55.2% of insects sporulating, while UTC, Centric-, and Diamond-treated insects averaged $1.5 \pm 0.8\%$ to $3.4 \pm 1.2\%$ of insects exhibiting fungal outgrowth (see Fig. 3). The fungal contamination exhibited in the UTC, Diamond-, and Centric-treated insects could be from several different sources, including natural infections in wild-collected individuals or from drift from spraying or contamination when we were transferring insects from cages to cups.

Greater mortality and more rapid death were observed in Centric, Diamond, and *Beauveria* treatments compared to the untreated control. All treated insects exhibit similar mortality rates (90.8 to 94.9%). The fastest death occurred in the Centric-treated insects (58.3% dying by day 2) followed by the *Beauveria*- and Diamond-treated insects (51.3 to 56.1% of insects dying by day 5). It is unknown if delay in death is a potential problem; we don't know if the plant bugs continue to feed after exposure to the IGR or infection with the fungus. More research is needed to examine plant bug behavior during the time after they become infected and before they die.

It is unknown why the addition of Diamond to *Beauveria* decreased pathogenicity to adults and not nymphs.

PRACTICAL APPLICATION

Results from the 2006 caged experiments indicate that Diamond and *Beauveria* show promise as tools to manage plant bug in cotton, but insect control is delayed compared to standard-use chemical insecticides. Diamond applications must be directed at controlling nymphs, and *Beauveria* should be targeted against adults.

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Table 1. Percentage of dead nymphs and adults. This table shows the percentage of dead adults and nymphs recorded at days 2, 5, and 10 days after application. It also includes the % survival of insects for each treatment.

Treatment	Nymphs					Adults				
	N	% Died 2	% Died 5	% Died 10	10 day % survival	N	% Died 2	% Died 5	% Died 10	10 day % survival
Untreated control	121	11.6	41.4	76.1	24.0	149	12.1	30.2	73.2	26.8
Centric	122	59.8	75.4	91.8	8.2	154	57.1	76.6	90.2	9.7
Diamond	112	21.4	68.7	91.1	8.9	150	17.3	46.6	93.3	6.7
Beauveria + Diamond	117	17.9	69.2	94.8	5.1	166	16.9	42.8	94.0	6.0
Beauveria	116	14.7	51.8	85.4	14.7	151	13.2	50.9	98.6	1.3

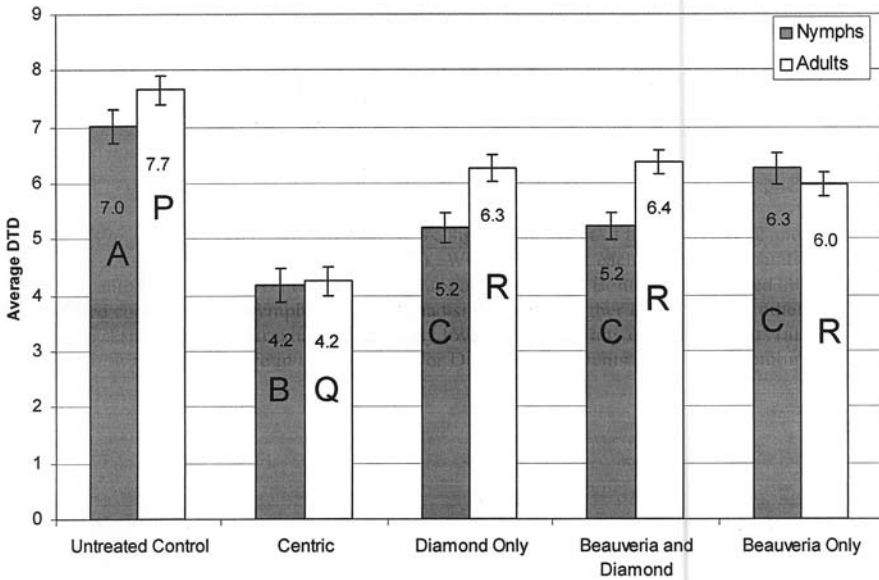


Fig. 1. Average days to death (DTD). Nymphs with the same letter (A, B, or C) signify no significant difference ($p=0.05$) between treatments. Adults' average DTDs with the same letter (P, Q, or R) represent no significant difference between treatments.

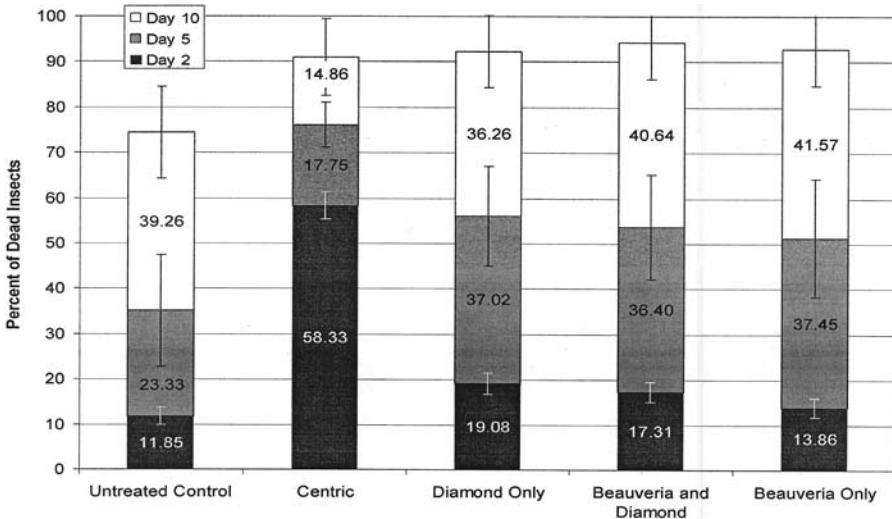


Fig. 2. Percentage of dead insects. This graph shows the percentage of insects (both nymphs and adults) dying between DAT 0 and 2, and DAT 3 and 5, and DAT 6 and 10.

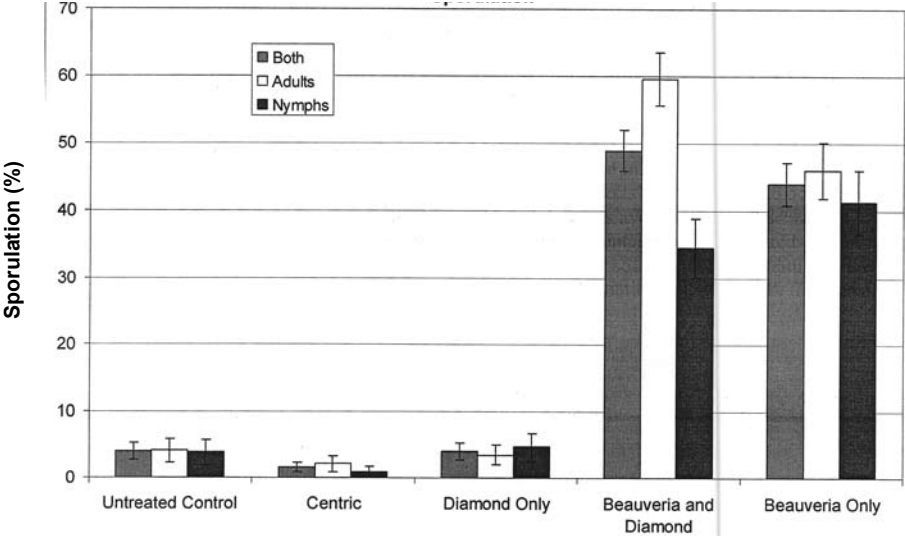


Fig. 3. Percentage sporulation. Percentage of nymphs, adults, and both exhibiting fungal outgrowth (sporulating).

Control of the Tarnished Plant Bug (*Lygus lineolaris*) in Cotton Using the Entomopathogenic Fungus *Beauveria bassiana*, the Insect Growth Regulator Novaluron, and Early-Season Trap Crop Practices

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Donald C. Steinkraus, and Jarrod E. Leland¹*

RESEARCH PROBLEM

Tarnished plant bug (TPB; *Lygus lineolaris* Palisot de Beauvois) is a season-long pest in Mid-South cotton. Current control methods for TPB rely solely on insecticides, but with current changes in EPA registration and with insecticide resistance emerging in TPB populations, alternative methods and techniques of control are needed.

BACKGROUND INFORMATION

The fungal entomopathogen, *Beauveria bassiana* has been found naturally infecting *Lygus* spp. in Mid-South cotton systems (Steinkraus and Tugwell, 1997; Leland and Snodgrass, 2005). Some studies with caged insects indicate that the *B. bassiana* can effectively kill 89 to 100% of adult insects (Steinkraus and Tugwell, 1997), but limitations in production of the fungus make widespread use in row crops implausible presently. Nymphal TPB are generally less susceptible than adults to *B. bassiana*. Novaluron, (trade name Diamond®) is an insect growth regulator that works by disrupting chitin development and molting. The product is used commercially in the Mid-South and it shows promise as a management tool for plant bug nymphs (Barkley and Ellsworth, 2004; Smith et al., 2004).

Trap cropping involves the manipulation of crop stands in time and space with the objective of concentrating a pest species within the trap crop rather than the main crop (Hokkanen, 1991). One way a trap crop is used is by planting a different plant species before the main crop to attract and subsequently kill target pests. We hypoth-

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esized that in the case of cotton, a cool-weather, early blooming trap crop like mustard or canola would be ideal for attracting overwintered TPB in the spring. Assuming we can concentrate the target pest, managing the pest in the trap crop so that the trap crop does not become a source of the pest rather than a sink, is essential. Other potential problems we may encounter are establishing an attractive trap crop sufficiently earlier than the commercial crop, accessing the trap crop with conventional pesticide application equipment, and providing sufficient economic incentives for large-scale, area-wide farmer adoption of the methodology.

RESEARCH DESCRIPTION

Field Design

Commercial fields located in northeast Arkansas, with and without spring canola trap crops, were used to evaluate effectiveness of the trap-crop tactic in suppressing populations of over-wintered TPB. We chose six fields at Wildy Farms, Mississippi County, as our test sites. In the field border adjacent to over-wintering habitat along three of the fields, we planted a conventional fall canola variety in mid-September 2005 and a glyphosate-tolerant spring variety in mid-March 2006. Strips were 400- to 800-m long by 2-m wide depending on field size and orientation to over-wintering habitat. Adjacent to the remaining three fields, wild TPB-host species grew along ditches and turn-rows. Stoneville 5599BR cottonseed was planted between 19 Apr and 6 May in each of the fields.

