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Summaries of Arkansas Cotton Research 2015

Derrick M. Oosterhuis
University of Arkansas, Fayetteville

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Summaries of Arkansas Cotton Research 2015 Oosterhuis AAES

Summaries of
Arkansas Cotton Research
2015

Edited by Derrick M. Oosterhuis

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RESEARCH & EXTENSION
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Cover Photo: (2006) Derrick Oosterhuis, Distinguished Professor of Crop Physiology in the Department of Crop, Soil, and Environmental Sciences, stands in a cotton field at the University of Arkansas Division of Agriculture's Lon Mann Cotton Research Center in Marianna, Arkansas.
Photo Credit: University of Arkansas System Division of Agriculture.

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2015

Derrick M. Oosterhuis, Editor

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

CONTRIBUTORS

Bararpour, Mohammed T., Post Doctoral Associate, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Barber, Tom L., Associate Professor, Department of Crop, Soil, and Environmental Sciences, Lonoke

Barnes, Brittany D., Graduate Student, Arkansas State University Research Unit, University of Arkansas Agricultural Experiment Station, Jonesboro

Benson, Ray, County Cooperative Extension Agent, Mississippi County, Blytheville

Black, Joseph, Program Technician, Department of Entomology, Lonoke Extension Center, Lonoke

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

Chaney, H. Michael. Program Associate, Department of Entomology, Lonoke Extension Center, Lonoke

Collie, Leah, Program Technician, Department of Crop, Soil, and Environmental Sciences, Lonoke Extension Center, Lonoke

Coomer, Taylor. Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Daniels, Mike, Professor, Extension Water Quality, Department of Crop, Soil, and Environmental Sciences, Little Rock

Doherty, Ryan C., Program Associate, Southeast Research and Extension Center, Monticello

Espinoza, Leo, Extension Soil Scientist, Department of Crop, Soil, and Environmental Sciences, Little Rock

FitzSimons, Toby R., Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Flanders, Archie, Associate Professor, Northeast Research and Extension Center, Keiser

Free, Amanda, Cotton Research Verification/Sustainability Program Associate, Newport Extension Center, Newport

Hale, Ralph R., Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Henry, Chris, Assistant Professor, Rice Research and Extension Center, Department of Biological and Agricultural Engineering, Stuttgart

Herron, Cindy G., Program Technician, Department of Crop, Soil, and Environmental Sciences Soil Testing and Research Laboratory, Marianna

Hill, Zachary, Program Associate, Southeast Research and Extension Center, Monticello

Ismanov, Mukammadzakhrab, Program Technician, Department of Crop, Soil, and Environmental Sciences, Little Rock

Loka, Dimitra A., Post Doctoral Associate, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Lorenz III, Gus M., Associate Department Head, Entomology, Lonoke Extension Center, Lonoke

Mann, Amanda M., Program Technician, Arkansas State University, University of Arkansas System Division of Agriculture's Arkansas Agricultural Experiment Station, Jonesboro

Martin, Steven, Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Meyer, Christopher J., Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Miller, M. Ryan, Senior Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Morris, D. Keith, Associate Professor, Arkansas State University, Jonesboro

Mozaffari, Morteza, Assistant Professor, Northeast Research and Extension Center, Keiser

Norsworthy, Jason K., Professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Oosterhuis, Derrick M., Distinguished Professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Osborn, Jason, County Cooperative Extension Agent, Mississippi County, Blytheville

Palhano, Matheus, Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Pilon, Cristiane, Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Plummer, Andrew W., Program Associate, Department of Entomology, Lonoke Extension Center, Lonoke

Raper, Tyson. Assistant Professor, Plant Sciences, University of Tennessee, Jackson

Reba, Michele L., Research Hydrologist, USDA ARS Delta Water Management Research Unit, Jonesboro

Robertson, Bill, Professor, Cotton Agronomist, Newport Extension Center, Newport

Ross, Aaron W., Program Technician, Department of Crop, Soil, and Environmental Sciences, Lonoke Extension Center, Lonoke

Rothrock, Craig, Professor, Plant Pathology, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Slaton, Nathan, Professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Spurlock, Terry N., Extension Plant Pathologist, Southeast Research and Extension Center, Monticello

Stevens, Steve, Producer, Southeast Arkansas Discovery Farms, Dumas

Studebaker, Glen E., Extension Entomologist, Northeast Research and Extension Center, Keiser

Taillon, Nichole M., Program Associate, Entomology, Lonoke Extension Center, Lonoke

Teague, Tina G., Professor, Arkansas State University, University of Arkansas System Division of Agriculture's Arkansas Agricultural Experiment Station, Jonesboro

Towles Logan, Program Technician, Northeast Research and Extension Center, Keiser

van der Westhuizen, Mathilda M., Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Wilson, Kyle D., Graduate Assistant, Plant Pathology, Southeast Research and Extension Center, Monticello

Young, Mason, Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2015

2015 IN REVIEW

Spring was slow to arrive in 2015. Conditions for planting cotton were not favorable until the last week of April. Rains began the end of the first week in May and continued through much of the month of May (Fig. 1). Areas north of Interstate 40 received more rain resulting in more prevented plantings for almost all commodities compared to south Arkansas. Cotton planting intentions were estimated to be 240,000 acres. The United States Department of Agriculture Farm Service Agency certified approximately 205,000 acres of cotton. The 2015 cotton crop was the lowest on record for acres, down 14% from the previous year.

Growing conditions were very favorable through squaring to flowering. Producers appear to be getting a better handle on managing resistant palmer pigweed as evident by the low number of grown up cotton fields. Hand hoeing is common on most farms to address problem areas. Plant bugs were the dominant insect pest. In 2015, they were perhaps a greater problem in the northern areas of the state. Pest control represents a significant expense and can impact yield greatly. In the 2015 Cotton Research Verification/Sustainability Program, insecticides, herbicides, and plant growth regulators represented 26% of the producers input costs. Planting seed with technology fees and fertilizers were 24% and 28% of input costs, respectively. All energy costs including diesel fuel for tillage, irrigation, and harvest represented 13% of input costs. These items represent approximately 91% of the producers input costs of approximately $450 per acre to grow the crop.

During flowering and boll fill, Arkansas cotton growers experienced three particularly hot and dry periods, two in July and one in August. These ultimately had an impact on the crop. The United States Department of Agriculture National Agricultural Statistics Service's August Crop Production report projected Arkansas producers to harvest a record high yield of 1226 lbs lint/acre. This estimate was based primarily on boll numbers and surpassed last year's record by 81 lbs. However, seed counts of bolls revealed the impact of the hot dry conditions. Under very good conditions it is not uncommon to count 35 to 38 seeds in well-developed five-lock bolls. In 2015, it was not uncommon to count 25 to 28 seed in a good sized five-lock boll. Yield projections dropped as the season progressed with the 2015 crop averaging 1112 lbs lint/acre at season's end. While lower than last season, this yield represented the fourth best crop on an acre basis behind 2014, 2013 and 2004. As a result of a record low number of acres, total production also represented an all-time record low of approximately 475,000 bales, down 40% from last year.

Fiber quality was a mixed bag. A large portion of the crop did not receive any significant rainfall from boll opening to harvest. As a result, color grades were great as over 90% of Arkansas cotton classed at Dumas had a color grade of 31 or better. Micronaire was a different story. In 2014, over 80% of Arkansas cotton classed at Dumas had micronaire in the target value range of 3.5 to 4.9. In 2015, greater than 60% was in the discount range with a value of 5.0 or greater. Approximately 25% of the total crop had micronaire values of 5.3 or greater with even greater discounts. Leaf trash and staple were slightly better in 2015 compared to 2014. Discounts related to high micronaire values greatly decreased the value of the lint even though other fiber quality parameters were acceptable to good.

Interesting observations can be made from the 2015 cotton crop and are all likely weather driven. Seed numbers per boll were down based on random seed counts. Gin turnout values discussed by producers were slightly lower and could translate to fewer but bigger seed. Reports from Planters Oil Mill were very favorable of the 2015 crop. They indicated that extracted oil yield from a ton of whole seed was greater than they have seen in previous years. It is possible that oil yield per unit of seed could increase if seed numbers per unit area decreased and seed size increased. Micronaire is perhaps the fiber quality parameter most impacted by environment. Micronaire values were extremely high even on fields where harvest aid treatments were initiated with less than 50% open bolls. This demonstrates that even with the best of management practices, weather has a tremendous and often overriding impact on the final outcome.

Bill Robertson
Professor, Cotton Extension Agronomist
Newport Extension Center, Newport

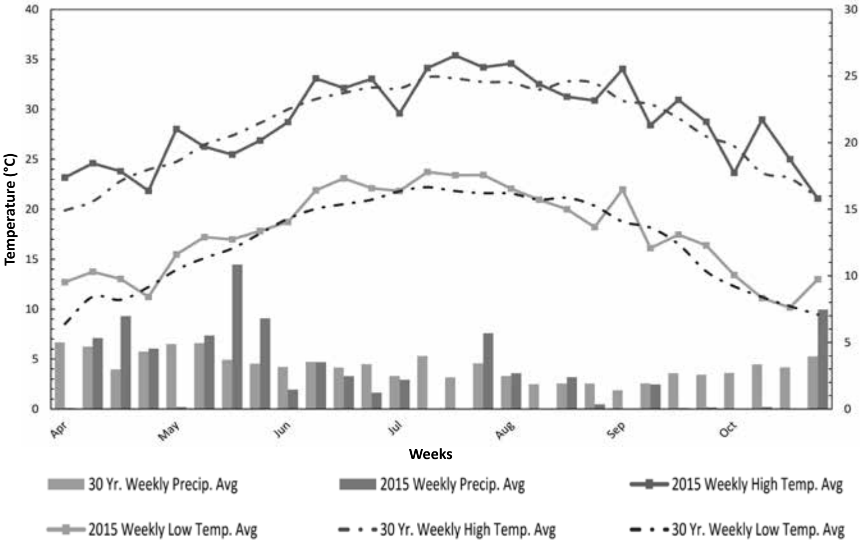

Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2015 compared with the long term 30 year averages in Eastern Arkansas.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research 2015* was 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 staff members of the University of Arkansas System Division of Agriculture, the Cotton Board, and Cotton Incorporated. Seven and one-half percent of the grower contributions to the Cotton Incorporated budget are allocated to the State Support Committees of 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, Tenn., administers the act, and contracts implementation of the program with Cotton Incorporated, a private company with its world headquarters in Cary, N.C. Cotton Incorporated also maintains offices in New York City, Mexico City, Osaka, Hong Kong, 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 2015.

	2014	**2015**
New Funds	$247,000	$218,000
Previous Undesignated	$51,400	$91,012
Total	$298,400	$309,012

Researcher	**Short Title**	**2014**	**2015**
Oosterhuis	Cotton Research In Progress	$5,000	$5,000
Bourland	Breeding	$26,000	$26,000
Henry	Irrigation	$31,500	$31,500
Burgos	Palmer amaranth Herbicide Resistance	$13,500	$13,500
Oosterhuis	Improving Cotton Fertility	$9,800	$9,800
Norsworthy	Cover Crops	$32,782	$32,782
Reba	Increasing yield through irrigation management	$13,620	$13,620
Robertson	Verification 2015	$0	$50,000
Lorenz	Alternative Thrips Control	$0	$32,000
Roberston	Potash	$0	$11,500
Barber	Replant Decisions	$13,500	$0
Lorenz	Herbicide, Insecticide Interactions	$31,000	$0
Barber	Verification	$74,208	$0
Uncommitted		$47,940	$83,310
Total		**$250,910**	**$225,702**

DEDICATION TO DR. DERRICK OOSTERHUIS

This issue is dedicated to retiring Distinguished Professor Derrick M. Oosterhuis, who is holder of the Clyde H. Sites Endowed Professorship in International Crop Physiology in the Department of Crop, Soil and Environmental Science at the University of Arkansas. He earned his B.S. in South Africa, his M.S. at the University of Reading in England, and his Ph.D. at Utah State University.

He joined the University of Arkansas, CSES faculty in 1985, and was promoted to Associate Professor in 1987, to Professor in 1989, and Distinguished Professor in 1999. Dr. Oosterhuis has over 40 years' experience as an agronomist/physiologist and has lectured or worked in 15 countries, taught or co-taught in 10 different courses. He has advised 48 graduate students, seventeen international visiting scholars, five postdocs, and a number of high school scholars. Dr. Oosterhuis' research focused on stress physiology, plant nutrition, foliar fertilization, high temperature stress, and drought tolerance. Dr. Oosterhuis has also had a strong international program, with collaborative research at various universities and research institutions in five continents. His publication record includes 185 refereed articles, 32 book chapters, 8 books compiled and edited, and 36 proceedings edited. He served as chair of the Arkansas Cotton Research Group, and compiled and edited the Summaries of Arkansas Cotton Research publication for 30 years. He received numerous awards including the Arkansas Alumni Distinguished Faculty Award for Teaching and Research, Gamma Sigma Delta Research Award, John W. White Team Award, Werner L. Nelson Award by the Fluid Fertilizer Society, and the Beltwide Outstanding Cotton Physiologist. He served as advisor to cotton boards in three countries, was a member of two UN/FAO committees on growth regulators and nutrition, as chair of the physiology metabolism section of the Crop Science Society of America, and is a Fellow in the American Society of Agronomy and in the Crop Science Society of America.

ACKNOWLEDGMENTS

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

SUMMARIES OF
ARKANSAS COTTON RESEARCH
— 2015 —

University of Arkansas Cotton Breeding Program: 2015 Progress Report

F.M. Bourland[1]

RESEARCH PROBLEM

The University of Arkansas System Division of Agriculture's Cotton Breeding Program attempts to develop cotton genotypes that are improved with respect to yield, yield components, 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 to 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 (2004, 2013) described the methods and output from the current program, which primarily focuses on the development of improved breeding methods and the release of conventional genotypes. Conventional genotypes continue to be important to the cotton industry, as a germplasm source and alternative to transgenic cultivars. Transgenic cultivars are usually developed by backcrossing transgenes into advanced conventional genotypes.

RESEARCH DESCRIPTION

Breeding lines and strains are annually evaluated at multiple locations in the University of Arkansas System Division of Agriculture's Cotton Breeding Program. Breeding lines are developed and evaluated in non-replicated tests because seed number in early generations is limited. Breeding line tests include initial

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[1] Director/professor, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

crossing of parents, generation advance in early generations, individual plant selections from segregating populations, and evaluation of the progenies derived from individual plant selections. 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, yield components, fiber quality, host-plant resistance and adaptation properties. Superior strains are subsequently evaluated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm lines or cultivars.

RESULTS AND DISCUSSION

Breeding Lines

The primary objectives of crosses made in 2009 through 2015 (F_1 through F_6 generations evaluated in 2015) included development of enhanced nectariless lines (with the goal of improving resistance to tarnished plant bug), improvement of yield components (how lines achieve yield), and improvement of fiber quality (with specific use of Q-score). Particular attention has been given to combine the fiber quality of UA48 into a higher yielding lines. Breeding line development is entirely focused on conventional cotton lines.

The primary focus of the 24 crosses made in 2015 was to combine lines having specific morphological traits, enhanced yield components and improved fiber characteristics. Eight of the 24 crosses were made between advanced Arkansas lines, and 16 were made between an Arkansas line and a line from either another public program or one of two private breeding companies (via specific agreement). The latter crosses should help to widen the genetic base of the breeding program. The 2015 breeding effort also included field evaluation of 16 F_2 populations, 24 F_3 populations, 24 F_4 populations, 744 1st year progeny, and 192 advanced progeny. Bolls were harvested from superior plants in F_2 and F_3 populations and bulked by population. Individual plants (1200) were selected from the F_4 populations. After discarding individual plants for fiber traits, progenies from the individual plant selections will be evaluated in 2016. From the 1st year progenies, 192 were advanced, and 72 F_6 advanced progenies were promoted to strain status. These selected 72 F_6 advanced progeny included 40 progenies derived from crosses with UA48 (Bourland and Jones, 2012a), 8 derived from crosses with UA222 (Bourland and Jones, 2012b), and 13 having both UA48 and UA222 in their pedigree.

Strain Evaluation

In 2015, 108 strains (Preliminary, New and Advanced) were evaluated at multiple locations. Screening for host-plant resistance included evaluation for resistance to seed deterioration, seedling disease, bacterial blight, Verticillium wilt, and tarnished plant bug. Work to improve yield stability by focusing on yield components and to improve fiber quality by reducing bract trichomes continued.

The 72 Preliminary Strains included 22 derived from crosses with UA48, 24 from crosses with UA222, and eight from crossing UA48 by UA222. The 2016 New Strain Test will include 15 of these lines.

Germplasm Releases

Germplasm releases are a major function of public breeding programs. Since 2004, a total of 52 cotton germplasm lines and three cotton cultivars have been released by the Arkansas Agricultural Experiment Station. Variation with respect to yield, adaptation, yield components, fiber properties, and specific morphological and host-plant resistance traits are represented in these lines. The lines provide new genetic material to public and private cotton breeders with documented adaptation to the mid-South cotton region. Additional lines are now being considered for release.

PRACTICAL APPLICATIONS

Genotypes that possess enhanced host-plant resistance, improved yield and yield stability, and excellent 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 and other public cotton breeders or released as cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions.

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Historical Influence of Temperature on Cotton Yields in the Mississippi Delta

T.R. FitzSimons[1] and D.M. Oosterhuis[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) yields are significantly greater now than in decades past. Historically, there has been high amounts of yearly yield variability. The cause of this variability has been attributed to many factors, but the most pervasive and uncontrollable factor is that of temperature. Due to cotton's inherent sensitivity to temperature on reproductive development and the subsequent timing of heat stress, temperature is responsible for a significant amount of variability in yields. Therefore, this research sought to determine if the influence of temperature could be identified in historic regional analysis of both irrigated and non-irrigated fields of the Arkansas Mississippi Delta region.

BACKGROUND INFORMATION

Across the South, many irrigation decisions rely upon the daily maximum temperatures for their application (Usman et al., 2010). Primarily, irrigation is used to maximize yields by minimizing seasonal water stress that occurs during the summer season (Guinn, 1976). This is due to cotton's sensitivity to high temperature stress (Gür et al., 2010), which has been reported under field conditions to occur at temperatures greater than 35 °C (Bibi et al., 2008). Field observations support an optimum range of enzymatic kinetics of between 23.5 °C to 32 °C (Burke et al., 1988). However, temperatures in the Mississippi River Valley routinely exceed these temperatures in the afternoons of the summer months, with maximal temperatures occasionally exceeding 38 °C (Boykin et al., 1995). Also many fields in the region are not irrigated. Thus the effects of low precipitation and higher temperature can cause increased boll abscission rates (Stewart, 1986). This is particularly true in the Mississippi Delta region where the primary bulk of precipitation is received in either spring or autumn. This lack of summer moisture has led to significant decreases in the Mississippi River Valley Alluvial Aquifer where much of the irrigation in the eastern part of the state is derived (Sullivan and Delp, 2007).

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[1] Graduate assistant and distinguished professor, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

RESEARCH DESCRIPTION

Cotton yield data was collected from the United States Department of Agriculture's National Agricultural Statistics Service (USDA-NASS, 2016) for both irrigated and non-irrigated fields from 1980 to 2014 for the state of Arkansas. Daily maximum and minimum temperatures were collected from three long-term Arkansas weather stations in Jonesboro, Marianna, and Rohwer from 1980 until 2014. Taking the average days of crop development as a guide (Ritchie et al., 2004) and that cotton is sown on average on the 20th week and first flower occurs on or near the 28th week of the year calculated from historical averages of planting dates at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Ark. This places flowering firmly in the month of July. Due to yearly variations, decadal periods were analyzed to investigate increasingly modern cultivated varieties and their response to temperature. Assumptions were made that producers would have provided proper management during the growing season and these were not included as confounding factors in this analysis. All regression analyses were performed in JMP 12.1 (SAS Institute, Inc. Cary, N.C.) and considered significant at or below an alpha level of 0.05.

RESULTS AND DISCUSSION

The number of irrigated fields in Arkansas have dramatically increased since 1980, comprising more than 90% of the fields in Arkansas by today (Fig. 1). This large increase has had strong negative consequences on the Mississippi Delta Alluvial Aquifer. Historically, irrigated fields have averaged about 20-25% greater yields than non-irrigated fields. It would be expected that these fields would be less tolerant of increased temperatures due to less moisture available to encourage greater vegetative development and subsequent greater yields. However, the analyses indicated that regardless of the irrigation strategy, temperature strongly impacted yield negatively.

Results in Fig. 2 indicate that during July, irrigated fields had similar trends as their non-irrigated counterpart. Examining decadal differences, maximum temperatures that exceeded 33 °C yields in the 1980s caused yields to decrease rapidly. Likewise, minimum temperatures of the same period suggest that there is an increase in yield until around 21.5 °C. During the 1990s, yield was also significantly impacted by increasing temperature. Maximum temperatures for irrigated fields indicated no positive trend for increasing yield and a linear decrease in yield with about 31 °C having the greatest yields.

Likewise, non-irrigated cotton had steeper declines in yield. Minimum temperatures during this time period did not indicate negative impacts of temperature until monthly averages exceeded about 22 °C. For more modern cultivars of the 2000s, temperature trends were just as similar to decades past. Maximum temperatures had less of an impact on yield as noted by the lower R^2 value of 0.17, however there is no positive yield increase for any temperature above 30 °C. Similarly, non-irrigated fields have a significant, negative near-linear decrease in yield with increasing maximum temperature during this time as well. The interaction of increasing minimum temperatures on irrigated fields had negative decreases until about 22 °C when yields moderated, whereas non-irrigated fields experienced no moderation and continued its strong negative linear trend.

PRACTICAL APPLICATIONS

This research demonstrates that temperature effects have a significant impact on crop yield for both irrigated and non-irrigated fields. This unique examination of historical temperature and yield reinforces several previous studies which identified temperature as being the strongest component of yield variability. Additionally, the data indicate that cotton still is as sensitive to temperature as it has been in the past. Though irrigated cotton still provides a significant boost in yield over non-irrigated cotton, temperature impacts irrigated fields with the same negative trends as in non-irrigated fields. This implies that modern cultivars still suffer from the same genetic bottleneck of temperature tolerance as did cultivars of the past.

ACKNOWLEDGMENTS

We acknowledge support of this research by Cotton Incorporated. Support also provided by the University of Arkansas System Division of Agriculture.

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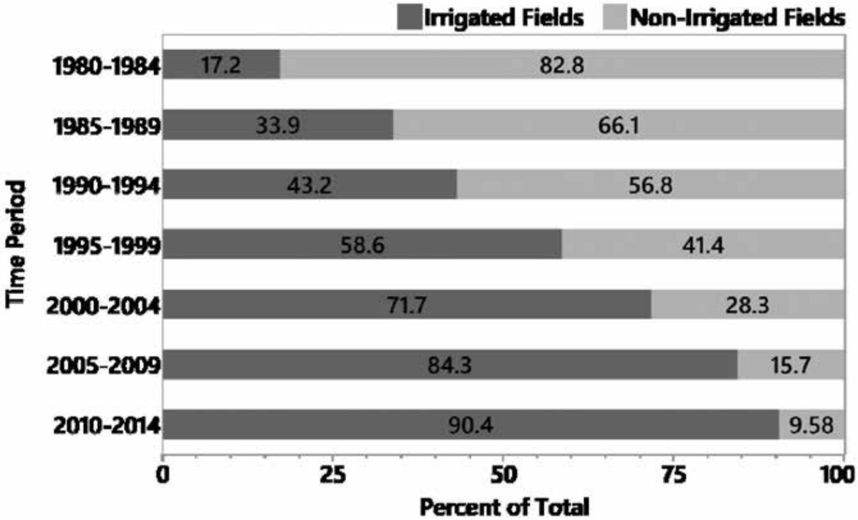

Fig. 1. The percentage of irrigated and non-irrigated Arkansas cotton averaged for each five-year period between 1980 and 2014.

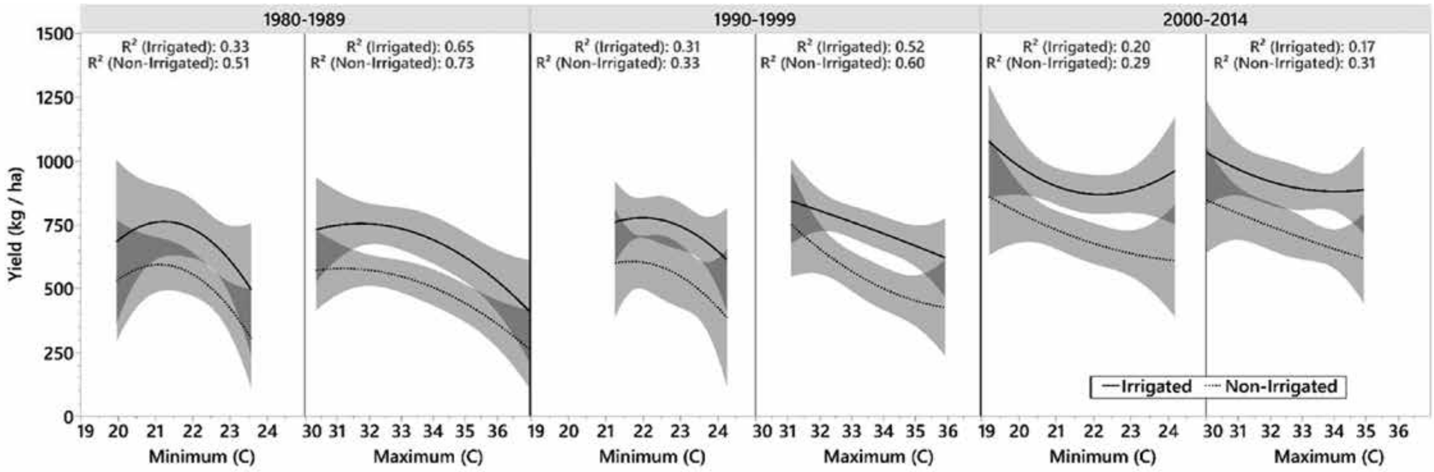

Fig. 2. Decadal effects of increasing minimum and maximum temperatures on cotton yield during the month of July for the state of Arkansas since 1980. The shaded areas indicate the 95 % confidence region for the respective irrigation factor.

Measurements of Internal Boll and Canopy Temperatures of Diverse Cotton Cultivars

M.M. van der Westhuizen[1], D.M. Oosterhuis[1] and T.R. FitzSimons[1]

RESEARCH PROBLEM

High-temperature stress as an abiotic stress factor will occur more frequently due to climate change endangering the performances and yields of cotton worldwide (Oosterhuis, 2013). Cotton is detrimentally affected by high-temperature stress, especially during the reproductive fruiting stage (Luo, 2011). Optimum temperature thresholds for boll growth and development of fibers is 25 °C (Reddy et al., 1999) which is frequently exceeded during the cotton production season. A field trial was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Ark. in 2015 to obtain canopy and internal boll temperatures and correlate them to crop yields.

BACKGROUND INFORMATION

Cotton is an important fiber crop with its growth and yield detrimentally affected by high-temperature stress, particularly during the fruiting stage (Snider et al., 2009). High temperatures (>35 °C) throughout the growing season affect growth, yield and fiber quality negatively (Hearn and Constable, 1984), and there is a strong negative correlation between temperature and yield, where high temperatures during the flowering period of cotton resulted in lower yields (Oosterhuis, 2002). Cotton is produced worldwide under a wide range of temperatures, but the ideal range for cotton is from 20 °C to 30 °C (Reddy et al., 1991). The thermal kinetic window for which metabolic activity is most efficient in cotton plants was reported to be 23.5 °C to 32 °C (Burke et al., 1988). Reddy et al (1992) reported that fruit retention and yields reached optimal levels when the mean temperatures ranged from 25 °C to 28 °C, with boll growth increasing up to 25 °C and then declining as temperature increased above 32 °C (Reddy et al., 1999). Brown and Zeiher (1997) indicated that fruit retention, seed number and boll size declined as mean temperatures increased above 28.0 °C. Typical daily high temperatures in cotton growing areas are often in excess of the optimum range during the growing season, and therefore high temperature represents a major limitation to crop de-

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[1] Graduate assistant, distinguished professor, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

velopment and productivity (Snider et al., 2009). Dabbert and Gore (2014) stated that although cotton cultivars are well adapted to specific growing environments, exposure to high temperature often act as an insurmountable barrier for the cotton crop to reach its maximum yield potential. The objective of this study was to measure canopy and internal boll temperatures in the field during flowering to quantify the influence of temperature extremes on boll growth and yield.

RESEARCH DESCRIPTION

Four cotton (*Gossypium hirsutum* L.) cultivars with different thermo-tolerance (Van der Westhuizen et al., 2015) were evaluated in a field study planted on 9 May, 2015 at Marianna, Ark. Cultivars planted included: VH260 (heat tolerant), Arkot 9704 (intermediate tolerance), DP393 (heat sensitive) and DP210 (unknown heat tolerance). Internal boll temperatures were measured with K-type thermocouples probes inserted to a depth of 1 cm into the top of 7 bolls of each cultivar in a single replication. The thermocouples were connected to a data logger. Canopy temperature was measured by thermocouples placed at main-stem node 10 of the cotton plants. Data collected were from 30 July 2015 to 18 August 2015.

RESULTS AND DISCUSSION

Different cotton cultivars react differently when subjected to high-temperature stress. For example, internal boll temperatures of cultivar DP393 were lower when measured during midday (1400-1600 h) when a high temperature stress of 35.5 °C was experienced compared to higher internal boll temperatures of cultivar DP210 at Marianna at 84 days after planting (Fig. 1). This resulted in DP393 with the highest lint yields of 2451.3 kg ha^{-1} while DP210 was the lowest yielding cultivar with 1982.3 kg ha^{-1}. Increased temperatures possess a negative correlation to yield (Oosterhuis, 2002). Pettigrew, 2008 reported a yield losses of 10% when temperatures were 1 °C warmer than ambient temperature when testing two different genotypes. In Fig. 2, the difference in temperature between DP393 and DP210 shows that temperatures of DP201 were higher than the temperatures of DP393 during midday. The relationship between canopy and internall boll temperatures of DP393 and DP210 indicated that canopy temperatures of DP393 during the maximum portion of the day were slightly less than in DP210, which can be attributed to a more dense canopy (Fig. 3).

PRACTICAL APPLICATIONS

The damage caused by heat stress can be quantified using internal boll temperatures. When DP210 resulted in boll temperatures higher than 30 °C, yield losses of up to 469 kg ha^{-1} occurred between DP393 and DP210. The measurement of internal boll temperatures gives breeders and researchers the opportunity to obtain a record of cultivar response to temperature at plant/boll level in different environments. Cotton cultivars should be evaluated for temperature tolerance and identified for yield performance at specific localities for recommendations to producers.

ACKNOWLEDGMENTS

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

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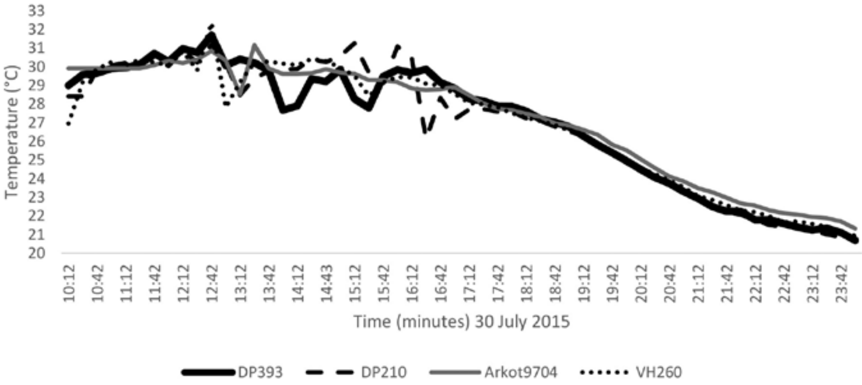

Fig. 1. Internal boll temperatures (°C) for cultivars DP393 and DP210 on the 30th of July 2015 (high-temperature stress – 34.5 °C) at Marianna field study, 2015. Measured on day 84 after planting at 15 minute intervals.

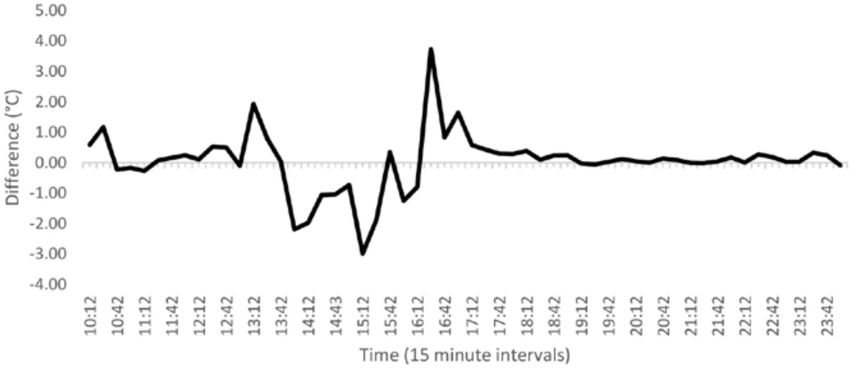

Fig. 2. Difference in internal boll temperatures (°C) between cultivars DP393 and DP210 on 30 July 2015 (high-temperature regime – 34.5 °C) at Marianna field study, 2015. Measured on day 84 after planting at 15 minute intervals.