Pre-Season Canola Trap Crop Sampling

We assessed the pre-season populations of TPB in the trap-crop canola and wild host species adjacent to our six cotton fields. Sampling started at canola flowering (28 Apr). Sweep-net samplings of TPB were made on 28 Apr, 2 May, 4 May, 8 May, 12 May, 14 May, 16 May, 22 May, and ended on 30 May. *B. bassiana* (1×10^{13} conidia per acre) and Novaluron (Diamond™) (12 oz/acre) sprays were made on 28 Apr, 2 May, 5 May, 12 May, 17 May, 24 May, and 30 May in the canola only using a tractor-mounted sprayer. On each sampling day, a subset of 40 to 60 adult TPB was brought back from each canola or wild host strip to the lab and held for ten days to assess cause of death. The canola trap crop was cut on 5 June.

In-Season Cotton Sampling

Starting at squaring, 36 sites in each cotton field were monitored using drop cloths. Two drop cloth samples per site (6 m of row) were made weekly. We sampled high- and low-biomass areas in three distances from the trap crop/border of the field.

COTMAN Field Measurements

Plant bug-induced plant injury was monitored in the field by assessing retention of fruiting forms and inspection of white flowers for anther injury. Retention was measured from using the Squaremap procedure in the COTMAN™ crop monitoring system (Danforth and O'Leary, 1998). Two sets of five consecutive plants in the center rows were monitored weekly. Sampling included measurement of plant height, number of sympodia, and presence or absence of first position squares (floral buds) and bolls (fruit).

RESULTS AND DISCUSSION

Pre-Season Canola Trap Crop Sampling

Over the spring sampling season, prior to cotton planting, *B. bassiana*- and Novaluron-treated canola plots had a lower average number of bugs per 10 sweeps (3.18 ± 0.62) than the wild-host untreated plots (6.73 ± 1.10). Adult TPB numbers in the canola trap crop stayed relatively level throughout the sampling period while adult TPB populations in the wild-host plots steadily decreased (Fig. 1). Nymphs were only found on one sampling day (12 May) in the canola plots while nymphs were found in the wild-host plots throughout the sampling period (Fig. 2). Nymphs in the wild-host plots appear to follow an opposite trend than the adults, with populations increasing towards the end of the sampling period (Fig. 2).

A lower percentage of dead insects by d 10 occurred in canola plots on all but two dates (22 May and 24 May) (Fig. 3). All the rest of the sampling days show a larger percentage of insects (that we held) dying before d 10 in the canola trap crop compared with the wild-host plots (Fig. 3).

For every sample date, there was higher percentage of sporulation for insects collected from *B. bassiana*/Novaluron-sprayed canola trap crop over TPB collected from the untreated wild-host plants. TPB from treated canola plots averaged 11% to 96% sporulation, while the insects collected from untreated wild hosts averaged between 0 and 22% exhibiting fungal outgrowth.

In-Season Cotton Sampling

The cooperating grower made two automatic insecticide applications in each field between 14 June and 28 June as part of standard practice. Plant bug numbers did not reach threshold (3 bugs per meter of row) at any point during the field season (Fig. 4). Neither distance from trap crop/wild host or biomass had any effect on plant bug counts (all $p < 0.05$).

COTMAN Field Measurements

Comparing the COTMAN standard curve and growth curves of cotton plants in this experiment demonstrated that growth patterns were not affected by trap-crop treatments at the field borders (Fig. 5). Square- and boll-retention levels remained high

through physiological cutout. Results from COTMAN sampling indicated sheds of first-position fruiting were at low levels of 15% in all fields (Fig. 6).

PRACTICAL APPLICATION

First of all, spring- and fall-planted canola were successfully established as spring-flowering trap crops for TPB and our canola trap crop was equally as attractive to TPB adults as wild host plants in the area. Secondly, Novaluron proved to be effective at controlling nymphs in the highly attractive spring trap crop.

Unfortunately, we were unable to detect the effect of *B. bassiana* on the trap-crop population due to the highly mobile nature of TPB adults. Also this trap-crop technique interfered with the agronomic practices on the commercial farm. Typically, producers will kill all pre-season weeds around crop borders and in ditches with an herbicide spray. We had to replant our trap crop with a glyphosate-tolerant variety of canola after inadvertent application of herbicide by the cooperating farmer.

We were also unable to measure any effect of the trap cropping to surrounding cotton crops when we looked at this technique at the field level. These insects are highly mobile and can move from surrounding fields without trap-crop borders into areas with them. Future studies need to look at area-wide application of this practice.

Finally, *B. bassiana* is very difficult to work with. It is highly sensitive to UV light and dry conditions. More research must go into the development of UV protectants and formulations that will make this product easier to use.

ACKNOWLEDGMENTS

Special thanks to David Wildy, Justin Wildy, and the staff at Wildy Farms for their assistance and support. The University of Arkansas Division of Agriculture and Arkansas State University also contributed to this research effort and are acknowledged for encouragement of innovative cotton-management systems. Finally, the authors would like to thank the USDA-CSREES PMAP for funding this project.

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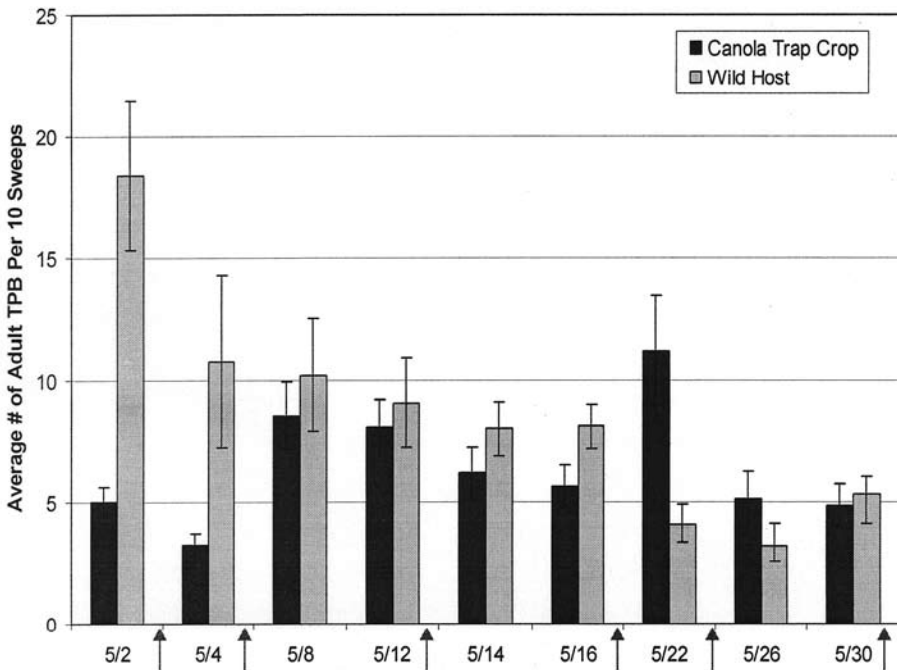


Fig. 1. Average number of adult TPB per ten sweeps over all pre-season sampling dates. Red arrows indicate *B. bassiana*/Novaluron applications.

Dates with a (*) denote a significant difference in the average number of adults per 10 sweeps between canola-trap and wild-host plots ($p < 0.05$).

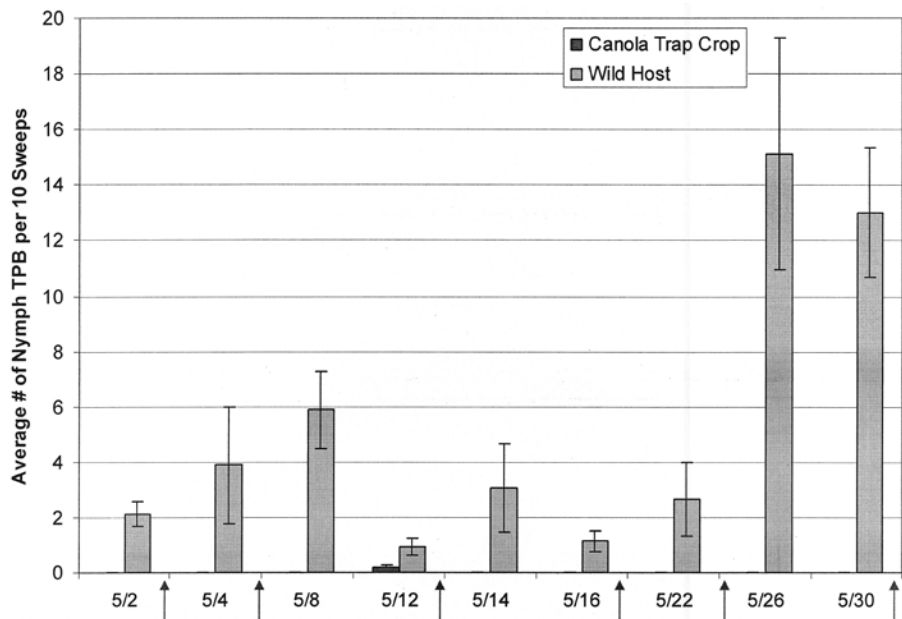


Fig. 2. Average number of nymph TPB per ten sweeps over all pre-season sampling dates. Red arrows indicate *B. bassiana*/Novaluron applications. All dates sampled had a significant difference in the average number of nymphs per 10 sweeps between canola-trap and wild-host plots (all $p < 0.001$).

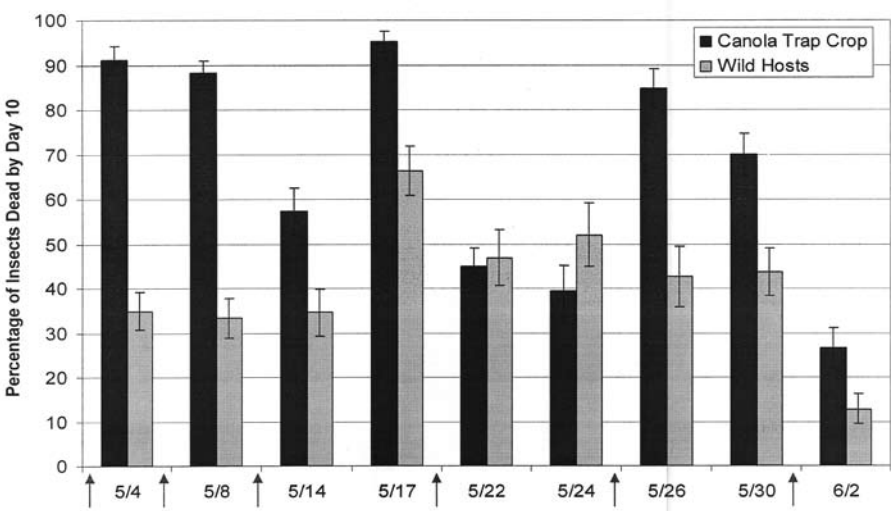


Fig. 3. Percentage of held insects that died by 10 days after treatment. Red arrows indicate *B. bassiana* and Novaluron applications.