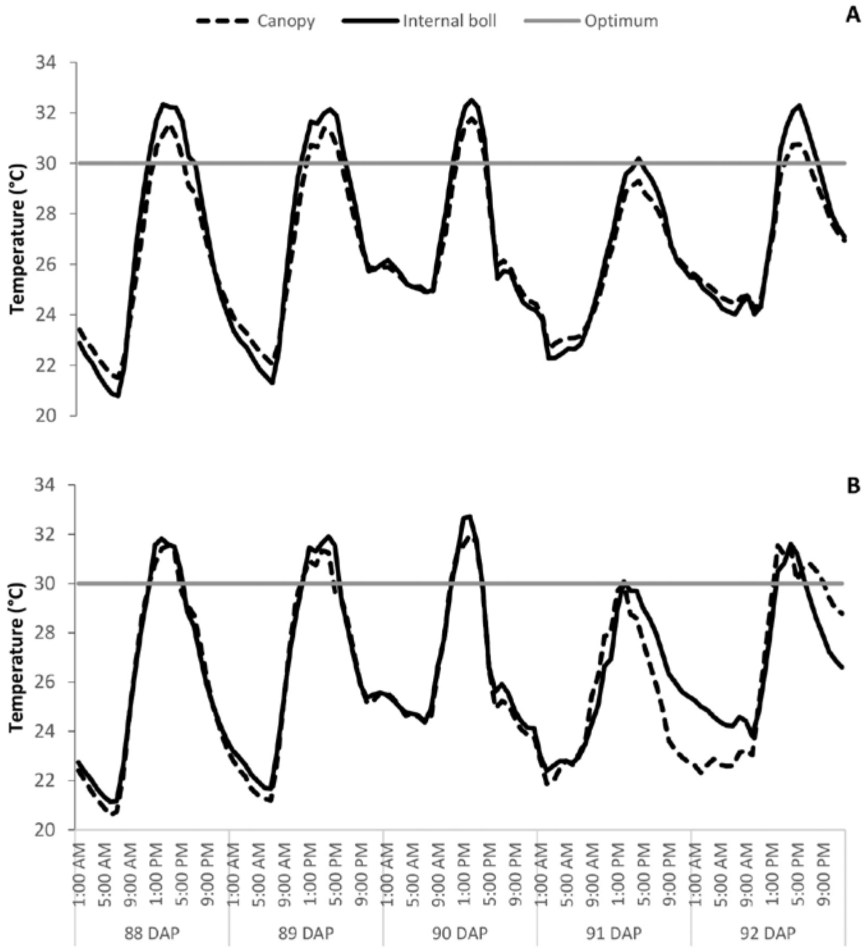

Fig. 3. Canopy and internal boll temperatures (°C) for cultivars DP393 (A) and DP210 (B) at Marianna field study, 2015. The optimum temperature (30 °C) for cotton growth is indicated. Measurements made on days 88 to 92 at 15 minute intervals averaged over one hour. DAP is days after planting.

Seeding Rate Decisions and Impacts on Spatial Yield Variability in Northeast Arkansas Cotton

N.R. Benson[1], A. Mann[2], D.K. Morris[3], and T.G. Teague[2]

RESEARCH PROBLEM

Expenditures for seed-embedded technology including transgenic traits, licensing fees, and seed protection treatments make cotton seed one of the most expensive input costs in cotton. At standard recommended seeding rates, treated, biotech seeds can cost as much as $100/acre. Arkansas cotton producers are searching for ways to improve profitability, and a simple reduction in seeding rate could help them reduce overall production costs. Use of variable rate seeding may also help reduce seed costs in spatially variable fields with well-defined crop management zones. Updated guidelines for uniform and prescription variable rate planting are needed.

BACKGROUND INFORMATION

Previous research findings in the Southeast and mid-South have suggested that seeding rates can be reduced without negatively effecting yield (Bednarz et al., 2005; Siebert et al., 2006; Wrather et al., 2008). These studies were small plot evaluations, where plant stand density had been hand thinned to a desired uniform level, but the study results indicate that adequate yields can be obtained from reduced seeding rates if target plant stand density can be achieved with lower seeding rates. This report summarizes results of an on-farm study in northeastern Arkansas to evaluate how changes in seeding rate affect plant development and yield in a commercial field with highly variable soils. The field study was conducted during the 2015 production season and represented the second year of a Cotton Incorporated funded project focused on supporting mid-South cotton producers as they expand adoption of spatial technology and sustainable management practices to increase cotton profitability.

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[1] County cooperative extension agent, Mississippi County, Blytheville.

[2] Program technician and professor, respectively, Arkansas State University, University of Arkansas System Division of Agriculture, Arkansas Agricultural Experiment Station, Jonesboro.

[3] Associate Professor, Agriculture Spatial Technologies, Arkansas State University, Jonesboro.

RESEARCH DESCRIPTION

The study was conducted in a 35-acre field on Wildy Family Farms in Mississippi County in northeastern Ark. There were four treatments, and these were arranged in a randomized complete block with 6 replications. One 12-row planter swath across the field was one treatment main plot. Treatments included 3 target seeding rates of 1.5, 3.0 and 4.5 seeds per foot of row. For the fourth treatment, we employed a variable seeding-rate prescription based on three management zones classified using soil electrical conductivity (EC) measurements. The cotton (*Gossypium hirsutum* L.) cultivar Stoneville 4946GLB2 was planted on raised beds spaced at 38 inches on 8 May 2015 using the cooperating producers' 12-row John Deere 1720XP vacuum planter. Other than seeding rates, all other production practices including land preparation, fertilizer application, irrigation and pest control were performed by the cooperating producers following their standard management regime and using their equipment (Table 1).

The soil type in the field was classed as a Routon Dundee-Crevasse Complex, and soil texture ranged from coarse sand to fine sandy loam to clay. We subdivided the field into three soil textural zones: coarse sand (= sand blow), loamy sand, and clay using historical yield monitoring data along with georeferenced soil electrical conductivity (EC) measurements, and results from soil textural analysis. Soil EC properties were classified from measurements using a dual depth Veris® 3150 Soil Surveyor. Midseason NDVI measures from 2006 as well as yield maps from 2011, 2012, 2013 also were referenced. For each of these measures, the general pattern of variability through the field was similar over different years. The textural zone classifications were similar to the standard practice of the cooperating producers in their zone management regime for selecting seeding rates. Our zone classifications also had been confirmed through extensive plant and soil monitoring in 2012 and 2013 (Kelly, 2016). A stratified, systematic sampling design was used to select the yield and fiber quality sampling sites in each 12-row strip. Strata were defined by soil EC measurements categorized as High, Medium and Low ranges representing the clay, loamy sand and coarse sand soil textures. Sample points were identified within each strata, marked with flags and referenced with GPS coordinates. These reference points were used to set 10 ft of row harvest areas.

Stand counts were collected to determine the accuracy of the target seeding rates planted as well as the accuracy of the variable rate prescription. Plant stand densities were determined in two, 3-ft transect samples made across each soil textural zone over 12 rows. Stand counts were made on four dates in the first month after planting. Yield and fiber quality assessments were made with hand-picked samples from the 10-foot harvest sites; these data were converted to lint yield per acre. Hand-picked bolls (40 consecutive bolls throughout plants in the hand-harvest site) were ginned on a laboratory gin, and fiber sent to the Texas Tech Fiber and Biopolymer Research Institute for HVI evaluations (data not included in this report). In addition, whole plot yields were extracted from the producer's yield monitor with data post-calibrated, and lint yields determined from the center 6 rows of each treatment strip. The experiment was analyzed as a split plot design with seeding rates considered main plots and soil textural classes considered subplots. Yield monitoring measurements were evaluated using analysis of variance. Means were separated using Fisher's protected least significant difference test at $P = 0.05$.

RESULTS AND DISCUSSION

The 2015 production season in northeast Ark. was characterized by cool temperatures and wet conditions during stand establishment. Rainfall levels were above average, and there were only two furrow irrigations applied during the crop season (Table 1). Insect pest control was maintained through the season, and no differences in either thrips abundance prior to first square, or tarnished plant bug abundance season-long, were associated with treatments or soil textures (data not shown). Uniform seeding resulted in stands within 85% of the targeted stand density in the coarse sand and loamy sand; lower stands (~50%) were observed in clay soil (Fig. 1). In the prescribed variable rate (VR) seeding application, inconsistent stands were observed compared to the targeted seeding rate. Inconsistencies in stand densities were more pronounced in the clay and course sand zones than in the loamy sand soil zones. Stand densities ranged from approximately 150% of the prescribed target rate in the coarse sand soil zones to slightly above 25% of the target seeding-rate density in the clay zones. Variations in size and frequency of the clay and coarse sand zones across the field likely contributed to the observed inconsistencies in stand densities in these zones. The rates prescribed for the zone with the largest area, the loamy sand soil texture, resulted in stand counts similar to the rate observed in the single rate, whole plot treatments. The consistency of stand densities observed in the larger sandy loam soil type zones was likely the result of planter rate controllers having sufficient time to adjust and equilibrate to prescribed rates. Adequate equipment calibration, and appropriate zone size are critical factors in successful variable seeding in designated zones. Additional work is needed to address these factors.

Analysis of yield data from hand harvested plots indicated no differences in lint yield among seeding-rate treatments (Fig. 2). Similar results were recorded in 2014 (Benson et al., 2015). Hand harvest yield from plants in the clay and coarse sand zones was significantly lower compared to plants in the loamy sand area of the field. It should be noted that areas with large skips between plants were not included in those hand harvest sites, but skips were included in yield assessments from whole plots collected from producer's yield monitor data. There were no differences in lint yield among any of the seeding rates in whole plot assessments (Fig. 2). Uniformity appeared to be a problem in the plots seeded at low 1.5 seed per foot, especially in the clay areas of the field. Stand uniformity from low seeding-rate treatments in clay soil areas may be less problematic in a low rainfall season; however, we also would expect differential plant response to reduced soil moisture availability for plants growing in coarse sand.

PRACTICAL APPLICATIONS

Seeding-rate density had no effect on yield in this field trial in 2015; similar results were observed in 2014. These findings indicate that reducing seeding rates may provide an opportunity for producers to lower production costs. Cost savings of ~$90 per acre would have been possible with lowest compared to highest seeding rate assuming a conservative per bag seed cost of $500. Based on these preliminary data, we suggest that reducing seeding rates to less than 2.5 seeds per foot should be considered a viable cost-saving tactic for mid-South producers using high-cost, treated, genetically enhanced seed. Producers should use the lowest rate required to get a stand of 1.5 plants per foot. Variable rate seeding across variable soils appears to offer no practical advantage compared to uniform seeding in the production system under evaluation.

ACKNOWLEDGMENTS

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Table 1. Dates of planting, irrigation and harvest for the 2015 seeing rate study at Wildy Family Farms, Manila, Ark.

Operation	Date	Days after planting
Date of planting	6 May 2015	
Stand Counts	13, 20, 27 May and 1 June	7, 15, 21, 26
Irrigation	25 June, 2 July	50, 67
Defoliation/boll opener	25 September, 5 October	142, 152
Hand harvest	16 October	163
Machine Harvest	17 October	164

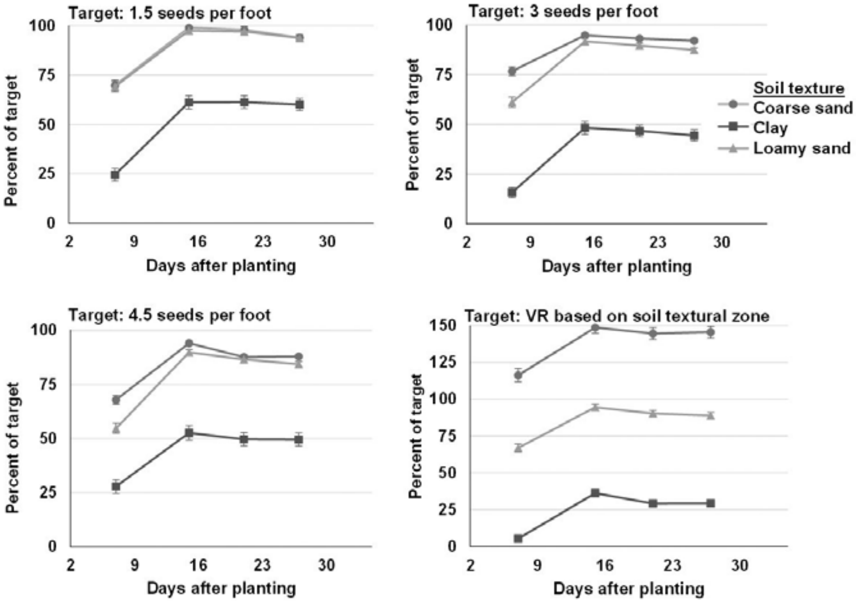

Fig. 1. Stand counts were made to determine the accuracy of the target seeding rates and the variable rate prescription seeding. Observed plant stand densities were determined in transect sampling across each soil textural zone over 12 rows and were made on four dates in the first month after planting for each of the four seeding rates (1.5, 3, 4.5 and variable rate (VR)). Results are expressed as a percent of target seeding rate in the 2015 seeding-rate field trial at Wildy Family Farms, Manila, Ark.

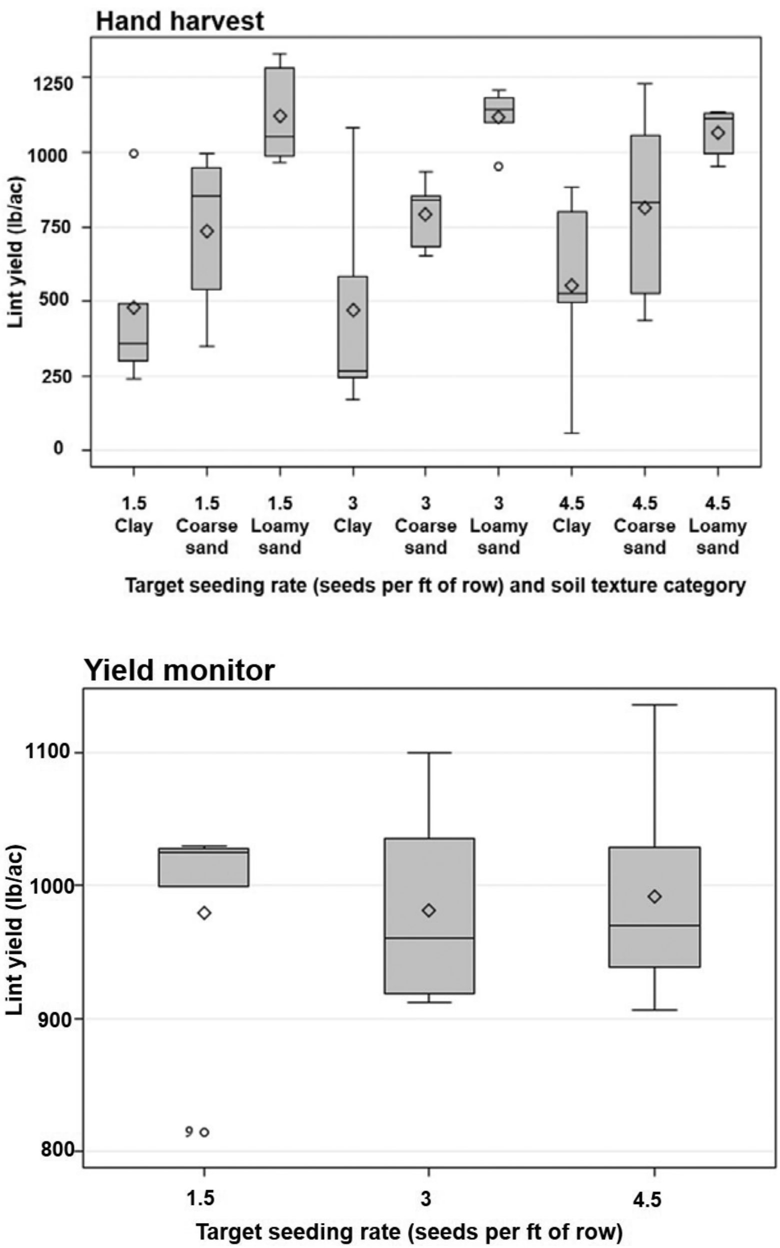

Fig. 2. Mean lint yields differed among soil textures ($P < 0.05$) but not seeding rates in assessments from hand harvested plots from different soil textural zones in the 2015 seeding-rate field trial (upper). For yield monitor data, seeding rate was not significant ($P > 0.60$) in lint yield assessments from field length strips (lower). Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value at 2015 Wildy Family Farms, Manila, Ark.

Evaluation of Foliar Fertilizer Products in Cotton

B. Robertson[1]*, R. Benson*[2]*, and J. Osborn*[2]

RESEARCH PROBLEM

Cotton producers are looking for ways to improve efficiency and increase yield to help off-set low commodity prices. Foliar-applied fertilizer has been a common practice for cotton producers in Arkansas for several years. However, yield responses from supplemental foliar N and K applications are often erratic. Therefore, the objective of this study was to evaluate the effects of foliar fertilizer products on cotton yield in a production field with adequate fertility levels while using best management practices for fertility management.

BACKGROUND INFORMATION

Recent adoption of yield mapping equipment has allowed producers to identify low yielding areas within production fields. It is not clear if foliar fertilizer products should be used to boost production in low yielding zones or to preserve and enhance yield potential in all yielding zones. The boll load or lack thereof can be an important factor in determining the positive outcome from foliar feeding.

Petiole sampling can give an accurate indication of the nutritional status of the plant. However, petiole sampling does not give the user any indication of the boll load or the impact of the boll load on plant development. The success rate of increasing yields and obtaining a return on investment would likely improve if greater efforts were made to evaluate boll load as well as the nutritional status in making supplemental foliar-N applications (Robertson et al., 2003).

Studies on coarse-textured soils have shown that N loss through leaching can result in a reduction of N uptake by cotton during the production season (Karlen et al., 1996). Although sufficient amounts of fertilizer are applied, crops produced in areas with a high percentage of coarse sand may experience deficiencies during the season. These deficiencies may be reduced with applications of foliar-applied fertilizers. Research in Arkansas has shown that nitrogen applied as a foliar treatment after first flower may help meet crop demands and improve yield (Maples and Baker, 1993).

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[1] Professor, cotton extension agronomist, University of Arkansas System Division of Agriculture, Newport Extension Center, Newport.

[2] County cooperative extension agents, staff chair and agriculture, respectively, University of Arkansas System Division of Agriculture Cooperative Extension Service, Mississippi County, Blytheville.

RESEARCH DESCRIPTION

Stoneville ST 4946 B2GT was planted at the Manila Airport Research Field on 8 May 2015. Production inputs were based on weekly field inspections and followed University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations for cotton production. All practices, with the exception of foliar-applied products were consistent across all plots in this study. All foliar fertilizer applications (including application rates and timings) were made based on recommendations of the manufacturer. Treatments were established on 17 July 2015, approximately 10 days after first flower, and included four rows 38 in. by 50 ft. long. Plots were arranged in a randomized complete block and included three replications. All foliar products were applied using a self-propelled plot sprayer calibrated to deliver 15 gal/acre. Plots were machine harvested on 21 October 2015 and converted to a per acre yield (Table 1).

RESULTS AND DISCUSSION

Yields from the 2015 crop were high and the range of yields from treatments in this study was similar to the yield observed in the producer's field. Results observed from treatments in this study showed that yield was not affected by foliar treatments (Table 1). Soil test levels were above optimum levels for most nutrients supplied in the foliar products tested. It is possible the high soil nutrient levels observed in this test location masked any fertilizer treatment benefits.

PRACTICAL APPLICATIONS

Best management practices employing the right rate, source, timing and placement of fertilizer products to achieve cropping system goals while minimizing field nutrient losses and maximizing crop uptake are necessary steps to improving efficiency and increasing yield. Taking care of the basics with regard to fertility management not only improves efficiency and yield but reduces the potential that foliar feed products are needed. Foliar fertilizer products do have their place and fit well in a program in which unexpected nutrient shortfalls are experienced.

ACKNOWLEDGMENTS

The authors express appreciation to the area agribusiness who supplied product for this study. We also acknowledge the Manila Airport Committee and Costner Farms for their support of this project. Support also provided by the University of Arkansas System Division of Agriculture.

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Table 1. Yields for foliar fertilizer treatments, Manila, Ark, 2015.

Trt No.	Treatment Name	Lint Yield lb/A
1	UTC	1224 a[†]
2	Soil Urea	1550 a
3	Soil Ammonium Sulfate	1039 a
4	Soil 0-0-60	1215 a
5	Soil 0-0-15	1354 a
6	Delivered K + Boron 10%	1152 a
7	Novus K + Boron 10%	1449 a
8	Novus B Boron 10%	1060 a
9	Delivered K Novus K	1414 a
10	Boost it VitBor	1221 a
11	Bloom Pro VitBor	1075 a
12	MaxIn	1244 a
13	CropKarb	1042 a
14	Utilize Full-Bor Coron	1129 a
15	VitaBor	1069 a
16	Foliar 23%	1319 a
17	Foliar 0-0-15	1230 a
18	Re-Nforce K	1286 a
19	Quick Ultra with Awaken	1203 a
20	TaskForce2	1449 a
21	N-Pact	1042 a
LSD $P = 0.05$		547.3
Standard Deviation		256.8
CV		20.93
Replicate F		1.193
Replicate Prob (F)		0.292
Treatment F		0.7
Treatment Prob (F)		0.7747

[†] Means followed by the same letter do not differ significantly.

Potassium Fertilization Increases Seedcotton Yield in an Arkansas Low Potassium Soil

M. Mozaffari[1], F.M. Bourland[2] and N.A. Slaton[3]

RESEARCH PROBLEM

In 2014, 330,000 acres of land were planted to cotton in Arkansas. Potassium (K) is one of the most important nutrients for growth and development of the cotton plant because it is required for regulating the stomatal opening and closing, maintaining leaf turgor pressure and leaf photosynthesis (Bednarz and Oosterhuis, 1999; Oosterhuis et al., 2014). Therefore, K deficiency will seriously limit cotton yield potential and fiber quality.

BACKGROUND INFORMATION

Advances in plant breeding, pest control, irrigation and other production practices are continuously increasing cotton lint yield potential. The state-average cotton yield in Arkansas increased from 598 lb/acre in 1976 to 1046 lb/acre in 2006 (Arkansas Agricultural Statistics Service, 2016) largely because of the introduction of fast-fruiting cultivars, improvements in pest management, and irrigation. Modern cotton cultivars produce higher yields and develop their boll load over a shorter period compared with obsolete cotton cultivars. Therefore, modern cotton cultivar's response to K-fertilizer application rates should be periodically evaluated to ensure that K deficiency is not limiting yield potential. The objective of this experiment was to evaluate the effect of K application rate on seedcotton yield under current production practices common to Arkansas. The information from this and similar studies can be used to evaluate and, if needed, modify the existing K-fertilizer recommendations for irrigated cotton production in Arkansas.

RESEARCH DESCRIPTION

In 2014, a one year replicated cotton K-fertility experiment was conducted at the University of Arkansas System Division of Agriculture Cooperative Research

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[1] Assistant professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory, Marianna.
[2] Director/professor, University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser.
[3] Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

Field at Judd Hill Plantation, near Trumann Ark. The soil at the experimental area is mapped as a Dundee silt loam. The experimental design was a randomized complete block with five rates of K ranging from 40 to 200 lb K_2O/acre and five replications of each treatment. Each individual plot was 40-ft long and 12.5-ft wide allowing for 4 rows of cotton with 38-inch wide row spacing.

Prior to application of any K fertilizer, six 2-inch-diameter soil cores were collected from the 0-to 6-inch depth of each replication and composited by replication. Plant-available nutrients were determined with Mehlich-3 method, and soil pH was measured in a 1:2 (weight: volume) soil-water mixture. All plots were fertilized with a blanket application of 100 lb N acre using urea (46-0-0). Cotton (*Gossypium hirsutum* L.) cultivar DP0912 was seeded into a conventionally tilled seedbed by hand on 23 May 2014. All K-fertilizer treatments were surface applied on 17 June. Cotton was irrigated as needed and the standard University of Arkansas System Division of Agriculture Cooperative Extension Service pest management practices were followed. The two center rows of each plot were harvested with a spindle-type mechanical picker on 12 November. Analysis of variance was performed to evaluate the effect of K application rate on seedcotton yield. Significant treatment means were separated by the least significant difference (LSD) test when appropriate ($P = 0.10$).

RESULTS AND DISCUSSION

Averaged across the five replications, pre fertilizer application soil pH was 7.0 and Mehlich-3 extractable K was 82 ppm. In Arkansas, Mehlich-3 extractable K concentration of 90 ppm is interpreted as Low. Potassium fertilizer application rate significantly increased seedcotton yield (Table 1). Seedcotton yield in the 0 K plot was 1490 lb/acre and that of K fertilized cotton ranged from 1597 to 2108 lb/acre. Potassium application rates >80 lb K_2O/acre significantly increased seedcotton yields compared to the no-K control. Application of 160 K_2O/acre produced the numerically highest seedcotton yield of 2151 lb/acre. The greatest yield was produced with the application of 160 lb K_2O/acre. The information from this study will be added to an existing database on the effect of K fertilization rate on modern irrigated cotton yield in Arkansas.

PRACTICAL APPLICATIONS

In a typical Low Testing Arkansas silt loam, application of ≥80 lb/K_2O/acre significantly increased the seedcotton yield of a modern cotton cultivar. Routine soil testing properly identified the need for K fertilization. However, the annual K application rate of 160 lb K_20/acre produced the highest numerical seedcotton yield, therefore more short- and long-term research is needed to develop a robust database to support and if needed modify the existing soil-test based K-fertilizer recommendations for modern irrigated cotton production in Arkansas. The results of this study are consistent with the previous research and suggest that soil-test based K-fertilization is a critical component of cotton fertilization.

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Table 1. Seedcotton yield as affected by surface application of K fertilizer in a K-fertilization trial conducted at the University of Arkansas System Division of Agriculture Judd Hill Plantation, near Trumann, Ark. in 2014.

K_2O rate lb K_2O/acre	Seed Cotton Yield lb/acre
0	1490
40	1597
80	1682
120	1957
160	2151
200	2108
P-value	0.0024
$LSD_{0.10}$[a]	265

[a] LSD = least significant difference at *P* = 0.10.

Cotton Responds Positively to Urea and Environmentally Smart Nitrogen in Arkansas

M. Mozaffari[1], N.A. Slaton[2], and C.G. Herron[1]

RESEARCH PROBLEM

Organic matter content of many Arkansas agricultural soils is low (< 2.0%), thus nitrogen (N) fertilization will increase cotton (*Gossypium hirsutumn* L.) yield in many Arkansas soils. In this region, a typical N application of 100-110 lb N/acre is required to produce an economically sustainable cotton yield because several biogeochemical and transport processes such as runoff, leaching, and denitrification contribute to the loss of soil and fertilizer N.

BACKGROUND INFORMATION

Improving N fertilizer use efficiency will reduce fertilizer-N losses to the environment, increase profit margins and reduce potential environmental risks associated with N fertilization. Polymer coated controlled release (slow release, programmed release) N fertilizers may provide the growers with the opportunity to increase their N use efficiency (Oosterhuis and Howard, 2008). A polymer-coated urea (44% N, Agrium Wholsales, Loveland, Colo.) is currently being marketed in Arkansas under the trade name of Environmentally Smart Nitrogen or ESN[3]. The objective of this study was to evaluate furrow-irrigated cotton response to ESN and urea fertilizers in representative Arkansas soils used for cotton production.

RESEARCH DESCRIPTION

A field experiment was conducted to evaluate the effect of preplant application of urea, ESN and their combination on cotton yield in a Memphis silt loam at the Lon Mann Cotton Research Station (LMCRS) in Marianna, Ark. in 2015. Before applying any fertilizer, soil samples were collected from the 0-to 6-inch depth and composited by replication. Soil samples were oven-dried, crushed, and soil

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[1] Assistant professor and program technician, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture's Soil Testing and Research Laboratory, Marianna.

[2] Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

[3] Mention of a trade name is for facilitating communication only. It does not imply any endorsement of a particular product by the authors or the University of Arkansas, or exclusion of any other product that may perform similarly.

pH, soil organic matter (SOM), NO_3-N, and Mehlich-3 extractable nutrients were measured.

The experiment was a randomized complete block design with a factorial arrangement of four preplant-applied, urea-ESN combinations that included five rates ranging from 30 to 150 lb N/acre in 30 lb N/acre increments and a no-N control. The four urea and ESN-N combinations were: 100% urea-N; 50% urea-N plus 50% ESN-N; 25% urea-N plus 75% ESN-N, and 100% ESN-N. Each treatment was replicated five times. We applied muriate of potash and triple superphosphate to supply 90 lb K_2O and 46 lb P_2O_5/acre to the entire experimental area. On 30 April 2015, all fertilizers including the N-fertilizer treatments were hand applied onto the soil surface and mechanically incorporated immediately into the top 2-3 inches of soil. After fertilizers were incorporated, the beds were pulled with a hipper and on 8 May 2015, cotton cultivar ST4946 was planted on top of the beds. Each cotton plot was 40-ft long and 12.6-ft wide allowing for 4 rows of cotton planted in 38-inch wide rows. Cotton was furrow-irrigated as needed and management closely followed the University of Arkansas System Division of Agriculture Cooperative Extension Service (CES) recommendations. The two center rows of cotton in each plot were harvested on 7 October 2015 with a spindle-type picker equipped with an electronic weight measuring and recording system.

RESULTS AND DISCUSSION

Average soil properties in the 0-to 6-inch depth were: 1.8% SOM, 28 ppm NO_3-N, 46 ppm P, 93 ppm K, and 7.5 pH. At the time of the study, the CES soil-test based N fertility guidelines for irrigated-cotton recommended application of 70 lb N/acre for this soil. The monthly precipitation from June to September was below the long-term average, thus conditions were not conducive for N loss via leaching, runoff or denitrification (Table 1). Additional N loss could have occurred during irrigation events.

Averaged across N sources, N application rate significantly ($P = 0.0030$) increased the seedcotton yield (Table 2). However, the main effect of N source and the N source × N rate interaction did not significantly influence seedcotton yield ($P > 0.10$; Table 2). The significant effect of N rate is consistent with our previous findings (Mozaffari and Slaton, 2014; Mozaffari et al., 2013, 2015), and non-significant N source or N source × N rate interaction is consistent with our 2013 results (Mozaffari and Slaton, 2014) perhaps because June to September precipitation in 2015 was below average (Table 1). Seedcotton yield for the cotton that received no N was 2524 lb/acre, which was numerically (16.4%) lower than the yield of cotton that received the lowest N rate of 30 lb N/acre, averaged across N sources (Table 2). Averaged across N sources, the seedcotton yield of cotton that was fertilized with 150 lb N/acre was significantly greater than all other treatments. Averaged across the five N rates and numerically, cotton fertilized with 100% ESN-N produced the highest numerical seedcotton yield (3277 vs 3056-3113 lb/acre; Table 2). Similar to the 2014 growing season, we observed that at N rates of 60-120 lb N/acre, ESN-fertilized cotton appeared more vigorous during the growing season.

PRACTICAL APPLICATIONS

The amount of precipitation during most of the 2015 growing season (June to September) was below the long-term average at the study site. Seedcotton yield was maximized by application of 150 lb N/acre. These results support our previous assertion that preplant-incorporated ESN is a suitable alternative to urea for furrow-irrigated cotton grown in Arkansas. Future research should compare the effect of the timing and rate of application of urea and ESN.

ACKNOWLEDGMENTS

This research was supported by Agrium Wholesales, Fertilizer Tonnage Fees and the University of Arkansas System Division of Agriculture. We thank Stoneville for donating the cotton seeds. We appreciate the assistance of the University of Arkansas Soil Testing and Research Laboratory staff with soil analyses.

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Table 1. Actual rainfall received by month in 2015 and the long-term (1960-2007) average monthly mean rainfall data at Lon Mann Cotton Research Station in Marianna Ark.

Precipitation	May	June	July	August	September	Total
	------------------- Precipitation (inches) ----------------------					
2013 [a]	6.36	3.35	2.85	0.00	0.58	13.14
Average[b]	5.90	3.90	3.90	2.80	3.20	19.70

[a] Cotton was planted on 28 May and harvested on 23 Oct.
[b] Long-term average for 1960-2007.

Table 2. Seedcotton yield as affected by the significant ($P < 0.10$) N rate (averaged across N sources) main effect; the non-significant ($P > 0.10$) N source (averaged across N rates), and the non-significant ($P > 0.10$) N source × N rate interaction for a cotton fertility experiment conducted at the Lon Mann Cotton Research Station in Marianna Ark. during 2015.

	N-fertilizer source						
N rate	100% Urea-N	50% Urea-N 50% ESN-N[a]	25% Urea-N 75% ESN-N	100% ESN-N	N rate yield mean	N-fertilizer source	N source yield mean
lb N/acre	-------------- Seed Cotton yield (lb/acre)		-----------------				lb/acre
0			2524[b]			None	2524[b]
30	2891	3111	2946	2939	2966	100% Urea-N	3092
60	2873	3024	3062	3125	3028	50%Urea-N, 50%ESN-N	3056
90	2967	3078	3234	3354	3158	25% Urea-N,75% ESN-N	3113
120	3226	2993	2831	3232	3071	100% ESN-N	3227
150	3464	3080	3494	3484	3381		
$LSD_{0.10}$		NS[c] (interaction)			185 [d]	LSD 0.10	NS
P value		0.5988			0.0030	*P* value	0.3029

[a] ESN, Environmentally Smart N, polymer coated urea.
[b] the no-N control is listed for reference only as it was not included in the analysis of variance.
[c] NS, not significant ($P > 0.10$).
[d] LSD compares the yield of treatments that received N, averaged across N sources.

Soil Moisture, Plant Water Use, and Infiltration in Different Arkansas Soils

M. Ismanov[1], L. Espinoza[1], and C. Henry[2]

RESEARCH PROBLEM

Efficient irrigation management depending on crop water demand is critical to achieve effective and sustainable agriculture in Arkansas. Plant water use, soil moisture, available water capacity, and leaching in different soil types are important factors in agricultural production under contrasting weather patterns, limited water availability and increasing production expenses.

BACKGROUND INFORMATION

Crop water use, also referred to as evapotranspiration (ET), is the water used by a crop for growth and cooling (Rogers et al., 2015). Plants require a lot of water to grow, but the amount varies considerably on a seasonal and a daily basis. According to Allen et al. (1998), ET is not easy to measure, because specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to determine ET. Sands, silts, and clays differ not only by particle size distribution, but also in the atomic arrangement and charge distribution at the molecular level. For this reason, experiments related to ET have to cover all of the main factors, including soil types and different crops (Ismanov et al., 2013).

RESEARCH DESCRIPTION

An experiment was designed to understand the dynamics of soil moisture, water infiltration, and plant water use under the identical weather conditions, typical crops and soils of Arkansas. The tests were conducted at the University of Arkansas System Division of Agriculture Lon Mann Cotton Research Station (LMCRS) in Marianna Ark. during 2013 and 2014. Three different soil types were selected for inclusion in the study: silty-clay loam (clay), silt loam (loam), and sandy loam

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[1] Program technician and extension soil scientist, respectively Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Little Rock.

[2] Assistant Professor, University of Arkansas System Division of Agriculture's Rice Research and Extension Center, Department of Biological and Agricultural Engineering, Stuttgart.