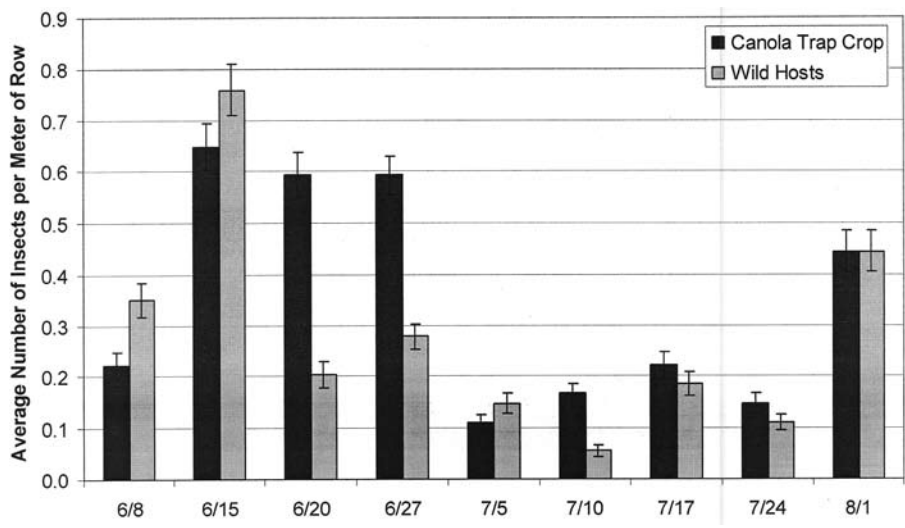


Fig. 4. Average number of adult and nymph TPB per meter row.

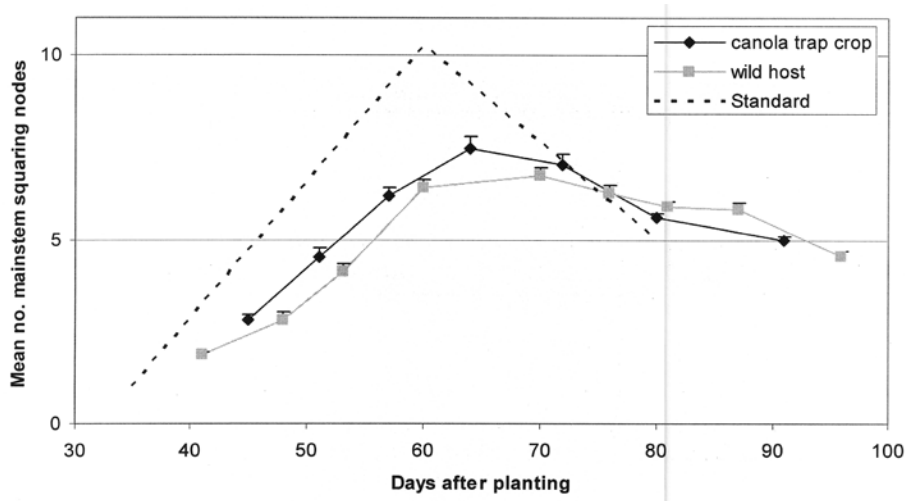


Fig. 5. The COTMAN standard target development curve (dashed line) and growth curves of cotton plants from commercial fields; growth patterns were not affected by trap-crop treatments at the field borders.

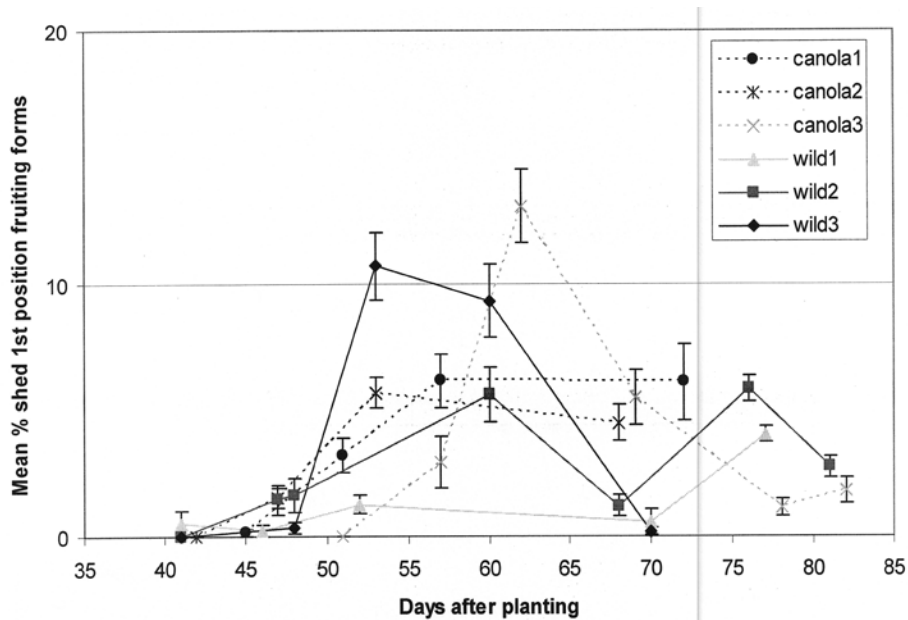


Fig. 6. Mean percentage shed ($\pm$ SE) of first-position fruiting forms season-long observed in 6 commercial cotton fields bordered by canola trap crops or wild plant hosts.

Summary of Arkansas Representative Panel Farm Project

Robert Hogan, Jr., K. Bradley Watkins, and Eric Wailes¹

RESEARCH PROBLEM

Many economic analyses are accomplished by allowing one variable to change while holding all other variables constant. In the real world, however, many variables typically change at once when there is a change of administration or a farm bill change. An economic model that describes Arkansas row-crop agriculture both statically and dynamically is needed. This model could then be used to compare various alternatives to a baseline strategy. An analysis can be constructed that shows the viability of the state's row-crop agricultural community under current production systems, product prices, and provisions of the current farm program.

BACKGROUND INFORMATION

Row-crop agriculture in Arkansas makes up a significant portion of total state agricultural income. In 2005, Arkansas row-crop agriculture added \$1.9 billion dollars to the \$6.9 billion dollars of total agricultural output. Cotton production contributed \$494 million dollars or approximately 26% of total row-crop agriculture (USDA-NASS, 2006). Across the state, the major row crops grown are soybean, rice, and cotton while corn, grain sorghum, and wheat round out most of row crops grown.

Similar to other southern cotton states, Arkansas cotton producers have been hit hard in recent years by dramatic price declines for U.S. cotton, rapidly rising costs of production, and strong international competition. In an effort to better analyze impacts to our cotton producers originating from changes in commodity price and production costs, the Arkansas Representative Panel Farm Project has been expanded to include representative farms that produce 1) all cotton, 2) diversified cotton, rice, and soybean, and 3) all rice-soybean in their operations.

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These representative farm models were created from panels of farmers using a consensus-building approach rather than averaged individual farm or census data. This approach results in a representative farm that is recognizable and at the same time relevant for each panelist and typical grower in that region, while preserving a high degree of anonymity for the individual farm panelists. These representative farms were developed from detailed farm data (including enterprise, operations, costs, finances, machinery, marketing, etc.) collected from each producer panel. The representative farms were processed using deterministic and stochastic simulations from the FLIPSIM model (Richardson, 1999), Agricultural and Food Policy Center (AFPC) and baseline agricultural and economic projections, Food, Agricultural and Policy Research Institute (FAPRI). Note that representative farm analyses are anchored to a baseline projection for the farms. This approach provides producers and policy makers a benchmark for comparing and interpreting policy alternatives and a starting place for future analyses of policy alternatives.

The objective of this study was to develop a baseline projection to be used to determine the viability of Arkansas row-crop agriculture.

RESEARCH DESCRIPTION

The Arkansas Representative Panel Farm Project has developed eight consensus farms. These panel farms were developed around the state independently of one another. A suggested group of producers in a given area were assembled in a consensus-building interview process to define a farm representative of that area in size, crop composition, and management style. Five of those eight produce cotton and are presented in this study.

After meeting with the panel, historical prices, yields, and production risk were integrated into the model from estimates and projections developed by the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri and Iowa State University. The panel farms continue to meet approximately once every three years to update the model.

RESULTS AND DISCUSSION

Table 1 illustrates the characteristics of the five Arkansas representative cotton farms from a total of eight representative panel farms in the state. The size of each panel farm in total acres, acres owned and leased, debt/asset ratios, and acres of each crop planted in 2006 is shown. Table 2 shows the assumed crop prices from 2006 to 2010. A comparison of assumed program-loan and target rates is shown in Table 3. Data in Tables 2 and 3 come from FAPRI August 2006 baseline estimates. It is assumed the current farm program will not change over the horizon of this analysis. Table 4 shows the results of the analysis.

From the 2006 to 2010 overall financial position for the panel farms, note that all farms are projected to be in a poor financial position under the August baseline. This means if nothing happens to change the operational outlook for these farms in

the intermediate term, they will have depleted their entire net worth and be forced to liquidate their remaining assets.

Change in real net worth (actual net worth adjusted for inflation) of the panel farms ranges from the smallest change, a 2% loss (ARNC5000) to the largest change, a 24% loss of their total net worth (ARCR4000). A measure of financial stability used in the analysis is NIA or **Net Income Adjustment**. For the representative panel cotton farms, the NIA required to maintain real net worth (net income adjustment required to hold net worth constant) ranges from 3% (ARNC5000) to 42% (ARCR4200). The 42% means it would require a 42% increase in net farm income to hold real net worth constant. The NIA required for zero ending cash balance (net income adjustment required so there would not be an ending cash flow deficit) ranges from 7% (ARNC5000) to 59% (ARCR4200).

Another measuring tool used to gauge the different panel farms is the costs-to-receipts ratio. This ratio ranges from 88% (ARNC5000) to a high of 129% (ARCR4200). In the case of the 101% measurement for example, panel farm (ARC6000) had \$1.01 of costs for every \$1.00 of farm income. Since all farms but one had a costs-to-receipts ratio greater than 100%, it can be seen that these farms are in financial trouble.