(sandy). Each soil type was dried, ground, and sieved through a number 4 mesh screen prior to the initiation of the study. Then, 28 lb of each soil was placed in plastic 5-gal bucket lysimeters in 2013 and 2014, while 17-20 lb of each soil was placed in plastic 2-gal bucket lysimeters during the 2014 season. This process was repeated three times for each soil resulting in 9 total containers in 2013. Cotton, soybean, and corn seeds were planted in each type of soil in 2014, resulting in 36 containers. In order to allow each soil to drain, four 2-mm holes were drilled through each container side and five 2-mm holes were drilled through the bottom of each 5-gal container. Similarly, four 2-mm holes were drilled through the bottom of each 2-gal container. The bucket-lysimeters with holes were installed in another identical container without holes in order to collect infiltrated and leached water. Lysimeters were placed outdoors on a 4 × 4 m square cement pad elevated 1 m above a grass surface in 2013, and in a 10 × 10 m natural grassy area in 2014. Potential evapotranspiration (PET) was estimated by an atmometer using the #54 alfalfa reference cover canvas. Periods from saturation to near permanent wilting point were created by either allowing rainfall to wet the containers or by pouring water into the containers without plants in 2013. After saturating events, the containers were left exposed to the atmosphere until very dry or to the wilting point. If rainfall was expected, containers were covered with a plastic tarp. Seeds of cotton (PHY 499WRF), soybeans (P49T97R), and corn (DKC 64-69) were planted in each soil type on 2 June 2014. These containers were exposed in rainfall events. Water added in the containers depended on soil moisture. Later, the water adding times were determined based on monitoring of the plant water stress symptoms (leaf rolling or wilting). Each container was weighed daily between 8:00 and 9:00 AM using a portable scale.

RESULTS AND DISCUSSION

A total of 5.4 inches of rainfall occured during the study period in 2013, which is less than the 14.3 inches of rainfall received in the study period in 2014. Added water in the containers without plants was 8.06 inches in 2013 and 0.3 inches in 2014. The weather during the 2013 season allowed for the occurrence of more consistent wetting/drying cycles compared to 2014. Thus, the average soil moisture in 2014 was higher than in 2013. The large amount of added water was the cause of more leached water in 2013. Infiltration was higher in sandy soils in both years. During the dry 2013 season, leached water in clay soil was less than loam and sandy soil, which was explained by more water capacity of the clay soil. However, the amount of leached water was similar in clay and loam soils during the wetter 2014, because of longer saturation periods in both types of soils (Fig. 1).

Corn is the row crop in Arkansas with the highest crop water demand (Fig. 2). The average water use of the corn plant is 600-800 g/day between 35 to 80 days after planting. However, variation of plant water use was higher than this and depends on air temperature, humidity, and solar radiation. The maximum water use period for cotton is between 40 and 90 days after planting. This time is approximately during July and the beginning of August when the air temperature and ET are high and plants are growing fast. Average water use of cotton plants during this time is around 400 g/day. However, wide variations are possible depending on plant size, weather conditions and potential evapotranspiration. The period of higher water demand of soybean plants under the studied conditions appears to be 40 to 85 days after planting. During this period, soybean plant water use averaged between 100 and 150 g/day. The determination of different plant water use allows the calculation of crop water use in inches for average plant density of different crops. Comparing water use and PET graphs (Fig. 3) shows that they have a high correlation in maximum plant water demand period.

Soil water evaporation varies depending on soil type and initial soil moisture. It appears that evaporation is higher in clay soils than sandy soils under low soil moisture levels, while it is higher in sandy soils than clay soils under high soil moisture levels. Figure 4 shows evaporation measured at different times during the day in three soil textures under study in high moisture conditions. Most evaporation occurred in the daytime because of higher energy gradients. Zero or negative evaporation was recorded at night due to relatively low energy gradients and lower vapor pressure deficits. Evaporation in clayey or loamy soils was considerably higher during the afternoon hours. Similarly, evaporation in the sandy soil was higher in the morning and afternoon hours. Potential evapotranspiration graphs during a 24 hour period in summer months (Fig. 5) show that PET has a fairly predictable pattern that increases between 9:00 AM and 12:00 PM, is fairly consistent and peaks between 12:00 PM and 3:00 PM before tapering off between 3:00 PM and 6:00 PM. This data can be compared to the water use measured in the buckets with the different crops to see how the soil water availability interacts with ET demand. What is interesting about these two data sets is that the soils show a slightly different change in when water is drawn by the plant during the day. Specifically, the sandy soil uses water early and midday, while the clay and loam soils lag behind the sandy soil and their peak water use is later in the day. The difference in the diurnal water use may be explained by matric potential, that is water is more readily drawn by the plants in the sandy soil and it takes longer for the water to be released from the loam and clay soils.

The average evapotranspiration of the three different crops during the last ten days of July is shown in Fig. 6. Water transpiration of cotton and soybean plants was higher in morning hours rather than in afternoon hours during the study period. Water transpiration of corn plants was similar during the morning and afternoon hours. The night transpiration was very small in all crops during the study period. Corn ET was higher than in cotton and soybeans, which have the lowest crop water demand.

PRACTICAL APPLICATIONS

The data obtained under the conditions of this test show that irrigation scheduling based on crop water demand is a reasonable approach that can increase water use efficiency. The crop water use data observed could also aid in the development of irrigation practices that more closely mimic field conditions. The contrasting evapotranspiration observed at different times during the day could also be used to avoid times during a day when the evaporation potential is high.

ACKNOWLEDGMENTS

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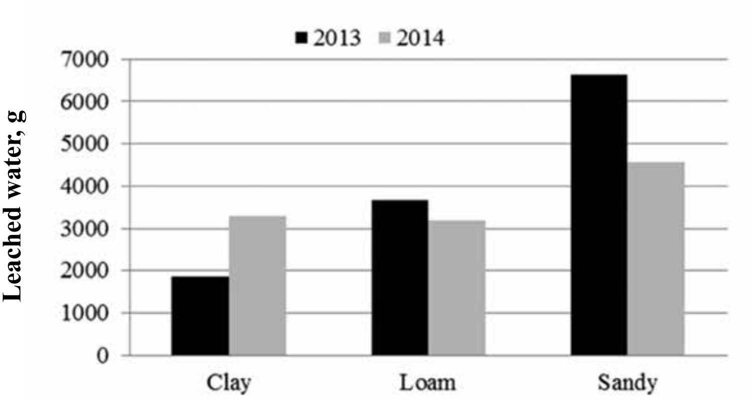

Fig. 1. Total leached water collected outside of the bucket-containers of the lysimeters in different soils during the 2013 and 2014 study periods.

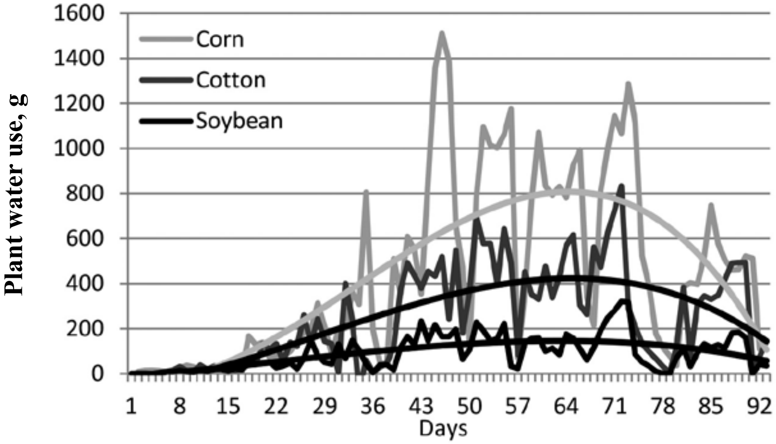

Fig. 2. Plant water use.

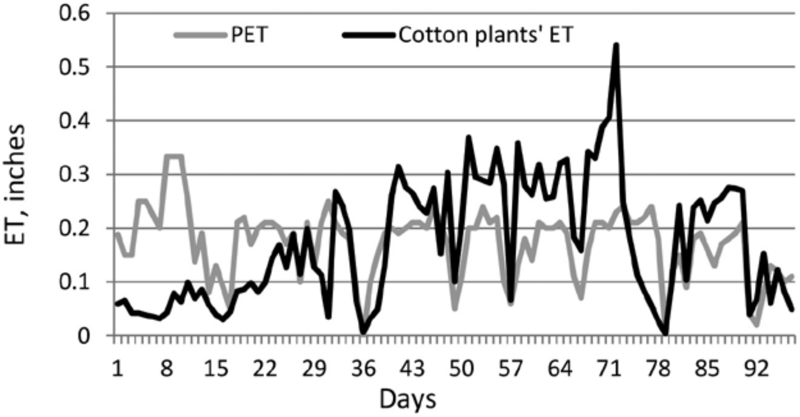

Fig. 3. Cotton crop water use (evapotranspiration) and potential evapotranspiration during the growing season.

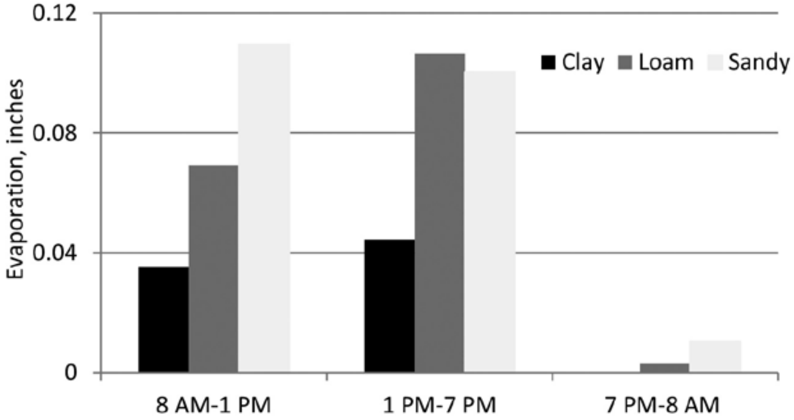

Fig. 4. Water evaporation during the day in three soil textures under the study.

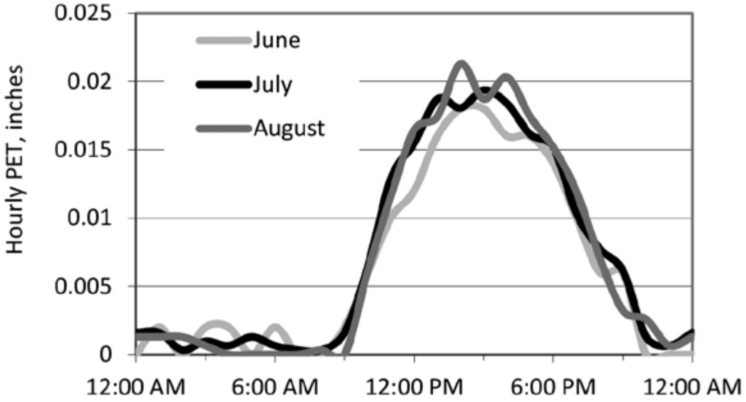

Fig. 5. Average hourly potential evapotranspiration (PET) in 24 hours measured by digital atmometer in June, July, and August.

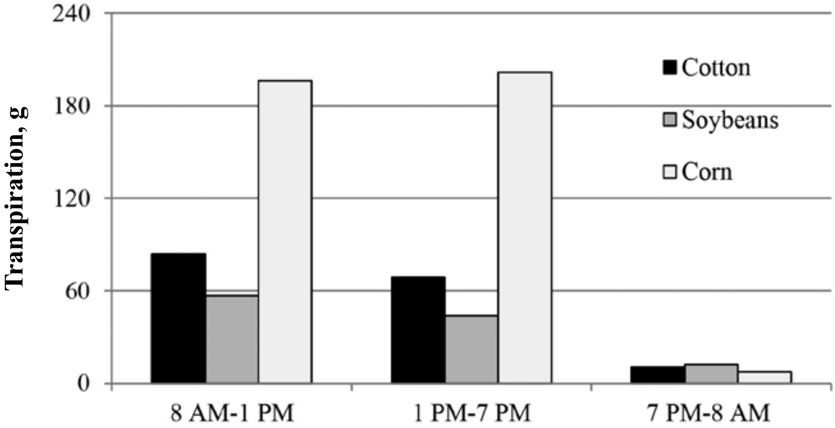

Fig. 6. Plant water transpiration for three crops during the day (in the last 10 days of July).

Evaluation of Profitability as Influenced by Practices to Improve Soil Health and Irrigation Water Use Efficiency

A. Free[1]*, B. Robertson*[1]*, A. Flanders*[2]*, M. Daniels*[3]*, C. Henry*[4]*, and S. Stevens*[5]

RESEARCH PROBLEM

As cost of agricultural production continues to increase, producers are continuously focusing on adjustments that can be made to increase efficiency in an effort to improve profitability. Practices that lead to improved efficiency often improve soil health as well as having a positive impact on fields' environmental footprint. A strategy that has a direct impact on improving both soil health and irrigation water use efficiency involves utilizing no-till with cover crops. However, producers are often skeptical about adopting new technology. Some concerns with converting to cover crops are the ability or inability to furrow irrigate the field efficiently and the costs associated with adopting new technology. Cotton producers utilize many different production practices to improve efficiency and profitability, as no single practice will benefit all.

BACKGROUND INFORMATION

The University of Arkansas System Division of Agriculture has been conducting the Cotton Research Verification Program (CRVP) since 1980. The Cotton Research Verification/Sustainability Program conducted research, along with Discovery Farms in Southeast Arkansas in 2015. Discovery Farms' main focus is edge-of-field water quality, where they trace irrigation efficiency and nutrient and sediment losses. Each field in this study was composed of two irrigation sets allowing for evaluation of farmer standard practices as well as that of a modified production system. This allowed for comparisons to be made on how each impacted edge-of-field water quality and ultimately profitability of each system.

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[1] Cotton research verification/sustainability program coordinator, and professor/ cotton extension agronomist, respectively, University of Arkansas System Division of Agriculture Newport Extension Center, Newport.

[2] Associate professor, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

[3] Professor, Extension Water Quality, University of Arkansas System Division of Agriculture, Department of Crop, Soil, and Environmental Sciences, Little Rock.

[4] Assistant professor, University of Arkansas System Division of Agriculture, Rice Research and Extension Center, Department of Biological and Agricultural Engineering, Stuttgart.

[5] Producer, University of Arkansas System Division of Agriculture, Southeast Arkansas Discovery Farms, Dumas.

All fields are monitored for inputs and entered into The Fieldprint Calculator. The Fieldprint Calculator is a relatively new tool developed by Field to Market: The Alliance for Sustainable Agriculture. The Fieldprint Calculator was designed in an effort to help educate producers on how adjustments in management could affect environmental factors. Utilization of the Calculator assists producers by making estimates over seven sustainability factors: land use, soil conservation, soil carbon, irrigation water use, water quality, energy use and greenhouse gas emissions. Fieldprint Calculator estimates a fields' performance and compares results to national and state averages. Calculated summaries give producers insight into the ability to identify areas for improved management on their farm.

RESEARCH DESCRIPTION

The two Discovery Farm fields utilized in this research were Weaver, a 40-acre field, and Shopcot, a 23-acre field. Two systems were studied in each field, the farmer standard tillage, stale seedbed with no cover, was compared to no-till with cover in an effort to improve soil health. Each system studied composed half of the field. Throughout the study, all producers' inputs were recorded providing the information needed to calculate both fixed and variable costs. Field data were collected through utilization of soil penetrometers, temperature sensors, rain gauges, ET gages, flow meters, and trapezoidal flumes. Soil penetrometers were used to measure soil compaction at both 3 and 6 inches during field visits in both farmer standard tillage, and no-till with cover. Flow meter readings allowed documentation for how much water was applied, and runoff data were collected after irrigations and rainfall events through the use of trapezoidal flumes.

RESULTS AND DISCUSSION

Soil compaction as measured by the use of a soil penetrometer was consistently lower in no-till with cover at both 3 and 6 inches throughout the growing season. Soil penetrometer readings often decreased following rain or irrigation events. The producer was initially concerned that water movement down the rows would be a problem in no-till cover. However after the initial irrigation, water movement was no longer a concern and actually resulted in a benefit. Irrigation water movement down the rows was 6.7% faster in till no cover. Irrigation water movement slowed as water worked its way through stubble allowing for better water infiltration and less runoff. Irrigation water use efficiency increased in no-till with cover. Overall efficiency across all irrigation events for farmer standard tillage no cover was lower than that of no-till with cover. These factors are believed to have played a major role with no-till cover producing a higher yield than till no cover. Lint yield was 1186 lb/acre in no-till cover, and 1011 lb/acre in till no cover (Table 1). No-till with cover produced a higher yield across both fields. Production expenses for no-till with cover was cheaper in Weaver field due to an extra application of herbicide that was applied to the farmer standard tillage practice, however production expenses were higher for no-till with cover in the Shop field. A higher yield in no-till with cover helped shift operating costs per unit of production to be lower in the Shop field even though the cost of production was higher for no-till compared to the farmer standard. The environmental footprint calculated by the Fieldprint Calculator showed a smaller or more sustainable footprint with the no-till.

PRACTICAL APPLICATIONS

In this one year study, no-till with cover increased irrigation water use efficiency. Although water movement through the field is slower than till no cover, better water infiltration and less runoff was seen, as well as higher yield in no-till with cover. No-till with cover was nine cents a pound cheaper to produce than the standard practice till with no cover. Additional research is needed to further evaluate how profitability, irrigation efficiency, size of environmental footprint, soil health, and continuous improvement are related.