PRACTICAL APPLICATION

At the outset of the year, it appeared these farms would be plagued by increased costs of production inputs. Cash reserves that had recovered some in the past several years will again be depleted. Even though good to excellent yields have prevailed over the past few years, poor cotton prices this year would offset those yields. Fuel costs that were predicted several years ago to decline will instead increase now. These increased fuel prices will bring about higher prices for irrigation and tractor fuel and cause higher fertilizer prices, as fertilizer price is closely linked to energy costs. In addition, farms will see much higher increases in steel prices and the cost of new machinery due to increased world demand. Technology fees may also increase. The bottom line for producers, in light of all these cost increases and decreases in the value of their cotton, will be to stay in business until some positive change occurs.

ACKNOWLEDGMENTS

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Table 1. Characteristics of Arkansas panel farms.

Panel farm number	ARNC5000	ARCR6500	ARCR4000	ARC6000	ARC4000
Location	Leachville	Osceola	Pine Bluff	McGehee	Forrest City
AR delta region	NE	NE	SE	SE	Central
Total cropland ^z	5,000	6,500	4,000	6,000	4,200
Acres owned	1,000	1,950	1,200	1,200	1,000
Acres leased	4,000	4,550	2,800	4,800	3,200
Debt/asset ratios					
Total	23%	31%	53%	34%	44%
Intermediate	29%	38%	33%	34%	24%
Long run	9%	11%	10%	10%	10%
2006 planted acres/% of total acres					
Corn	0	0	0	0	400
	0%	0%	0%	0%	10%
Cotton	5,000	2,925	1,320	2,000	2,600
	100%	45%	33%	33%	62%
Rice	0	1,625	800	2,000	0
	0%	25%	20%	33%	0%
Soybeans	0	1,950	1,880	1,500	1,200
	0%	30%	47%	25%	28%
Wheat	0	0	0	0	0
	0%	0%	0%	0%	0%

^z Planted acres may exceed total crop acres due to double or triple cropping.

Table 2. Comparison of crop prices.

Crop	Year				
	2006	2007	2008	2009	2010
Corn (\$/bu.) Jan-06	2.89	3.00	3.02	3.07	3.08
Cotton (¢/lb.) Jan-06	46.74	50.29	51.85	51.92	51.96
Rice (\$/cwt.) Jan-06	9.10	8.12	8.18	8.55	8.59
Soybeans (\$/bu.) Jan-06	5.66	6.38	6.70	6.69	6.64
Wheat (\$/bu.) Jan-06	4.27	4.13	4.11	4.18	4.22

Source: Food and Agricultural Policy Research Institute

Table 3. Comparison of assumed loan and target rates.

Crop	Loan rate 2006	Target rate 2006
Corn (\$/bu.) Jan-06	1.95	2.63
Cotton (¢/lb.) Jan-06	52.00	72.40
Rice (\$/cwt.) Jan-06	6.50	10.50
Soybeans (\$/bu.) Jan-06	5.00	5.80
Wheat (\$/bu.) Jan-06	2.75	3.92

Source: Food and Agricultural Policy Research Institute

Table 4. Implications of the January 2006 FAPRI Baseline on the economic viability of Arkansas representative farms.

Panel farm number	ARNC5000	ARCR6500	ARCR4000	ARC6000	ARC4200
Location	Leachville	Osceola	Pine Bluff	McGehee	Forrest City
Overall financial position ('06 to '10)	Poor	Poor	Poor	Poor	Poor
Change real net worth ('04 to '10)% ^z	-2%	-8%	-24%	-7%	-22%
NIA to maintain real net worth % ^y	3%	18%	43%	13%	37%
NIA for zero ending cash balance ^x	7%	27%	59%	25%	49%
Cost to receipts ratio (%) ^w	88%	108%	129%	101%	125%

^z Real net worth is the "nominal" or actual net worth corrected for inflation.
^y NIA to maintain real net worth-the percentage of net income adjustment necessary to hold real net worth constant.
^x NIA for zero ending cash balance-the percentage of net income adjustment necessary to keep the operation from having an ending cash deficit.
^w Total costs divided by farm receipts.

An Economic Analysis Comparing Harvest Aid Programs in Arkansas

Robert Hogan, Jr. and William C. Robertson¹

RESEARCH PROBLEM

Use of harvest aids to terminate and prepare the cotton crop for machine harvest has been an accepted practice for expediting crop maturity, increasing harvest efficiency, and improving lint yield and quality. Many materials have been registered and recommended for use as harvest aids in the United States. Aim, CottonQuik, Def/Folex, Dropp, Finish, Ginstar, Harvade, and Prep/ethephon are some of the most popular products currently in use. These products are rarely evaluated on an economic basis.

BACKGROUND INFORMATION

New harvest aid products continually come onto the market and are tested. Some products become quite popular and others do not. Proper use of these products is important to ensure the quality of defoliation, boll opening, and control of regrowth. However, variability of growing conditions during the season, different varieties, cultural systems used, and environmental factors during the harvest all combine to result in no standard method for harvest aid timing or choice of materials (Patterson and Smith, 2001). Although not exact, timing of harvest aid application is generally guided by such techniques as percent open bolls, the cut boll technique, and nodes above cracked boll (Banks, 2001). Choice of harvest aids varies with production region, type of harvest, and physical and environmental factors. As there is great variability of growing conditions during the season and many alternative cultural practices, there is also great variability in the cost of various harvest aid programs. The objective of this study was to analyze this component of production cost to determine if generalizations can be drawn regarding a best management practice.

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¹ Extension economist, Northeast Research and Extension Center, Keiser; and extension cotton specialist, Crop, Soil, and Environmental Sciences Department, Little Rock, respectively.

RESEARCH DESCRIPTION

These tests used both single and sequential defoliation regimes. The goal of a good defoliation treatment is to have a performance index rating greater than 85% at 14 days after treatment (DAT). The performance index is a value assigned to show a treatment's rating to defoliation, desiccation, boll opening, and regrowth. A rating of 100% would represent a treatment with no green or desiccated leaves, all bolls open and harvestable, and no regrowth (terminal or basal) present. As a sidebar, regrowth did not become a factor in this study until 30 DAT on any treatment regime. Cotton plants in the fields used for sequential-application treatments were bigger and ranker, i.e. more vegetative growth, than cotton plants used for single-application treatments. Single-application treatment was intended for fields where regrowth would not be an issue. In some years, there were as few as 8 treatments, and in other years as many as 16 treatments were used, but on the average about 11.25 single or sequential treatments per year. Defoliation treatments were applied to individual plots at NAWF = 5 (Nodes Above White Flower) plus 850 accumulated heat units by COTMAN™ measurements.

Economic analysis of the test was accomplished in two parts: 1) create individual budgets for the 124 treatments with the Mississippi State Budget Generator version 6.0 using current (2006) input prices, and 2) select top treatments that exhibited a performance index $\geq 85\%$ (85% is considered minimum commercially acceptable results) and lower costs. The one exception to this was in the 2003 crop year when none of the treatments attained a performance index greater than 70%. Thus in 2003, the single and sequential treatments with the greatest performance index were selected. In each treatment, it was assumed that all defoliation and harvest aid products were applied aerially at a rate of 5 gallons of water per acre and a cost of \$5.50 per acre. It was further assumed that a two-part treatment required two aerial applications. Since the applications were done on a custom basis, fixed costs were not an issue. Interest on operating capital was not considered.

RESULTS AND DISCUSSION

The results of each year's test were recorded and the "best" (performance index $\geq 85\%$ and least cost treatment alternative) treatments were then summarized and reported in Table 1. The summary is categorized both by year and treatment type, single or sequential application treatment. Both treatment types show the product composition of the treatment, performance index, and cost of treatment. It should be noted that cost of treatment includes application costs at \$5.50/acre, one application charge for single treatments (\$5.50/acre total), and two application charges for sequential treatments (\$11.00/acre total).

With respect to single-application treatments, treatment costs ranged from \$11.82/acre with a performance index of 94% in 2005 to a maximum cost of \$25.83/acre in 2001 and 2002. The performance index was 92% and 86% in those years, respectively. When considering sequential-application treatments, treatment cost ranged from \$13.22/acre with a performance index of 87% in 2005, to a maximum cost of \$39.63/acre with a performance index of 97% and 92% in years 2001 and 2002, respectively.

Grower standard defoliation treatment (Table 2) cost \$31.42/acre in each year as only 2006 prices were used and performance index values were: 2001 - 96%, 2002 - 93%, 2004 - 83%, 2005 - 91%, and 2006 - 92%. In the year 2003, a grower standard treatment was not used. It may be noted that the grower standard treatment included two aerial applications at a cost of \$5.50/acre for each application (a total of \$11.00/acre).

PRACTICAL APPLICATION

In summary, there was quite a lot of cost variability witnessed in this study. From the price of the least expensive – \$11.82/acre (Table 3) to the most expensive \$32.74/acre “best” treatments, there was a difference of \$20.92/acre. Looking at the grower standard of \$31.42 and the least expensive “best” treatment of \$11.82, this represented a cost difference of \$19.60 or a cost reduction of 62%/acre. There was an average cost reduction of 37% for the selected “best” treatments over the traditional regime. This is a significant cost reduction and appears to be a management alternative worth considering. However, rank cotton or cotton with regrowth potential may require more regrowth inhibition as possessed by the grower standard treatment. In addition, when there is uncertainty about when the picker will be available, the traditional treatment offers some security against regrowth potential.

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Table 1. Summary of “best” single and sequential treatments considering least cost and efficacy by year.

Year	Single application	Sequential applications	Sequence ^z
2001			
Products:	Def/Folex - 0.1 pt/acre Prep - 2.33 pt/acre	Harvade - 0.41 lb/acre Dropp - 0.1 lb/acre COC ^y - 1 pt/acre Def/Folex - 0.67 pt/acre	A A A B
Performance index	93	97	
Cost per acre (\$/acre)	12.69	28.66	
2002			
Products:	CottonQuik - 3.5 pt/acre Def/Folex - 0.5 pt/acre	Def/Flex - 0.63 pt/acre CottonQuik - 0.8 pt/acre CottonQuik - 3.2 pt/acre Def/Folex - 0.38 pt/acre	A A B B
Performance index	90	91	
Cost per acre (\$/acre)	16.72	27.82	
2003			
Products:	Finish - 2 pt/acre	Finish - 0.33 pt/acre Ginstar - 4 oz/acre Finish - 1.33 pt/acre Def/Folex - 0.33 pt/acre	A A B B
Performance index	70	69	
Cost per acre (\$/acre)	20.13	32.74	
2004			
Products:	Finish - 1.33 pt/acre Def/Folex - 0.38 pt/acre	Finish - 2.0 pt/acre	A
Performance index	89	90	
Cost per acre (\$/acre)	16.72	21.63	
2005			
Products:	FirstPick - 1.5 qt/acre Def/Folex - 0.38 pt/acre	CottonQuik - 1.31 pt/acre Blizzard - 0.5 oz/acre COC - 0.42 pt/acre	A A A
Performance index	94	87	
Cost per acre (\$/acre)	11.82	13.22	
2006			
Products:	Prep - 1.6 pt/acre ET - 1.5 oz/acre COC - 0.4 pt/acre	Def/Folex - 0.25 pt/acre Drop - 2 oz/acre Prep - 2 pt/acre	A A A
Performance index	88	87	
Cost per acre (\$/acre)	15.24	21.07	

^z For sequential treatments, sequences A and B are the first and second defoliation applications, respectively.

^y COC = crop oil concentrate.

Table 2. Cost and composition of grower standard treatment - all years.

Products and rates	Sequence ^z
Def/Folex - 0.5 pt/acre	A
Drop - 1.6 oz/acre	A
Prep/ethephon - 0.4 pt/acre	A
Prep/ethephon - 2 pt/acre	B
Def/Folex - 0.67 pt/acre	B
Cost per acre (\$/acre) all years application (2) cost included (\$11.00/acre)	31.42

^z For sequential treatments, sequences A and B are the first and second defoliation application, respectively.

Table 3. Percent cost of savings of “best” selected treatment over grower standard treatment.

Year	Best single treatment cost (\$/acre)	Cost reduction (%)	Best sequential treatment cost (\$/acre)	Cost reduction (%)
2001	12.69	60	28.66	9
2002	16.72	47	27.82	11
2003	20.13	36	32.74	-4
2004	16.72	47	21.63	31
2005	11.82	62	13.22	58
2006	15.26	51	21.07	33
Averages	15.56	50	24.19	23

Utilization of COTMAN to Enhance Profitability of Cotton in Arkansas

*William C. Robertson, Gus M. Lorenz, III,
Diana M. Danforth, and Robert Hogan, Jr.¹*

COTMAN OVERVIEW

COTMAN is a crop-management system based on in-season plant monitoring (Danforth and O'Leary, 1998). The COTMAN computer software makes it easy to enter data and generate the reports used to make management decisions. The program is divided into two parts, SQUAREMAN and BOLLMAN. SQUAREMAN is used to monitor crop development up to the time of first flower. At first square, plant stand counts and average first-fruited node numbers are recorded. During squaring, ten plants at each of four sites per field are monitored weekly for presence of first-position squares. Reports provide feedback on square retention and plant stress based on nodal development. Square-shed information alerts growers to pest problems and augments insect scouting reports. A quick comparison to the target development curve tells if crop pace is too slow, too fast, or just right for an early crop and high yields. BOLLMAN is used when the crop is flowering to monitor boll-loading stress and to assist with end-of-season crop termination decisions. Beginning at first flower, nodes above white flower (NAWF) counts are recorded weekly from ten plants at each of four sites per field. Establishing the last effective boll population or the last group of bolls that will contribute significantly to yield and profit is essential for making end-of-season decisions. Cutout is reached when NAWF counts become less than five or when the probability of accumulating sufficient heat units (850 DD60s) to mature a flower falls below a user-defined threshold of 85% or 50%. From cutout until defoliation, daily high and low temperatures are recorded from a local weather source. Crop termination guidelines are based on heat unit accumulation beyond cutout.

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PLANT GROWTH OVERVIEW

The perennial nature of cotton often forces managers to manipulate growth and development to optimize seed and lint production. Maintaining the proper balance between vegetative and reproductive growth is essential for high yields. During squaring it is important to maintain good square retention and to develop the plant structure necessary to achieve yield goals. A realistic goal at first flower is to achieve a range of square retention from 80 to 85% and nodes above first-position white flower of nine to ten. Square retention values prior to first flower are most impacted by insect pressures. Plant structure prior to flowering is negatively impacted by stress. Fertility and moisture are the dominant factors impacting plant structure prior to flowering. Square retention values less than 80% will often result in delayed maturity and excessive vegetative growth due to the lack of adequate fruiting forms during boll development. Boll weevil eradication efforts and Bollgard technologies have helped to reduce the occurrences of low retention rates through squaring as well as into flowering. Retention rates of 90% or greater can present logistical challenges to managers because margins of error for input timings are small. Delays in timing can result in excessive square shed. High retention values coupled with poor plant structure can result in premature cutout, significantly impacting yields. Shed as a result of environmental stresses is often greater in situations where retention rates are very high. Managing inputs to achieve nine to ten NAWF at first flower will result in the plant having the necessary “horsepower” to avoid premature cutout in most instances. Fields in which NAWF values are in a range of six to seven will require immediate action to alleviate stress to avoid premature cutout. High retention values will magnify the urgency to relieve the stress in this situation. As a rule, early or more determinate varieties are more sensitive to having adequate “horsepower” at first flower to achieve desired yield potential than later or less determinate varieties. Being on track at first flower or taking corrective actions to get back in line shortly thereafter is necessary to achieve high yield goals.

COTMAN FROM FRUITING TO CUTOUT

The BOLLMAN component of COTMAN is much less labor intensive than the SQUAREMAN component. This component of COTMAN offers the manager great insight on the crop with little additional time requirements. Essentially all consultants record NAWF data. Tracking NAWF from first flower to cutout and evaluating the slope can help managers identify fields that can be “pushed” to help preserve existing yield potential. The target for comparison during flowering is a value of 9.25 NAWF at first flower or 60 days after planting and NAWF of 5 at 80 days after planting. The actual line from the field does not necessarily have to match this line exactly but should run parallel to it. The rate at which this line falls is a measure of stress. There are two types of stress. A boll load stresses the plant and is thought of as a good stress. Lack of moisture and fertility stresses the plant and is thought of as a bad stress. Excessive stress will generally produce a line that falls much faster than the target slope. Lack of stress, good or bad, will result in a line that runs flatter than the target. Fields experiencing slopes of NAWF values that are parallel to the target and possessing high

retention values are most often the fields that will respond favorably to additional inputs to “push” the crop.

CROP TERMINATION

Once the last effective boll population or cutout is established, heat units (HU), or DD60s, are accumulated to aid in termination decisions. Crop termination guidelines published in the 2006 Arkansas Cotton Newsletters were as follows:

Insecticide termination for lepidopterous and lygus species	NAWF=5 + 350 HU
Irrigation termination for North Arkansas	NAWF=5 + 350-400 HU
Irrigation termination for Central Arkansas	NAWF=5 + 400-450 HU
Insecticide termination for stink bug	NAWF=5 + 450 HU
Irrigation termination for South Arkansas	NAWF=5 + 450-500 HU
Insecticide termination for fall armyworm	NAWF=5 + 650-700 HU
Insecticide termination for defoliating insects	NAWF=5 + 650 HU
Defoliation initiation	NAWF=5 + 850 HU

PRACTICAL APPLICATION

COTMAN is an effective management tool. Better information means better decision making. Each field has its own report. COTMAN provides users timely information on square retention, plant, and fruit numbers per acre. The graph of crop development pace reveals much about the “horsepower” of the crop. Flowering dates of the last effective boll population (cutout) provide the benchmark for all end-of-season decisions. COTMAN eliminates end-of-season guesswork. It helps users determine when bolls are safe from insect pests and when to defoliate for optimal yield and quality. The cost of full-season crop monitoring is more than offset by savings on late-season insecticide. Timely feedback on crop development pace and stress gives growers potential to take prompt corrective actions. This program is easily integrated into management systems and helps tie everything together to enhance overall profitability.

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An Overview of the Arkansas Cotton Research Verification Program

Frank E. Groves, William C. Robertson, and Robert Hogan, Jr.¹

RESEARCH PROBLEM

Prior to 1980 Arkansas cotton production was behind that of neighboring states Louisiana and Mississippi. At the time producers lacked confidence in research-based production recommendations. Many producers believed small-plot research findings were not transferable to large-scale production practices. University and Extension personnel believed enhanced adoption could be achieved with a program that verified University of Arkansas recommendations at the farm level.

BACKGROUND INFORMATION

In 1980, the Cotton Research Verification Program (CRVP) was established by Gene Woodall in an effort to train producers and county extension agents in University of Arkansas cotton recommendations. The initial year of the program was a resounding success. The excessive heat and droughty conditions of 1980 allowed the CRVP to demonstrate the benefits of irrigation. At that time, Arkansas produced 645,000 acres of cotton and averaged 330 lb/acre. Louisiana produced 560,000 acres with an average of 394 lb/acre, while Mississippi produced 1,125,000 acres and averaged 488 lb/acre (Table 1). In its initial season, the CRVP more than doubled the state lint yield average with 816 lb/acre (Fig. 1) and efforts were made to expand the program. The program of today has the following objectives: i) Conduct on-farm field trials to verify the utility of research-based recommendations with the intent of optimizing potential for profits, ii) Develop an on-farm database for use in economic analyses and computer-assisted management programs, iii) Aid researchers in identifying areas of production that require further study, iv) Improve or refine existing recommendations that contribute to profitable production utilizing all production systems applicable to the commodity, v) Increase county extension agents' expertise in the specified commodity, and vi) Utilize

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and incorporate data and findings from the Research Verification Program into Extension educational programs at the county and state.

RESEARCH DESCRIPTION

To accomplish these objectives, a producer agrees to follow University recommendations on a field over two production seasons. During that time, the county extension agent and the CRVP coordinator meet with the producer on a weekly basis and determine inputs. Since 1986, the CRVP has utilized COTMAN in each field as both a training device and a means of enhancing the database. At seasons' end, cropping inputs, yield and fiber quality are used to develop an economic analysis of the field. These data are distributed through newsletters and annual reports to extension agents and clientele.

RESULTS AND DISCUSSION

Over the last 27 years, cotton lint yield in the Mid-South has trended upward (Table 1). Much of the success can be attributed to improved genotypes, but education has certainly played a role. Cotton educational programs vary from state to state and all have been successful. However, the University of Arkansas, Division of Agriculture is unique in being the only system with a Cotton Research Verification Program (CRVP). Since 1980, the trend line of Arkansas irrigated state lint yield/acre has increased at a faster rate ($y=16.792x+509.62$) than those of Mississippi ($y=7.6862x+647.25$) and Louisiana ($y=9.8584x+563.91$). Irrigated cotton lint yield has increased in Arkansas 70% and 118% more than in Louisiana and Mississippi, respectively (Fig. 2).