Table 1. Harvested lint yield[†], operating expenses and metrics used to evaluate sustainability as affected by tillage and cover crops.

	No-till with Cover			Till No Cover			% Change
Parameters	**Weaver**	**Shop**	**Average**	**Weaver**	**Shop**	**Average**	**No-till vs. Till**
Yield (lb lint har/A)	1107	1265	1186	965	1057	1011	+ 14.76%
Operating Expenses ($/A)	503.62	582.69	534.16	518.95	576.39	547.67	- 2.53%
Operating Expenses ($/lb lint har)	0.45	0.46	0.455	0.54	0.55	0.545	- 19.78%
Land Use (A/lb lint eq)	0.00075	0.00066	0.00071	0.00086	0.00079	0.00083	+ 16.90%
Soil Conservation (tons/lb lint eq/ yr)	0.00097	0.00052	0.00075	0.00030	0.00432	0.00231	- 67.53%
Irrigation Water Use (A-in/lb lint eq above dryland)	0.020	0.022	0.021	0.029	0.033	0.031	- 47.62%
Energy Use (BTU/lb lint eq)	5419	5096	5257.5	6660	5716	6188	- 17.70%
Greenhouse Gas Emissions (lb CO_2eq/lb lint eq)	1.33	1.19	1.26	1.63	1.32	1.48	- 17.46%

[†] To account for the economic contribution of cotton seed to the value of lint with regard to sustainability, harvested lint yield/0.83 = lint.

Carbohydrate Metabolism of Cotton Flowers Under Water-Deficit Stress

C. Pilon[1] and D.M. Oosterhuis[1]

RESEARCH PROBLEM

Cotton plants subjected to water-deficit stress have their physiological and metabolic processes impaired. Changes in carbohydrate metabolism have been reported to cause a reduction of carbon supply by the plants with consequent reduction in growth. As cotton cultivars differ in tolerance to water-deficit stress, carbohydrate metabolism as a contributing factor to the ability to tolerate water scarce periods is not completely elucidated. Therefore, studies on diverse cotton cultivars are needed to understand carbohydrate metabolism of leaves and flowers from plants that experience water-deficit stress.

BACKGROUND INFORMATION

Flowering development of cotton plants has been reported as a sensitive stage to drought conditions and the crop becomes less sensitive as boll development progresses (Loka et al., 2011). Cotton plants accumulate photoassimilates during the day and translocate the reserves to the sinks at night (Warner and Burke, 1993). Due to the photosynthesis process, leaves are the main source of assimilates, and subtending leaves are known to contribute approximately 60% of the photoassimilates translocated to the subtending fruit under well-watered conditions (Schubert et al., 1986). However, when plants experience drought conditions, growth is affected and an imbalance of carbohydrates flow occurs with higher accumulation of sucrose in relation to well-watered plants (Timpa et al., 1986). In addition to the imbalance of carbohydrates metabolism, water potential of plant tissue is reduced, which indicates less water available for physiological and metabolic processes essential to growth. However, changes in carbohydrate metabolism in flowers and subtending leaves of cotton plants under water-deficit conditions are still not well elucidated. The purpose of this study was to characterize the carbohydrates metabolism changes in leaves and pistils of two commercial cotton cultivars under drought stress during the flowering stage.

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[1] Graduate assistant and distinguished professsor, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

RESEARCH DESCRIPTION

A field experiment was conducted in 2014 at the University of Arkansas System Division of Agriculture Arkansas Agricultural Research and Extension Center in Fayetteville. Treatments consisted of two cotton (*Gossypium hirsutum* L.) cultivars, DP 0912 B2RF and PHY 499 WRF, and two water regimes, a well-watered control, and water deficit during peak flowering stage (70 d after planting). The experimental design was a strip block with the water regimes as the main plots. Cotton was planted on 20 May 2014 at a plant density of 3.5 plants/foot. Plots consisted of four rows, 50 feet in length. Row spacing was 38 inches. The experiment was uniformly fertilized according to pre-season soil tests and recommended rates. Mepiquat chloride was applied as needed to control vegetative growth. Weeds and insect control were performed according to recommendations. The field was maintained well-watered until the flowering stage. The control treatment received the optimum quantity of water throughout the duration of the experiment using furrow irrigation. Water stress was imposed by withholding water from the water deficit treatments for ten days. Discs (10 mm diameter) of subtending leaves of white flowers in the first sympodial fruiting position were excised for determination of water potential (Ψ_w). Samples were measured with screen-caged thermocouple psychrometers (model 74 series, J.R.D. Merrill Specialty Equipment, Logan, Utah) equipped with stainless-steel sample chambers using the technique described by Oosterhuis (2003). Readings were made using a micro-voltmeter and chart recorder. Subtending leaves and pistils from white flowers in the first sympodial fruiting position were collected for carbohydrates measurements, according to protocol adapted from Hendrix (1993). Data were subjected to analysis of variance and Tukey's test ($\alpha = 0.05$) was used to separate treatment combination mean performance using JMP Pro 11 (SAS Institute, Inc. Cary, N.C.).

RESULTS AND DISCUSSION

Water potential was measured in subtending leaves from white flowers in the first sympodial fruiting position. Similar trends were observed for the two cultivars with lower (more negative) water potential in leaves of water-stressed plants compared with the well-watered control (Fig. 1). Leaf water potential of water-stressed plants was 43% and 47% more negative than the well-watered control for DP0912 and PHY499, respectively (Fig. 1). Water potential of leaves is considered as an indicator of plant water balance (Karamanos, 2003). In our study, a reduction in water potential (more negative values) of leaves demonstrated that the plants subjected to water-deficit conditions responded to the stress by lowering water potential in vegetative tissues. We speculate that cotton plants respond to water-deficit stress by reducing water potential of vegetative tissues in order to buffer water potential of reproductive tissues, thus preventing water loss from these units.

Water-deficit stress also caused a significant decrease in soluble sugars and sucrose concentrations in the subtending leaves of DP0912, while starch concentration remained unaffected (Fig. 2a). For PHY499, concentrations of soluble sugars, sucrose and starch in the subtending leaves were decreased by water-deficit conditions (Fig. 2b). Concentrations of sucrose and starch in the pistil were significantly increased by water-deficit stress in DP0912, while soluble sugars were unaffected by the water regimes (Fig. 2c). For PHY499, starch was the only carbohydrate component affected by water-deficit stress, with significantly lower concentration in the pistil of water-stressed plants (Fig. 2d). Carbohydrate metabolism is documented to be directly involved with plant growth (Smith and Stitt, 2007), and as plant growth was affected by water-deficit stress, alterations in carbohydrate concentration are expected to occur. The distribution of carbohydrates among the cotton plant tissues was different between the cultivars and also the water regimes. Carbohydrate metabolism in subtending leaves was reduced in water-stressed plants. Under water deficit, pistils are stronger sinks of carbohydrates (especially sucrose) as the pistils increased sucrose concentrations under water-deficit conditions. One possible explanation is that the ovaries (part of the pistil) grow into bolls responsible for seed production and consequently crop yield, thus the plants would ensure reproduction even with lower plant growth.

PRACTICAL APPLICATIONS

Studies have demonstrated that water-deficit stress affects carbohydrate metabolism of several crops. However, this mechanism has not been fully understood for reproductive tissues of commercial cotton cultivars. The knowledge of changes in carbohydrates metabolism in diverse cotton cultivars is relevant, since it has been shown that some cultivars have the ability to adjust and shift carbohydrates concentration to reproductive tissues to maintain growth of reproductive units under water-deficit conditions.

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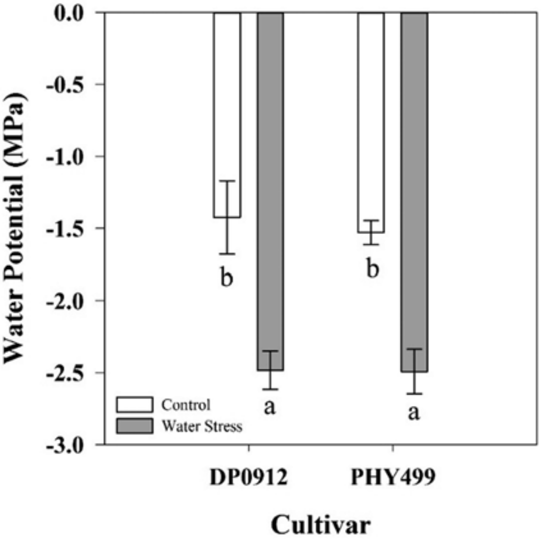

Fig. 1. Water potential (MPa) of subtending leaves of two cotton cultivars, D0912 and PHY499, under two water regimes, well-watered control and water-deficit stress. All values are means ± standard error (n = 10). Different letters indicate significant difference between water regimes within the same cultivar according to Tukey's test (*P* ≤ 0.05).

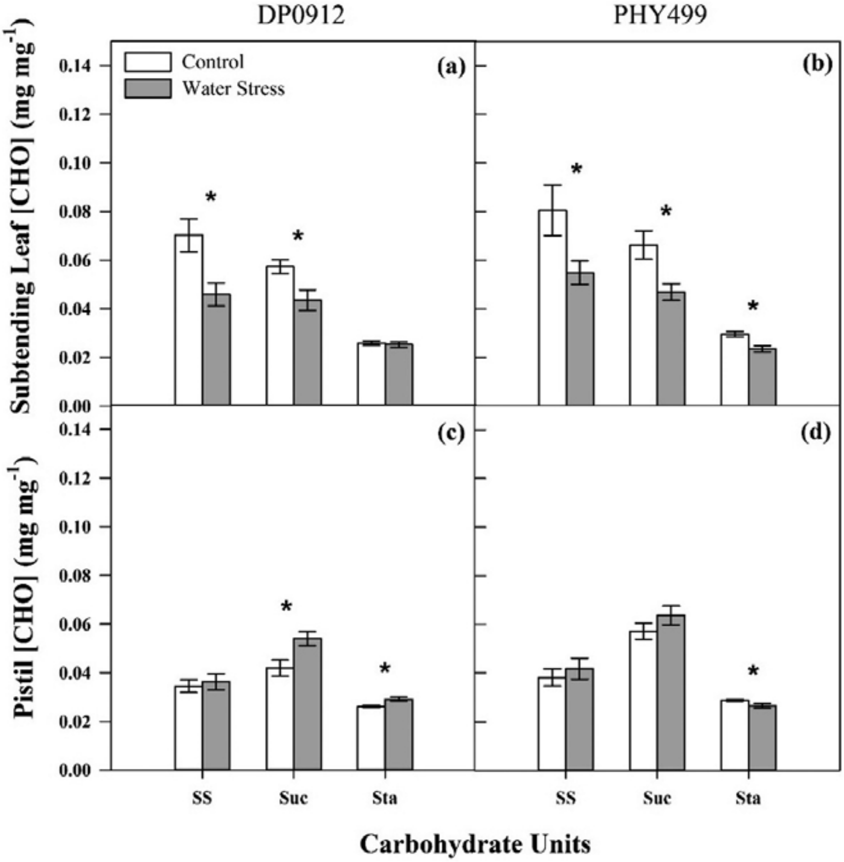

Fig. 2. Concentrations of soluble sugars (SS), sucrose (Suc), and starch (Sta) in subtending leaves (a and b), and pistils (c and d) of two cotton cultivars, DP0912 (a and c) and PHY499 (b and d), under two water regimes, well-watered control and water-deficit stress. All values are means ± standard errors. Asterisks indicate significant differences between water regimes within the same carbohydrate unit according to Tukey's test (*P* ≤ 0.05).

Non-Structural Carbohydrate Dynamics of the Cotton Flower

D.A. Loka[1] *and D.M. Oosterhuis*[1]

RESEARCH PROBLEM

Carbohydrates are the main component of the cotton fiber, however the carbohydrate content of the cotton reproductive units has received little attention. This study was aimed at quantifying the carbohydrate content of the cotton pistil (ovary and style) and petals one day before anthesis, the day of anthesis and one day after anthesis.

BACKGROUND INFORMATION

More than 90% of cotton fiber consists of carbohydrates (Constable and Oosterhuis, 2010) and previous research has reported that inadequate carbohydrate supply to the developing cotton bolls could result in low fiber quality and yield (Pettigrew, 2001). Development and elongation of the cotton fiber, the individual epidermal cells on the outer integument on the seed coat, begin on the day of anthesis (Stewart, 1986). Research in other species has indicated that a significant amount of carbohydrates in the petals is redistributed to other parts of the flower or plant during corolla senescence (Nichols and Ho, 1975; Bieleski, 1995), however, no information exists on the cotton corolla and the amounts of carbohydrate content of the petals.

RESEARCH DESCRIPTION

Growth chamber studies were conducted in the University of Arkansas System Division of Agriculture's Altheimer Laboratory, Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) ST5288B2F was planted into 2-L pots containing a horticultural mix (Sun-Gro horticulture mix). The growth chambers were set for normal conditions of 32/24 °C (day/night), ±60% relative humidity, and 14-h photoperiod, while half-strength Hoagland's nutrient solution was applied daily in order

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[1] Graduate assistant and distinguished professor, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

to maintain adequate nutrients and water. Plants were arranged in a completely randomized design with 20 replications. Approximately 8 weeks after planting, flower buds 1 day before anthesis, white flowers, and flowers 1 day after anthesis were sampled from the 8th main-stem node of each plant and glucose, fructose, sucrose and starch content of their pistils and petals were determined. Carbohydrate extraction was done according to Zhao et al. (2008) and the supernatants were analyzed with a multiscan microplate reader.

RESULTS AND DISCUSSION

Carbohydrate content of the cotton petals was significantly higher than that of the cotton pistil for all sampling times. Fructose, sucrose and starch content of the petals peaked at the day of anthesis (Fig. 1b,c,d) , while petal glucose content (Fig. 1d) remained similar to that of the day before anthesis but significantly decreased one day later. A decreasing pattern was observed for glucose and fructose content of the cotton pistil with their concentrations the day of anthesis being significantly lower than the day before anthesis and decreasing the day after anthesis. However, pistil sucrose levels were significantly higher the day of anthesis than the day before and after anthesis. Pistil starch content, on the contrary, remained similar to that on the day before anthesis before significantly decreasing one day after anthesis. Our results indicated that a significant amount of soluble carbohydrates is allocated in the petals instead of the pistils; however, no apparent redistribution of the petal carbohydrates was observed to the cotton pistils since sucrose and starch levels of the cotton pistils were shown to peak at the day of anthesis in contrast to glucose and fructose that were at their highest one day before anthesis.

PRACTICAL APPLICATIONS

The results of our study indicated that petal carbohydrate content was significantly higher than that of the pistils one day before anthesis, on the day of anthesis and one day after anthesis. However, that substantial amount of carbohydrates did not re-distribute to the cotton pistil, since no increase in the carbohydrate content of the pistils was observed one day after anthesis. Further research is needed in order to elucidate the allocation of the carbohydrates stored in the petals.

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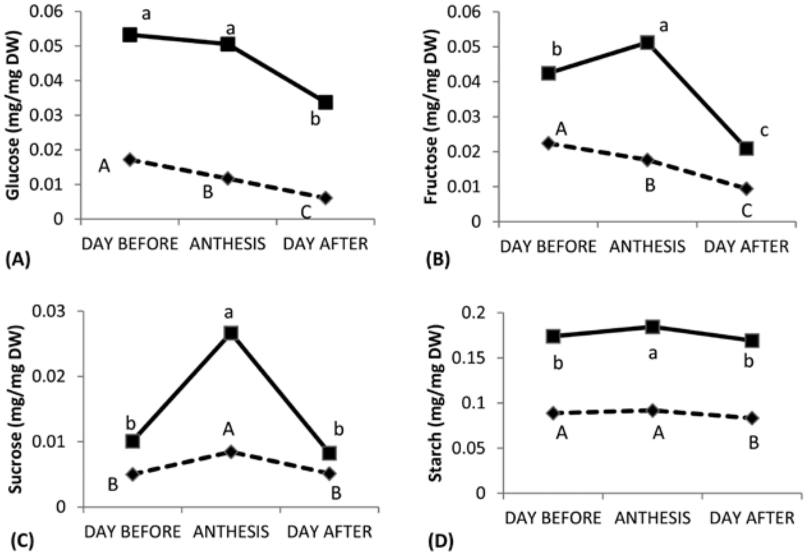

Fig. 1. Glucose (A), fructose (B), sucrose (C) and starch (D) content of the cotton pistil and petal one day before anthesis, at anthesis, and one day after anthesis. Different letters indicate significant differences at α = 0.05. The composite line refers to the petals, dotted line refers to pistils

Use of Remote Sensing in Cotton to Determine Potassium Status and Yield

T. Coomer[1], D.M. Oosterhuis[1], L. Espinoza[2], and T. Raper[3]

RESEARCH PROBLEM

Sensing deficiencies in the soil is usually carried out by soil and plant analysis, which can be time consuming and expensive (Ponzoni and Goncalves, 1999). It is believed that early detection of soil and plant nutrient deficiency problems can be achieved by using remote sensors that utilize the electromagnetic spectrum. Therefore, the objectives of this study were to to determine if cultivars differed in values from currently available indices formulated for N-status detection from active sensors. It also set out to determine if these N-sensitive indices were sensitive to leaf K concentration and available K_2O in the soil, and to evaluate the role these indices play in predicting yield.

BACKGROUND INFORMATION

Reflected and emitted energy wavelengths between 400 to 900 nm are measured by remote sensing techniques (Thomas et al., 1967). The reflecting capacity of plant canopies changes with plant species, and within a single plant species. Reflectance changes occur due to plant characteristics such as foliage density, plant height, vigor, growth habit, and maturity. While the spectral reflectance curve for nitrogen (N) is well documented (Samborski et al., 2009), nutritional monitoring of other elements is not so well defined (Pimstein et al., 2011).

It was hypothesized that normalized difference vegetation index (NDVI) would more accurately predict leaf K and yield than the normalized difference red-edge index (NDRE), due to the red-edge band used in the NDRE reflecting changes in chlorophyll, which is not affected by K deficiency. It was also believed that the NDVI and the NDRE would more accurately determine the K parameters chosen than the canopy chlorophyll content index (CCCI), due to the strong influence of the red-edge band in the index. Yield would be most accurately predicted by the CCCI, due to yield being influenced by both chlorophyll content and

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[1] Graduate assistant and distinguished professsor, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

[2] Extension soil scientist, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Little Rock.

[3] Assistant professor, Department of Plant Sciences, University of Tennessee, Jackson.

biomass, and the CCCI involving the red-edge band to reflect chlorophyll content and the near infrared band to detect biomass.

RESEARCH DESCRIPTION

The early detection of K deficiency using remote sensing experiments was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Ark. Three cultivars of cotton (*Gossypium hirsutum* L.) (DeltaPine 0912 B2RF, Phytogen 499 WRF, and Stoneville 5458 B2F) were planted in mid May 2014 and 2015. All fertilization besides K fertilization was applied following soil-test recommendations. Four K treatments of 0, 33.6, 67.2, and 100.8 kg K/ha (0, 30, 60, and 90 lb/acre) were applied as potassium chloride (KCl) at approximately pinhead square (PHS) on 25 June. Plots consisted of four rows, 1 m (38 inches) rows wide and 15.24 m (50 feet) long with cotton planted 11.5 plants per meter (3.5 plants per foot). Plots were furrow irrigated as needed.

Spectral reflectance measurements were taken at first flower (FF) and three weeks after first flower (FF3) using a Crop Circle ACS-470 sensor with a GeoSCOUT GLS-400 data logger (Holland Scientific, Inc., Lincoln, Neb.). Sensor was held at 0.914 m (36 inches) above canopy. Wavelengths measured included 650 nm (red), 720 nm (red-edge), and 840 nm (near infrared [NIR]). Three indices from these wavelengths were calculated: NDVI, NDRE, and CCCI.

Leaf samples were taken from the fourth main-stem node from the top of five plants in each plot and were analyzed for K concentration (Soil and Plant Testing Laboratory, University of Arkansas System Division of Agriculture, Fayetteville, Ark.). Leaf K concentration and available K_2O were compared to spectral index measurements to determine the accuracy of spectral reflectance values to determine K deficiency. Lint yield from the middle two rows per plot was also recorded at harvest and was compared to index measurements to observe any correlation between spectral reflectance and yield.

RESULTS AND DISCUSSION

The NDVI was significantly correlated ($P < 0.05$) with the interaction between cultivar and leaf K concentration at FF with an r^2 value of 0.815 (Table 1). The NDRE was also significantly ($P < 0.05$) correlated with the interaction between cultivar and leaf K concentration at FF with an r^2 value of 0.617 (Table 1). The significant interaction indicates that to accurately determine K status using the NDVI or NDRE, a cultivar correction factor must be used. The CCCI was not significantly correlated ($P < 0.05$) with leaf K concentration at FF (Table 1). At FF3, no interaction between cultivar, leaf K and NDVI was significant; however, the NDRE and the CCCI had significant correlations ($P < 0.05$) with cultivar with r^2 values of 0.335 and 0.689, respectively (Table 1). This indicates NDRE and CCCI differ by cultivar, regardless of leaf K status. The leaf K concentration range at

FF3 was 0.4-1.2%, well below the sufficient leaf K range of 2-4%. It is likely that leaf K was too low overall at the FF3 stage for the spectral reflectance indices to detect leaf K status.

Index values at FF and FF3 were correlated with yield data to observe if it was possible to use spectral reflectance data to predict yield early- or late-season. All three indices had significant interactions between cultivar and yield at FF and FF3 (Table 2). AT FF, the NDVI, NDRE, and CCCI had r^2 values of 0.311, 0.339, and 0.201, respectively. At FF3, the NDVI, NDRE, and CCCI had r^2 values of 0.338, 0.277, and 0.693, respectively (Table 2). The highest r^2 value was observed using the CCCI at FF3. Yield was best predicted later in the season and using an index that involves both bands that reflect changes in chlorophyll and biomass.

PRACTICAL APPLICATIONS

Overall, leaf K concentration was best described using early-season NDVI with a cultivar correction factor. Late-season K concentrations were too low for accurate detection of significant differences. The indices chosen for this experiment were unable to determine available K_2O in the soil, possibly due to the long-term fertility research field history. Yield was best predicted using the CCCI with a cultivar correction factor later in the season. These results indicate that N-sensitive indices are sensitive to other crop growth parameters, and that more research needs to be conducted to further understand the role of spectral reflectance sensors in crop production.

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Table 1. Cultivar and leaf K% correlated with NDVI, NDRE, and CCCI at first flower (FF) and three weeks after first flower (FF3) in the 2014 and 2015 growing seasons.

Growth Stage	Effect	NDVI		NDRE		CCCI	
FF	Cultivar	0.0343[a]	r^2 = 0.815[c]	NS[b]		NS	
	Leaf K%	0.0274		0.395	r^2 = 0.617	NS	
	Cult * Leaf K%	0.0014		0.0087		NS	
FF3	Cultivar	NS		0.0058	r^2 = 0.335	0.0131	r^2 = 0.689
	Leaf K%	NS		NS		NS	
	Cult * Leaf K%	NS		NS		NS	

[a] Numbers in these columns indicate *P*-values.

[b] NS = not significant at $P < 0.05$.

[c] r^2 values represent the interaction between main effects when interaction is significant. NDVI = normalized difference vegetation index, NDRE = normalized difference red-edge index, and CCCI = canopy chlorophyll content index.

Table 2. Yield predicted by NDVI, NDRE, and CCCI at first flower (FF) and three weeks after first flower (FF3) in the 2014 and 2015 growing seasons.

Growth Stage	Effect	NDVI		NDRE		CCCI	
FF	Cultivar	NS[b]		NS		NS	
	Yield	<0.0001[a]	r^2 = 0.311[c]	<0.0001	r^2 = 0.339	NS	
	Cult * Yield	0.0009		0.0032		0.0019	r^2 = 0.201
FF3	Cultivar	0.0004	r^2 = 0.338	0.0003	r^2 = 0.227	0.0036	r^2 = 0.693
	Yield	0.0408		NS		NS	
	Cult * Yield	<0.0001		0.0031		0.0056	

[a] Numbers in these columns indicate *P*-values.

[b] NS = not significant at $P < 0.05$.

[c] r^2 values represent the interaction between main effects when interaction is significant. NDVI = normalized difference vegetation index, NDRE = normalized difference red-edge index, and CCCI = canopy chlorophyll content index.

Termination Timing for Irrigation and Insect Control in No-Till, Cover Crop, and Conventional Tillage Systems

A.M. Mann[1], T.G. Teague[1], and M.L. Reba[2]

RESEARCH PROBLEM

In response to high cotton production costs and stagnant commodity prices, cotton producers must find ways to improve profitability if they are to sustain this important mid-South industry. There may be opportunities to trim production costs by reducing late-season input costs for irrigation and insect control. Decision guides are available to aid in late-season management decisions; however, there may be questions on whether to deviate from those recommended practices in cases where the crop is delayed because of late planting date or with atypical production practices including conservation tillage. In this 2015 small plot field study in Northeast Arkansas, late-season termination timing for irrigation and tarnished plant bug control (*Lygus lineolaris* (Palisot de Beauvois)) was evaluated in late-planted cotton in different tillage systems.

BACKGROUND INFORMATION

Long-term cotton research efforts in the mid-South have focused on development and validation of decision guides for late-season management and termination. The work was the basis for initial development of the COTMAN™ crop monitoring system (Bourland et al., 2008). Critical to termination decisions is determination of the flowering date of the last effective boll population, defined as "cutout" in COTMAN. As those last effective bolls mature, decision makers use accumulated heat units to identify maturity endpoints for insect control and irrigation. For example, University of Arkansas System Division of Agriculture Cooperative Extension Service (CES) recommends a termination endpoint of cutout + 250 heat units (DD60s) for tarnished plant bug control (Studebaker, 2014). For timing the final irrigation, research findings suggests that cutout + 350 DD60s is appropriate for mid-South cotton (Vories et al., 2011; Reba et al., 2014). There are two categories of cutout. With appropriate date of planting and good growing conditions in Arkansas, crop plants typically reach "physiological cutout" (aver-

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[1] Program technician and professor, respectively, Arkansas State University, University of Arkansas System Division of Agriculture Agricultural Experiment Station, Jonesboro.

[2] Research hydrologist, USDA-ARS Delta Water Management Research Unit, Jonesboro.

age of five squaring nodes above white flower = 5 (NAWF = 5) in late July or early August; otherwise, a "seasonal cutout" date would be used based on historical weather for the production region. Typically a boll needs 850 DD60s to mature with acceptable size and quality; therefore a conservative seasonal cutout date is the calendar date on which there is a 50% probability that the crop will have the benefit of temperatures sufficient to develop a mature boll. The seasonal cutout date for Northeast Arkansas is 11 August.

The objective of this study was to evaluate if current termination recommendations using weather-based decision guides for timing of irrigation and insect control termination should be modified under different tillage systems and with a late date of planting. We compared extended insect control for tarnished plant bug with recommended termination timing and also evaluated whether additional irrigation would improve crop yield compared to an early termination approach.

RESEARCH DESCRIPTION

The 2015 tillage and termination timing study was conducted on the University of Arkansas System Division of Agriculture's Judd Hill Foundation Research Farm near Trumann, Ark. in long-term tillage plots that have been maintained since fall 2007. The study was arranged in a split-split plot design as a 3 × 2 × 3 factorial (tillage × irrigation × insect control) with 3 replications. Tillage treatments were considered main plots and were 1) conventional, 2) no-till, and 3) winter wheat cover crop with conservation tillage (cover crop). Tillage main plots were split with either early irrigation termination (early) or extended irrigation (late). The three insect control treatments were either unprotected (UTC), protected with standard termination of insect control (early), or protected with extended protection with insecticides (late). Tillage main plots were 16 rows wide and irrigated subplots were 8 rows wide, extending the 450-ft length of the field. Randomized within main plots were insect control subplots; these were 80 ft long separated by 10-ft alleys.

Fall 2014 tillage practices in the conventional and cover crop treatments consisted of using disk bedders to re-form beds. In mid-October wheat was broadcast planted (10 lb/acre) in the cover crop main plots; wheat was terminated in spring 2015 with glyphosate herbicide applied by air across the entire experiment. In-season practices were similar across all tillage treatments with the following exceptions used only in conventional tillage treatment: disk bedders were used to re-form beds prior to planting, beds were flattened with a Do-All prior to planting, and row middles were cleared with sweep plows prior to the first irrigation. Furrow irrigation was provided using poly-pipe. Production details are included in Table 1, and termination timing is listed in Table 2.

Plant stand density assessments were made 8 days after planting (DAP) by counting the emerged plants in 3 ft of row. Six transects where made across the length of the tillage main plot. In-season plant monitoring was initiated during squaring node development using standard COTMAN Squaremap sampling protocols (Oosterhuis and Bourland, 2008). Insect pest monitoring included weekly assessments for tarnished plant bug using drop cloth sampling in each plot during squaring node development and through effective flowering. Yield determinations were made using a 2-row research cotton picker in designated harvest rows. Cotton was harvested 22 October, 2280 DD60s after planting and 895 DD60s after seasonal cutout. Data were analyzed using PROC GLM with protected least significant difference and PROC MIXED (SAS Institute, Inc. Cary, N.C.).

RESULTS AND DISCUSSION

Mean plant stand density was significantly reduced in no-till with 6.3 plants per 3 ft of row compared to 9.5 plants per 3 ft in conventional and cover crop treatments ($P < 0.05$). Unevenness of beds in the no-till plots likely resulted in reduced soil-seed contact in portions of the seed bed, despite use of a no-till planter. COTMAN growth curves were similar for plants among tillage, insect control, and irrigation treatments (Fig. 1a). There was above average rainfall at the study site in 2015; however, there was a dry period in late season at the time of the late irrigation (Fig. 1b). That final irrigation was applied 1 September, and there were many local farmers in the production region irrigating cotton during that time. Final insecticide application in protected subplots was either seasonal cutout +71 DD60s or cutout + 513 DD60s (Table 1). Numbers of tarnished plant bugs were similar among tillage systems. Insecticide applications reduced plant bug numbers (Fig. 1c); numbers were slightly above threshold for the final application.

Mid-South cotton producers growing modern cotton varieties can achieve both early and high yields with just 3 weeks of effective flowering (Kerby et al., 2010). With the late date of planting in this study, yield potential was "season-limited" with the effective flowering period shortened to under 2 weeks. First flowers were observed 58 DAP, just 5 days before latest possible cutout date. Tillage system, insecticide applications, and irrigation practices all affected yield ($P < 0.05$); there were no significant interactions Plants in the no-till system produced lower yields compared to conventional and cover crop systems (Fig. 2). After 8 continuous no-till seasons, the beds in the no-till plots were flat, and irrigation water moved into the early terminated areas during the final irrigation split. Consequently, only the late-irrigation termination data were included in the final analysis for yield in the no-till. For the conventional and cover crop treatments, adding one last irrigation application reduced mean yields ($P < 0.05$) compared to early termination (Fig. 2). Plant bug feeding damage in UTC subplots resulted in significant yield reductions ($P < 0.001$); however, there was no difference in yield associated with early and late insecticide termination treatments, indicating that the final insecticide application was unnecessary.

PRACTICAL APPLICATIONS

Results from this 2015 late-planted field trial supports current recommendations which suggest maintaining control of plant bugs through cutout + 250

DD60s. There was no indication that the insect control termination rules should be modified for different tillage systems. Current CES recommendations suggest the final effective irrigation be applied at cutout + 450 DD60s. In this study, lint yield was reduced with an irrigation applied at seasonal cutout + 359 DD60s compared to earlier termination. The late irrigation appeared to promote unproductive, late-season growth. It may be appropriate for irrigation specialists and agronomists to review the termination timing recommendation for late dates of planting in northern portions of the mid-South.

ACKNOWLEDGMENTS

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Table 1. Production details for 2015 Judd Hill tillage and termination trial including dates of planting, irrigation, insecticide application, defoliation timing, and harvest date.

Operation	Date	Days After Planting
Date of planting	9 June	
Insecticide[a,b]	14, 29 July, 4, 14 August, 8 September	35, 50, 56, 66, 91
Irrigation	29 July, 17 August, 1 September	50, 69, 84
Defoliation	5 October	118
Harvest	22 October	135

[a] Insecticides were applied using a 8-row, high clearance sprayer to protected treatments only; rates, product and applications date were: 1.5 oz Transform 50WG (sulfoxaflor) at 35 and 50 days after planting (DAP), Centric 40WG 2.5 oz at 56 DAP, acephate (.67 lb) + bifenthrin (0.075 lb) at 66 DAP.

[b] Final insecticide applied in the extended (late) treatment on 91 DAP was acephate (.67 lb) + bifenthrin (0.075 lb).

Table 2. Termination timing for final applications of insecticide and irrigation for 2015 Judd Hill tillage and termination study—days after planting (DAP) and heat units (DD60s) after the seasonal cutout date, 11 August.

	Days after planting (date)		Heat units (DD60s) after seasonal cutout[a]	
Treatment	Early	Late	Early	Late
Insect Control	66 (14 Aug)	91 (8 Sep)	71	513
Irrigation	69 (17 Aug)	84 (1 Sep)	128	359

[a] Heat unit accumulations were derived from measurements taken by the Campbell Scientific Weather Station on the University of Arkansas System Division of Agriculture's Judd Hill Research Farm (weather.astate.edu).