PRACTICAL APPLICATION

Throughout the duration of the program, 217 fields have been enrolled and all 24 cotton-producing counties have participated. The program has been instrumental in the testing and training of the University of Arkansas Irrigation Scheduling Program and COTMAN. The extensive database of inputs across various production systems allows for multi-year economic analysis and tracks the evolution of Arkansas cotton production. The CRVP database is the information source for cotton crop budgets. These data have been successfully incorporated into county programs and continue to serve as the training vehicle for county agents, producers, and consultants across the state. The success of the program has led to the development of similar programs in soybeans, wheat, rice, corn, grain sorghum, beef cattle, and catfish.

Table 1. Mid-South cotton production for 1980 and 2006.

Region	1980		2006	
	Acreage	Lint (lb/acre)	Acreage	Lint (lb/acre)
Arkansas	645,000	330	1,160,000	1,059
Louisiana	560,000	394	620,000	991
Mississippi	1,125,000	488	1,210,000	853

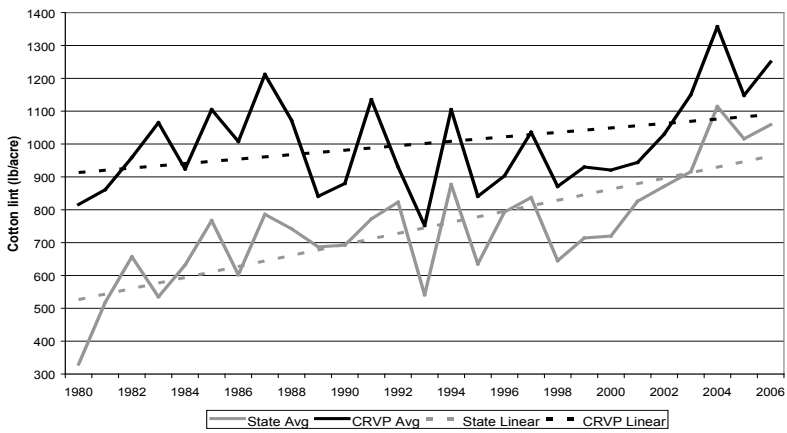


Fig. 1. Arkansas and CRVP average irrigated cotton lint yields from 1980 through 2006.

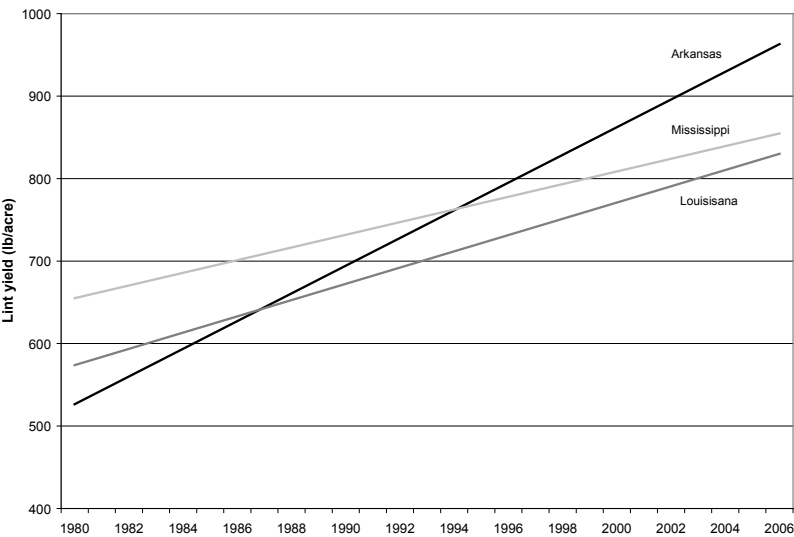


Fig. 2. Mid-South cotton lint yields from 1980 through 2006.

The Influence of COTMAN on the Arkansas Cotton Research Verification Program

Frank E. Groves and Don Plunkett¹

RESEARCH PROBLEM

The utilization of COTMAN has varied depending on the users' objectives. Consultants may only be interested in the BOLLMAN component, while researchers may be interested in season-long SQAREMAN data. These adaptations have made it difficult to estimate utilization and benefit to Arkansas producers.

BACKGROUND INFORMATION

One way to evaluate the effect of COTMAN on Arkansas cotton production would be to observe its impact on the Cotton Research Verification Program (CRVP). Since the inception of the CRVP in 1980, the program has strived to train extension personnel and clientele on University of Arkansas recommendations. Through the early 1990's, the potential of COTMAN was easily recognized, although COTMAN was only in the developmental stage. As the software was refined it became an integral component of the CRVP and currently serves as a fundamental tool of the program. Beyond the obvious implications for educators, growers, and consultants, COTMAN has been vital in the development of an on-farm database (Table 1). These data continue to provide insight into the verification of cotton recommendations.

RESEARCH DESCRIPTION

Since 1995, COTMAN data have been collected in 86 irrigated CRVP fields. Extension agents, producers, consultants, and CRVP personnel have collected COTMAN data for the program. These data served as the basis for in-season production recommendations.

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¹ Cotton research verification program coordinator, Southeast Research and Extension Center, Monticello; and county extension agent, Jefferson County, Pine Bluff, respectively.

RESULTS AND DISCUSSION

The benefits of late-season pest management and defoliation timing have received the most attention and have been instrumental in increasing grower profitability. Extension clientele across the state have adopted these recommendations although many outside of the CRVP have not realized the full potential of the software.

SQUAREMAN has been a valuable early-season management tool. The CRVP has utilized this component of COTMAN to validate early-season insect and irrigation recommendations. The data collected for SQUAREMAN have provided an illustration of the penalties associated with non-recommended plant bug applications and delayed irrigation. Recognition of the detrimental effects of these practices have greatly facilitated the training efforts of the CRVP and helped to instill grower confidence in current recommendations. The BOLLMAN component of COTMAN has also reinforced University of Arkansas recommendations. The CRVP has utilized the graphical evidence of crop pace to instruct producers and consultants in methods to manipulate crop stress. A heavy boll load has been shown to prevent excessive vegetative growth. Consequently, growers and consultants in the program have refrained from making pre-determined plant growth regulator (PGR) applications and have realized the need for late-season fertility and irrigation. In the absence of boll associated stress, vegetative growth has been discouraged with PGR applications.

Growers are able to speed up or slow down crop development to ensure earliness or maximize production while increasing net returns (Figs. 1 and 2). Although this is common in today's CRVP, it was a risky venture prior to the development of COTMAN.

PRACTICAL APPLICATION

COTMAN has served as a selling point for the CRVP. Through the years the CRVP has enjoyed increased grower interest due to the software. An advanced understanding of the software has typically resulted in a better understanding of cotton physiology and helped change the mindset of producers and consultants. Prior to COTMAN a cotton consultant was primarily an insect scout. Today's consultant is expected to make recommendations consistent with the goals of COTMAN.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

Table 1. CRVP COTMAN data from 2004 and 2005 at physiological cutout.

Season	County	Variety	Planting	Cutout	Nodes	Boll	Total shed
2004	Crittenden	ST4892 BR	5 May	21 July	16.3	19.5	13.4
2004	Lee	DP 444 B/RR	6 May	25 July	16.7	14.9	8.7
2004	Lonoke	ST5599 BR	6 May	31 July	16.4	10.0	5.7
2004	Crittenden	ST4892 BR	5 May	1 Aug	18.0	40.2	26.9
2004	Lee	DP 444 B/RR	5 May	1 Aug	17.9	26.2	17.5
2004	Lonoke	ST5599 BR	5 May	18 Aug ^z	19.9 ^y	47.3 ^y	29.6 ^y

^z Projected date of physiological cutout based upon 30-yr average temperatures.

^y Data collected on 1 August 2005.

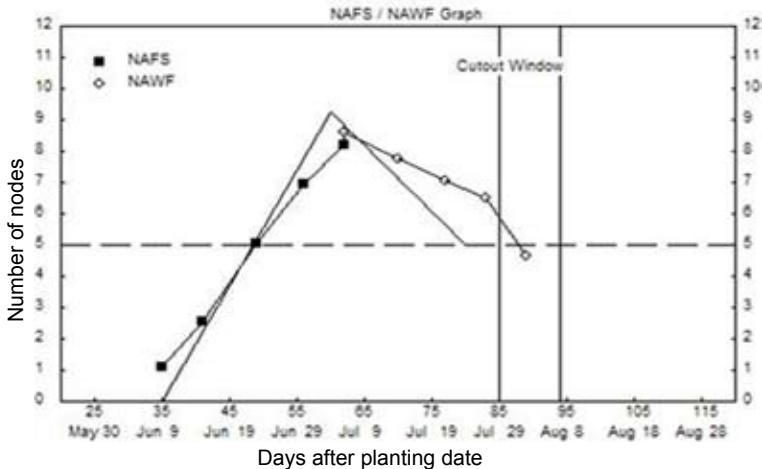


Fig. 1. The pattern of crop development from standard management compared to the target development curve.

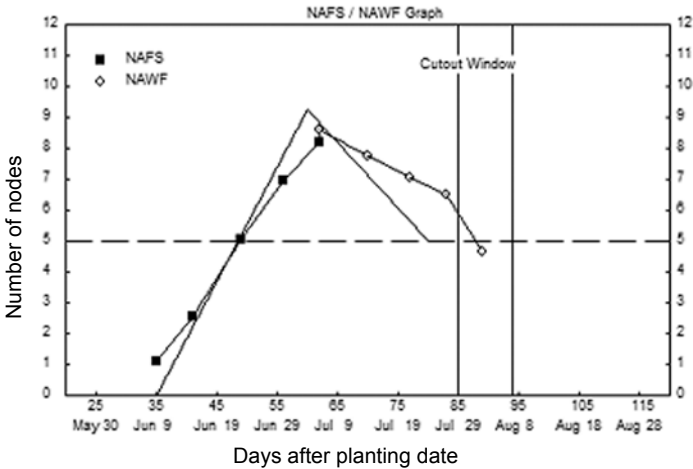


Fig. 2. The curve for accelerated management compared to the target development curve.

Cotton as an Innovative Fabric for Firefighter Protective Clothing

Mary M. Warnock¹

RESEARCH PROBLEM

Firefighting is a dangerous occupation that relies heavily on the effectiveness of protective clothing. This type of protective clothing must resist heat, flame, rough surfaces, and sharp objects as well as protect the wearer against biological/chemical surfaces. In order to address these issues, a survey was administered to firefighters to determine necessary changes that would make the present uniforms more efficient to use and comfortable to wear. Innovative cotton, Nomex, and Twaron fabrics providing lighter weight fabrications and additional moisture-management protection for chemical and biological substances were obtained. Fabric characterizations were performed on these selected innovative fabrics in order to determine their utility in firefighter protective clothing.

RESEARCH DESCRIPTION

Survey

An Ergonomic Test Protocol (Johnson, 2005) addressed the functional characteristics of ensembles as they affected the ability of firefighters to perform the tasks required when chemical/biological agents might be present. The protocol was tested with local firefighters who were training on station gear associated with the current required firefighter suit. Each of eight firefighters was tested under five different conditions: station clothes, current suit-wet, new suit-dry, and new suit-wet. The entire testing process for each condition took 2.5 hours per person. A questionnaire was used to assess the ensemble fit and comfort.

Experimental Fabrics

Results of the Ergonomic Test Protocol indicated that surveyed firefighters desired lighter weight suits that were more comfortable and yet retained high flammability

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protection; therefore, a search was conducted to locate innovative fabrics for firefighter protective clothing. Those fabrics selected for this project and shown to have possible use in future firefighter uniforms included the following:

- 100% cotton print cloth (3.34 oz/yd²) treated with epoxy bis-phosphonate monomer, cyanoguanidine, and citric acid (Chang et al., 2004)
- 100% cotton needlepunched nonwoven fabric with a carbon filler
- Twaron woven fabric with ripstop weave
- Nomex III A moisture barrier fabric

Textile Testing Procedures

The experimental fabrics were assessed for comfort and flammability plus performance and durability properties according to the American Association of Textile Chemists and Colorists (AATCC) (Anon., 1989a) and the American Society for Testing and Materials (ASTM) (Anon., 1989b) standards. Baseline NFPA 1971 requirements (National Fire Protection Association, 2000) had to be met or exceeded by these experimental fabrics for them to be considered for use in firefighter protective clothing. Specific textile tests included fabric weight, stiffness, flame resistance, and tear resistance. Additional moisture barrier tests determined water repellency and liquid/chemical penetration. All experimental fabrics were tested separately and three were combined and tested as a composite.

RESULTS AND DISCUSSION

In order for any fabric to be used in firefighter uniforms, it must meet or exceed baseline NFPA 1971 requirements (National Fire Protection Association, 2000). See Table 1 for criteria related to outer shell, thermal barrier, and moisture barrier fabric requirements.

The battery of tests (Table 2) performed on the individual experimental fabrics, without layering to produce a composite, supports the concept that they each can be used in the construction of a firefighter uniform. The Twaron fabric meets, or in some cases, exceeds the baseline requirements, making it suitable as an outer shell fabric (Fig. 1).

Nomex III A is a moisture barrier fabric that has a 100 water repellency rating, exceeding baseline requirements. There was no sticking or wetting of the upper surface of the fabric. The fabric, being of medium weight, will tear; however, this fabric would be the third layer of a composite so there should be no penetration of objects or punctures that would affect this layer. Flame resistance is excellent (Fig. 2). Fabric does exhibit some stiffness, but it does exceed baseline requirements, giving mobility to the wearer. Nomex III A can be used as a moisture barrier within the firefighter uniform.

The two fabrics in question as to their utilization within a firefighter uniform were the epoxy bis-phosphonate monomer, cyanoguanidine, and citric acid flame-resistant cotton print cloth and the carbon-filled needlepunched cotton nonwoven. Questions needing to be answered were as follows:

Cotton Print Cloth:

- Could the light-weight cotton print cloth give adequate protection when exposed to flame?
- Would the cotton print cloth tear too easily to be worn as an outer shell?
- Being 100% cotton, would water absorption be a problem?

Needlepunched Cotton Nonwoven:

- Knowing that this carbon-filled needlepunched cotton fabric was specifically created to be a high-absorber of chemical agents (Ramkumar, 2005), could the fabric be considered in firefighter uniforms?
- What flame resistance properties does this specialty nonwoven possess?
- Would a flame resistant finish, possibly the same one as used on the 100% cotton print cloth, be appropriate?

The 100% flame-resistant finished cotton print cloth does tear easily and without any type of finish – flame resistant and/or water repellent – does exhibit a “0” rating with complete wetting of whole upper and lower surfaces. Even when the flame-resistant finish was applied, water repellency did not improve. This epoxy bis-phosphonate monomer, cyanoguanidine, and citric-acid finish does meet baseline requirements for flame resistance (Fig. 3), but would need to be combined with a water-repellent finish for consideration as a firefighter uniform fabric choice.

Consideration for use in firefighter uniform construction was given to the needlepunched nonwoven cotton fabric because of the carbon filler. Ramkumar (2005) has established that this fabric has excellent chemical absorption power, but what are its flammability characteristics? As seen in Figure 4, this particular fabric did combust, and exhibit a char length of 304.8 mm. This result does not meet baseline requirements, which prevents this fabric from being used in firefighter uniforms. The heavy fabric weight and supersaturation capabilities also are to be considered as negative attributes for this designated use.

On the positive side, a three-layer composite (Fig. 5) was burned in the vertical flammability tester to see if the carbon-filled needlepunched cotton fabric would pass the baseline requirement for after-flame and after-glow times as well as char length specifications. The outer shell consisted of the Twaron fabric, the thermal barrier became the needlepunched nonwoven cotton fabric and the moisture barrier was the Nomex III A. This composite exhibited flame-resistance results that are comparable to baseline requirements. None of the composite fabrics demonstrated after-flame or after-glow times. Char length of the Twaron fabric, outer shell, was 25.4 mm while that of the needlepunched nonwoven cotton (thermal barrier) and Nomex III A (moisture barrier) was 6.4 mm. Further research is needed to determine if this three-layer fabric combination is a viable choice for a future firefighter prototype design.

PRACTICAL APPLICATION

- Nomex III A and Twaron meet baseline requirements and can be used in firefighter uniforms. Twaron would be the outer shell and Nomex III A would be the moisture barrier fabric.

- 100% cotton print cloth can become flame resistant through use of the epoxy bis-phosphonate monomer, cyanoguanidine, and citric-acid finish.
- 100% cotton print cloth cannot be used in firefighter uniforms due to lack of water repellency and tear resistance properties.
- Carbon-filled needlepunched, nonwoven cotton fabric scorches in the presence of flame, but could be used as part of a three-layer composite fabric. When used as the middle layer of a composite, the nonwoven cotton fabric does not burn. Possibilities for use in protective wearing apparel are worthy of further study.
- Conjecture is that because of the high absorbency power of the carbon-filled needlepunched, nonwoven cotton fabric, it would have the capabilities to absorb and retain flame-retardant chemicals, therefore, making it viable for protective wearing apparel.

ACKNOWLEDGMENTS

Support for this research was provided by the Division of Agriculture, University of Arkansas.

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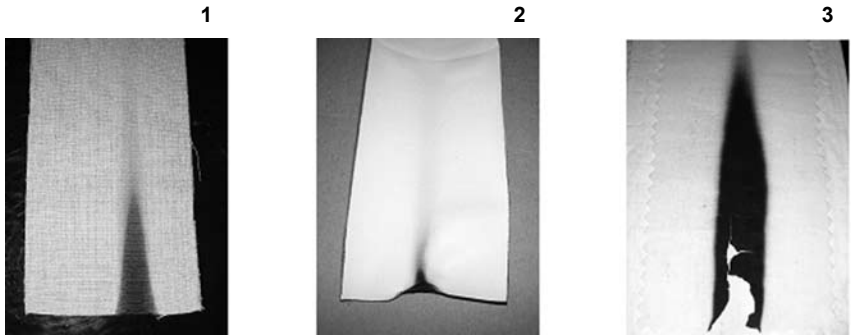
Table 1. Baseline requirements of fabrics for firefighter uniforms.

Property	Test method	Measurement	Criteria
Weight	ASTM D 1776	Unit area weight	≤ 7.0 oz/yd ² (os ^z) ≤ 5.0 oz/yd ² (mb) ≤ 7.0 oz/yd ² (tb)
Stiffness	ASTM D 1388	Bending length	≤ 25 mm
Flame resistance	ASTM D 6413	After-flame time	≤ 0.5 s (os/mb) ≤ 2.0 s (mb)
		After-glow time	≤ 0.5 s (os/mb) ≤ 2.0 s (mb)
		Char length	≤ 50 mm (os/tb) ≤ 100 mm (mb)
			≤ 100 N (os) ≥ 22 N (mb/tb)
Tear resistance	ASTM D 5587	Tear force	≥ 80
Water repellency	AATCC 22	Repellency rating	≥ 80

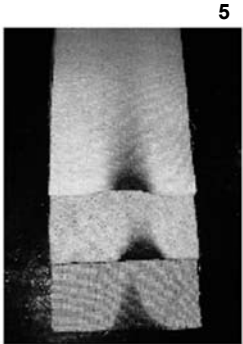
^z os = outer shell, tb = thermal barrier, and mb = moisture barrier.

Table 2. Experimental fabric characteristics.

Characteristics	Twaron	Cotton print cloth	Needlepunched cotton nonwoven	Nomex III A
Weight (oz/yd ²)	4.92	3.34	9.73	4.95
Stiffness (mm)	6.5	4.2	12.8	8.0
Flame resistance:				
After-flame time (sec)	0	0	75.2	0
After-glow time (sec)	0	0	0	0
Char length (mm)	50.8	110	304.8	12.7
Tear resistance (g/f)	5440	1664	6400 *	2880
Water repellency (rating)	5	0	0	100



Figs. 1, 2, and 3. Flammability characteristics of Twaron (1), Nomex III A (2), and cotton print cloth (3).



Figs. 4 and 5. Flammability characteristics of needlepunched, nonwoven cotton fabric (4), and composite fabrics (5).

A Comparison of Image Indices for Cotton Biomass Estimation

William H. Baker¹

RESEARCH PROBLEM

The use of imagery to map cotton biomass, or stress, is being adopted as a means to assess the crop and save production costs by supporting variable-rate applications. As information and GPS technologies improve, the use of imagery to make crop-production decisions will become a regular practice. The cost savings from reduced chemical input have been shown to more than offset the cost of acquiring and processing the imagery. The purpose of this paper was to investigate the image processing step that is commonly used to assess plant biomass.

BACKGROUND INFORMATION

The normalized difference vegetation index (NDVI) has been used successfully to classify cotton plant biomass. The NDVI takes advantage of the plant's strong absorption in the red band and high reflectance in the infrared band. There are several other indices that utilized the same spectral information, but they are not as commonly used as NDVI. The work reported in this paper was an examination of the possible improvement in producing a classified map using four other common indices. The remainder of this project was to provide imagery for the Arkansas Cooperative Extension Service Cotton Research Verification Program (CRVP).

RESEARCH DESCRIPTION

Five fields used in the study were in the CRVP for the 2006 season. Imagery was obtained as requested by the Verification Coordinator and made available for scouting. Variable rate applications were planned for some of these fields. Other cotton fields were imaged to support the data needs for this investigation.

The imagery was acquired using the Terrahawk imaging system. The camera used by this system was a Duncantech model 4100. Table 1 gives the specifications for this

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camera. The altitude of the imagery was usually below 6000 feet, which yielded a pixel resolution near 1.5 meters. The image processing software was SMS by AgLeader and ERDAS Imagine by Leica. ESRI ArcView was also used to process much of the data.

RESULTS AND DISCUSSION

The various band combinations used in this study are shown in Table 2. After each index was computed, the image data were classified into eight classes using the unsupervised classification method in Imagine. The cotton fields used in this study exhibited a wide number of stressed cotton-plant conditions. This was due to the sand blows in the fields that limit moisture, even under irrigation conditions. The ground truthing can be seen in Figure 1. Stressed cotton is readily apparent in the foreground of the field photograph. The RGB image of the entire field reveals these areas. A 200-sq. meter area was selected that was found to contain several categories of stressed and non-stressed cotton.

Figure 2 shows the results of the vegetation index classifications. All the indices were found to provide useful information about the crop. The NDVI, TNDVI, and SQRT (IR/R) were found to give similar results. The most detailed indices in terms of producing the best separation in the highest stressed area were the IR/R and the Veg. Index indices. These two indices produced a distinct class in the high-stress zone that the other 3 indices did not appear to distinguish. This area is indicated by the circle.

PRACTICAL APPLICATION

While NDVI does a good job, there were instances when image information from the CRVP fields did not scout as closely as was needed to produce a variable-rate application. Work in this study indicated that perhaps the IR/R or the Veg. Index might be more sensitive and produce better resolution in crop biomass to allow the image information to be more useful.

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Table 1. Spectral resolution of the Duncantech camera.

Band	Spectral region	Resolution (nm)
Band 1	Green	530 - 570
Band 2	Red	640 - 680
Band 3	NIR	768 - 832

Table 2. Band combinations used to compute the various imagery indices.

Index	Band combinations
NDVI	band 3 - band 2 / band 3 + band 2
TNDVI	$\text{Sqrt} ((\text{band 3} - \text{band 2} / \text{band 3} + \text{band 2}) + 0.5)$
IR / R	band 3 / band 2
SQRT (IR / R)	$\text{Sqrt} (\text{band 3} / \text{band 2})$
VEG. INDEX	band 3 - band 2

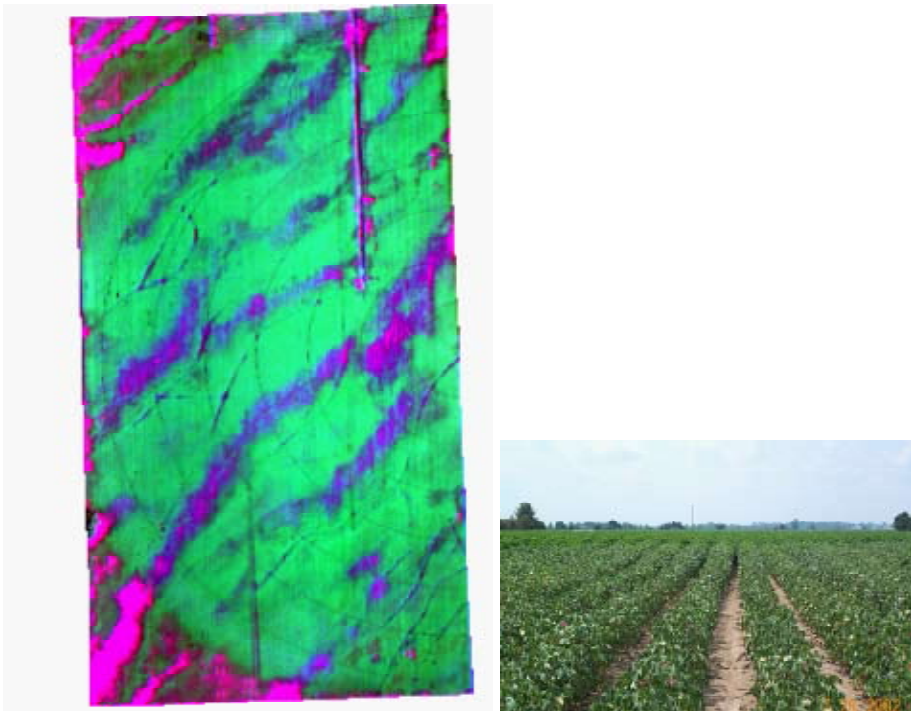


Fig. 1. An RGB image of the center pivot-irrigated cotton field with sand blows. The photograph of the field shows the water-stressed cotton in the sand-blow area adjacent to the high-biomass (low-stress) cotton.

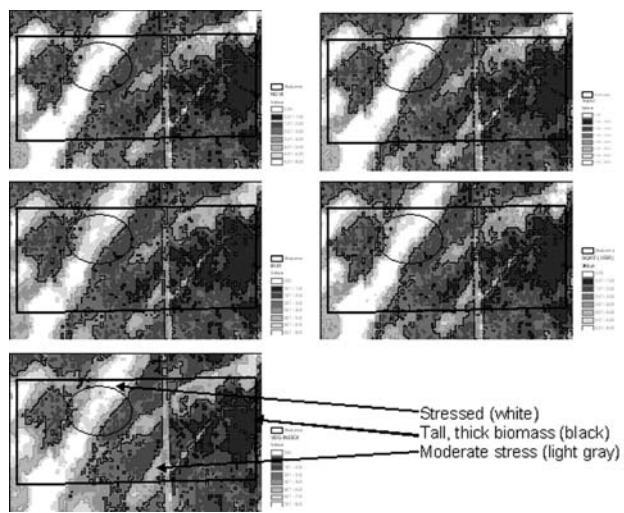


Fig. 2. Classified vegetation indices as described in Table 2.

APPENDIX I
STUDENT THESES AND
DISSERTATIONS RELATED TO COTTON
RESEARCH IN PROGRESS IN 2006

- Allen, Kerry Clint. Spatial and temporal distribution of *Helicoverpa zea* (Boddie) and *Heliothis virescens* (F.) in heterogeneous cropping environments in southeastern Arkansas. (Ph.D., advisor: Dr. Luttrell)
- Avila, Carlos A. Transfer of reniform nematode resistance from diploid cotton species to tetraploid cultivated cotton. (PhD, advisor: Dr. Stewart)
- Bibi, Androniki. Effect of high temperatures on the biochemistry of the reproductive process in cotton genotypes. (Ph.D., advisor: Dr. Oosterhuis)
- Chappell, Adam. Evaluation of a new cotton aphid threshold and the impact of selected insecticides on the beneficial arthropod complex found in Arkansas cotton with emphasis on predacious coccinellids important for cotton aphid suppression. (M.S., advisor: Dr. Lorenz)
- Doukopoulos, Alexandros. Phylogenetic analysis of *Gossypium hirsutum* from the Caribbean basin and Florida. (M.S., advisor: Dr. Stewart)
- Galligan, Larry. Optimizing release strategies of *Neozygites fresenii* (Entomophthorales: Neozygitaceae) for induction of epizootics in *Aphis gossypii* (Heteroptera: Aphididae). (M.S., advisor: Dr. Steinkraus)
- Griffith, Griff. Glyphosate-resistant Palmer amaranth: Resistance mechanism and gene flow. (Ph.D., advisor: Dr. Norsworthy)
- Groves, Frank. Inheritance of cotton yield components and relationships among yield, yield components, and fiber quality. (Ph.D., advisor: Dr. Bourland)
- Gonias, Evangelos. Environmental factors and plant growth regulator effects on radiation use efficiency in cotton. (Ph.D., advisor: Dr. Oosterhuis)
- Hendrix, Bill. Molecular characterization of cotton: Genome size evolution and the genomics and metabolomics of osmotic stress in roots. (Ph.D., advisor: Dr. Stewart)
- Jackson, Sarah. Relationships of marginal trichomes on cotton bracts to yield and fiber quality. (MS., advisor: Dr. Bourland)
- Kay, Sasha. Effect of *Neozygites fresenii* infection on fecundity, honeydew production, movement, and ultrastructure of the cotton aphid, *Aphis gossypii*. (M.S.,

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- Kulkarni, Subodh. Soil compaction modeling in cotton. (Ph.D., advisor: Dr. Bajwa)
- Loka, D. Effect of high night temperatures on cotton gas exchange and carbohydrates. (M.S., advisor: Dr. Oosterhuis)
- Mills, Nathan. Cotton (*Gossypium hirsutum* L.) seedling root growth in response to low temperatures. (M.S., advisor Dr. Oosterhuis)
- Nader, Anna Camila. Effect of transgenic antifungal peptides on mycorrhizal associations. (M.S., advisor: Dr. Stewart)
- Navas, Juan Jaraba. The influence of the soil environment and spatial and temporal relationship on *Meloidogyne incognita* and *Thielaviopsis basicola* and their interaction on cotton (Ph.D., advisor: Dr. Rothrock)
- Osorio, Juliana. Comparison of BC₁ and F₂ maps of an interspecific hybrid (*G. darwinii* x *G. hirsutum*). (M.S., advisor: Dr. Stewart)
- Still, Josh. Ecology and overwintering ability of *Rotylenchulus* reniforms in Arkansas. (M.S., advisor: Dr. Kirkpatrick)
- Tiwari, Rashmi. Molecular characterization of the diversity and natural hybridization of the *Gossypium* species of the arid zone of Australia. (M.S., advisor: Dr. Stewart)

APPENDIX II

RESEARCH AND EXTENSION

2005 COTTON PUBLICATIONS

REFEREED PUBLICATIONS

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