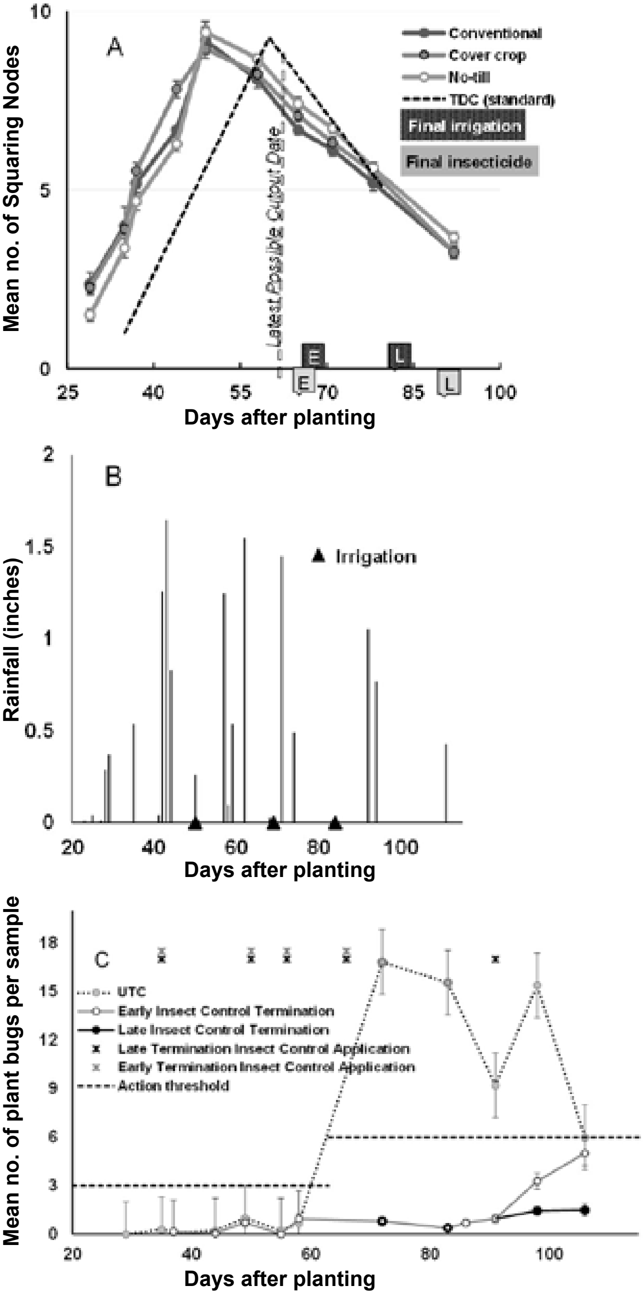

Fig. 1. COTMAN (crop monitoring system) growth curves for tillage system main plots showing irrigation and insecticide termination treatment timing (A), seasonal precipitation and irrigation dates (B), and seasonal tarnished plant bug abundance observed in insect control subplots (C) through the 2015 season, Judd Hill, Ark.

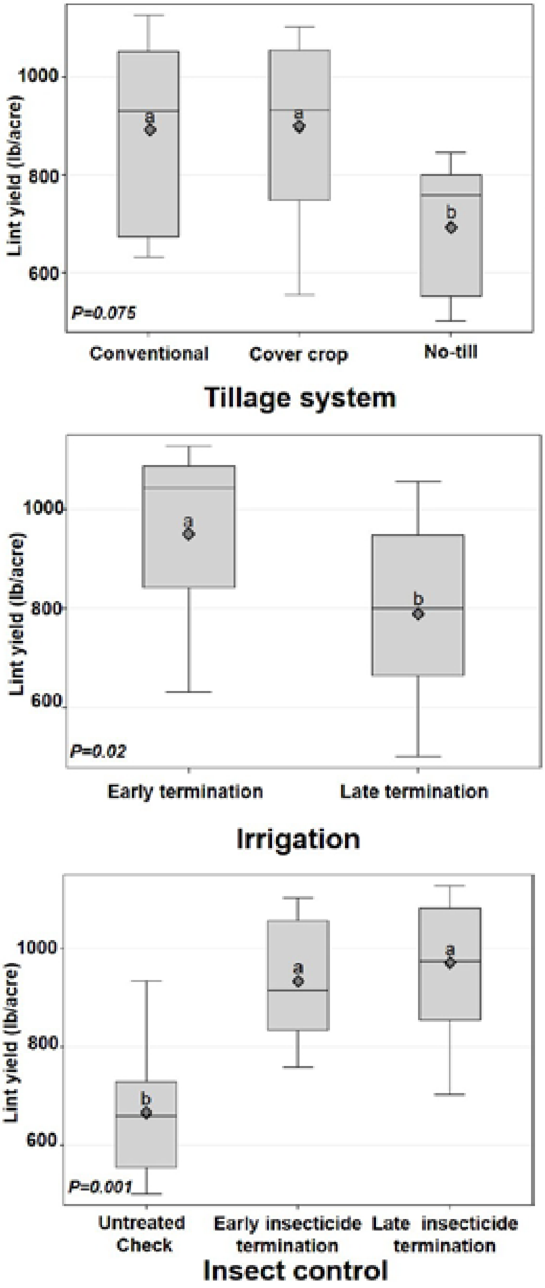

Fig. 2. Mean lint yield for tillage system, irrigation termination and insect control termination timing effects for the 2015 tillage and termination trial, Judd Hill, Ark. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value. Means with similar letters do not differ significantly using Fisher's protected least significant difference test; 2015.

Impacts and Benefits of Polyacrylamide (PAM) on Irrigation Efficiency, Soil Conservation, and Water Quality in Mid-South Cotton Production: 2015

B.D. Barnes[1]*, M.L. Reba*[2]*, and T.G. Teague*[1]

RESEARCH PROBLEM

Arkansas is one of the leading states in total irrigated cropland. Improvements in irrigation management are needed to reduce the negative impacts resulting from groundwater decline and irrigation-induced soil erosion. This includes expanded adoption of practices that improve irrigation water infiltration and reduce loss of nutrients in runoff water.

BACKGROUND INFORMATION

Polyacrylamide (PAM) is a high molecular weight, chemical anionic polymer that is highly water soluble. Research in the western U.S. has shown that applications of PAM in furrow irrigated systems can improve irrigation water use efficiency by increasing infiltration and reducing irrigation advance times (Barta et al., 2004). Polyacrylamide applications have been shown to increase soil aggregate stability resulting in reduced soil erosion and improved runoff water quality (Sojka and Lentz, 1996). The objective of this project was to evaluate PAM in a mid-South cotton production system including its effects on irrigation efficiency, crop performance, and runoff water quality.

RESEARCH DESCRIPTION

The field study was conducted at the University of Arkansas System Division of Agriculture's Judd Hill Foundation Research Farm near Trumann, Ark.. Soils at the study site were classified as a Dundee silt loam (77.3%)—ranging from silt loam to loamy fine sand; Mhoon silt loam (20.9%)—ranging from silt loam to silty clay loam; and Hayti soils (1.8%)—ranging from loam to sandy clay loam. The field was bedded on 38-in (96.5 cm) centers in the fall, using disk bedders

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[1] Graduate student and professor, respectively, Arkansas State University, University of Arkansas System Division of Agriculture Agricultural Experiment Station, Jonesboro.

[2] Research hydrologist, USDA ARS Delta Water Management Research Unit, Jonesboro.

(hippers), and again in the spring. Tops of beds were flattened just prior to planting with a Do-All fitted with incorporation baskets. The field slope was 0.1%. Cotton cultivar Delta Pine 0912 RFB2 was seeded on 8 June 2015. The field was irrigated using 15-in. (38.1 cm) polyethylene irrigation tubing (polypipe), with groundwater from the Mississippi River Valley Alluvial Aquifer (MRVAA) from a well. The computerized hole selection program PHAUCET (Yazoo Mississippi Delta Joint Water Management District, Stoneville, Miss.) was used to ensure uniformity of the irrigation advance.

There were three treatments: Irrigation (IRR), Irrigation plus PAM (IRR + PAM), and Rainfed. The experiment was arranged as a randomized complete block with 3 replications. Plots were 530 ft (161.54 m) long and 10 rows wide. Granular PAM was broadcast-applied to the IRR + PAM treatment plots just after planting on 8 June 15 at a rate of 10 lb per acre (11.2 kg ha^{-1}). Irrigation was applied on 29 and 31 July, 4 August, and 17 and 18 August. Prior to the first irrigation, the furrows were cultivated using a V-shaped furrow-forming plow 3 in. (7.6 cm) deep. On 31 July and 18 August, liquid PAM (Flobond L33 (30% active product, 30% anionic charge) (SNF Holding Company, Riceboro, Ga.)) was injected into the polytubing using a small pump and was applied at concentrations of 2 ppm. To avoid cross contamination, a separate section of polytubing was used to deliver irrigation to the IRR treatment plots.

Data collection included yield and fiber quality assessments, weekly plant and insect pest monitoring, soil moisture measurements, infiltration evaluations, and water quality sampling. The COTMAN plant monitoring system (Oosterhuis and Bourland, 2008) was used to document differences in plant development among irrigation treatments from squaring until physiological cutout. Defoliants and boll openers were applied 30 September, and plots were harvested 19 October using a two-row research cotton picker. For fiber quality evaluations, fifty boll samples from each treatment plot were hand-picked, ginned with a laboratory gin, and submitted to the Fiber and Biopolymer Research Institute (Texas Tech University, Lubbock). All plant monitoring, yield and fiber quality data were analyzed using analysis of variance.

To monitor soil moisture among treatments, Decagon EC5 Volumetric Water Content sensors (Decagon Devices, Inc., Pullman, Wash.) were deployed in each treatment plot in one replication. There were three sensing stations in one center row at 1, 2, and 3 meter(s) from the plot edge down the furrow. Each station consisted of four sensors positioned at 15-cm and 30-cm depths both in the edge of furrow and in the top of the bed directly below the plant. A Campbell Scientific CR1000 data logger (Logan, Utah) was used to continuously record volumetric moisture from planting through defoliation.

Grab samples for water quality analysis were collected for three irrigation events. Two collection events occurred over the course of two days (29 and 31 July; 17 and 18 August); PAM was applied on day one. No PAM was applied on 4 August. Water samples were collected at the start of the irrigation event directly from the polytubing to determine source water quality and at the end of the plots near the field edge. Samples were collected every two hours over a six hour period; these were delivered to the Ecotoxicology Research Laboratory at Arkansas State University for analysis that included suspended sediment concentration (ASTM method D3977-97), Nitrate (APHA 2005 method 4500-NO3-E), Orthophosphate (OP) (APHA 2005 method 4500-P E), and Total P & N (4500-P J). A weather station, located within 1 km of the field study provided measurements of precipitation, air temperature, humidity, radiation and soil temperature data for the season (http://weather.astate.edu).

RESULTS AND DISCUSSION

There were multiple in-season precipitation events in 2015 (Table 1). Pace of plant nodal development, depicted in COTMAN growth curves (Fig. 1), was similar among irrigated and rainfed plants. Mean number of days to physiological cutout (NAWF = 5) was not affected by irrigation.

Results from soil moisture monitoring in IRR + PAM and IRR treatment plots provide insight into the impact of PAM application on infiltration (Fig. 2). Soil moisture levels for the irrigated treatment show infiltration to the 6-in. sensors but did increase volumetric water content at the 12-in. sensors. Soil moisture levels for the IRR + PAM plot suggest infiltration in both 6-in. and 12-in. sensors while also showing an increase in water movement to the sensors placed in the bed when compared to IRR. Infiltration data is currently being analyzed.

There were statistically significant differences between water quality from the IRR and IRR + PAM treatments in several of the parameters measured for irrigation events. Irrigation events 1 (29-31 July) and 2 (4 August) included differences ($P < 0.05$) in levels of OP, total P, nitrate, and nitrite (Fig. 3). There was a significant decrease in IRR + PAM samples collected from edge-of-field compared to IRR + PAM control sample (Fig. 3) for total P, OP, and nitrate levels (Fig. 3a, b). Further analysis will be conducted to explore reasoning behind the observed differences in IRR and IRR + PAM controls since the samples were collected during the same event.

Irrigation treatments had no impact on lint yield in 2015. Mean yield for the IRR treatment was 1158 lb acre^{-1} (1298 kg ha^{-1}); IRR + PAM treatment was 1257 lb acre^{-1} (1409 kg ha^{-1}), and Rainfed treatment was 1245 lb acre^{-1} (1395 kg ha^{-1}). There were no significant differences among irrigation treatments for HVI fiber quality assessments (data not shown). The 2015 study was a continuation of a preliminary trial (Reba et al., 2015), but unlike findings in 2014, there was no reduction in yield associated with use of PAM.

PRACTICAL APPLICATIONS

Results from the 2015 field trial provided encouraging indications of improved irrigation water infiltration and reduced loss of nutrients in irrigation runoff when PAM was applied at planting and with irrigation water. These results suggest that PAM could have positive impact on irrigation efficiency in the mid-South. Expanded evaluations are planned for 2016.

ACKNOWLEDGMENTS

Research funding from the Cotton Incorporated State Support Committee is acknowledged. We recognize and appreciate the support and collaboration of the Judd Hill Foundation and the staff at the University of Arkansas System Division of Agriculture and Arkansas State University Cooperative Research Farm at Judd Hill.

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Table 1. Monthly precipitation and average temperature for 2015 at the University of Arkansas System Division of Agriculture's Judd Hill Foundation Research Farm, near Trumann, Ark. compared to 30-year (1981-2010) averages from nearby Jonesboro, Ark.

	May	June	July	Aug.	Sept.
Sample Period	---inches---				
2015	7.9	1.8	5.3	5.4	1.8
1981-2010	4.6	3.8	3.5	2.5	3.1

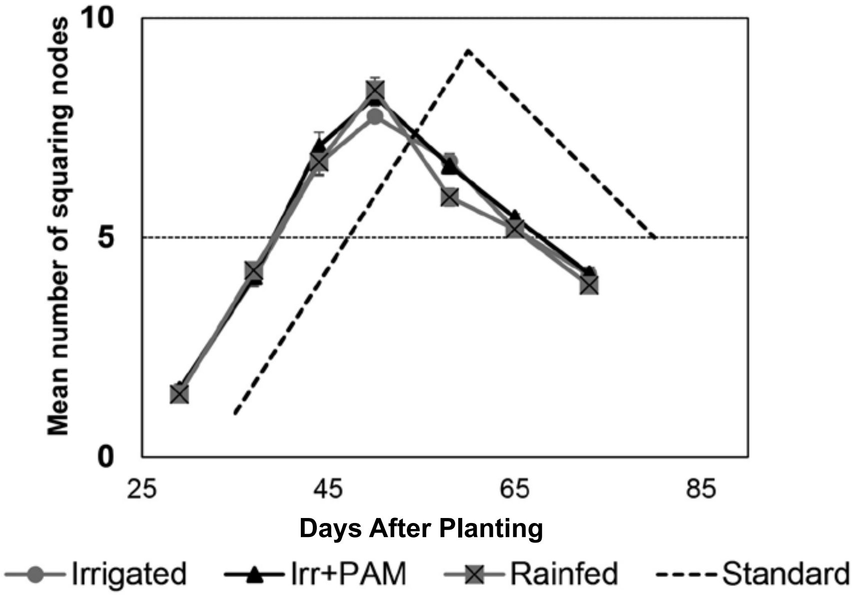

Fig. 1. Growth curves (measured using COTMAN crop monitoring system) for plants in the irrigated, irrigated + polyacrylamide (PAM) and rainfed treatments compared to the standard target development curve at the University of Arkansas System Division of Agriculture's Judd Hill Foundation Research Farm, near Trumann, Ark. 2015.

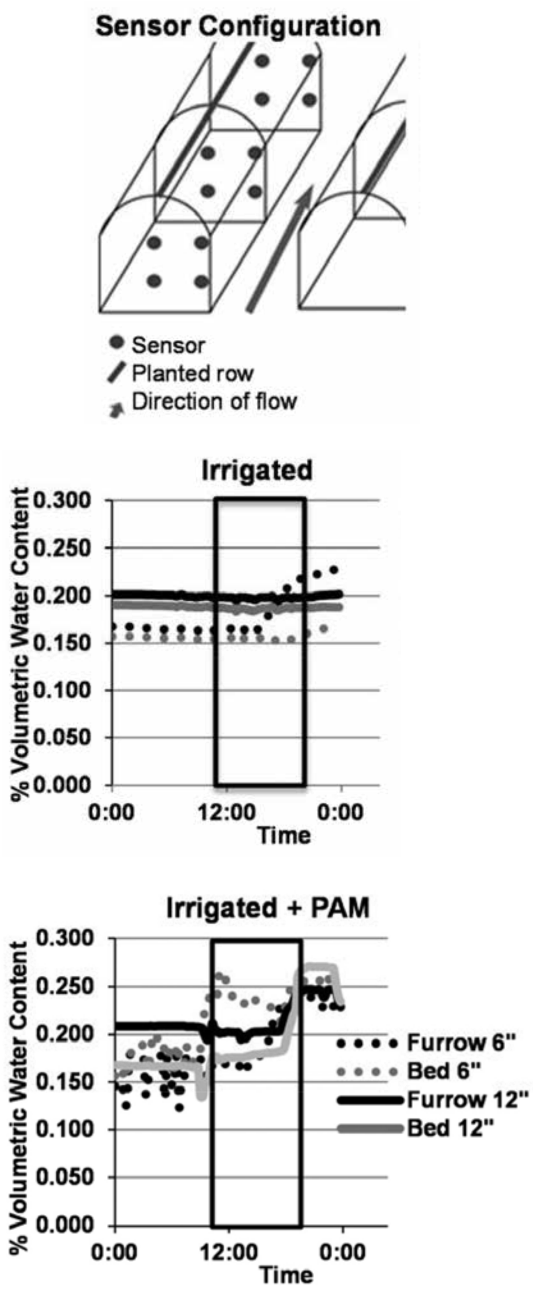

Fig. 2. Volumetric water content from the irrigation (IRR) and IRR + polyacrylamide (PAM) treatments from both shallow (15 cm) and deep (30 cm) sensors placed in the center of the bed and at the edge (shoulder) of the bed. Timing of the irrigation event is indicated by the black rectangle. Sensor configuration is shown in schematic (top).

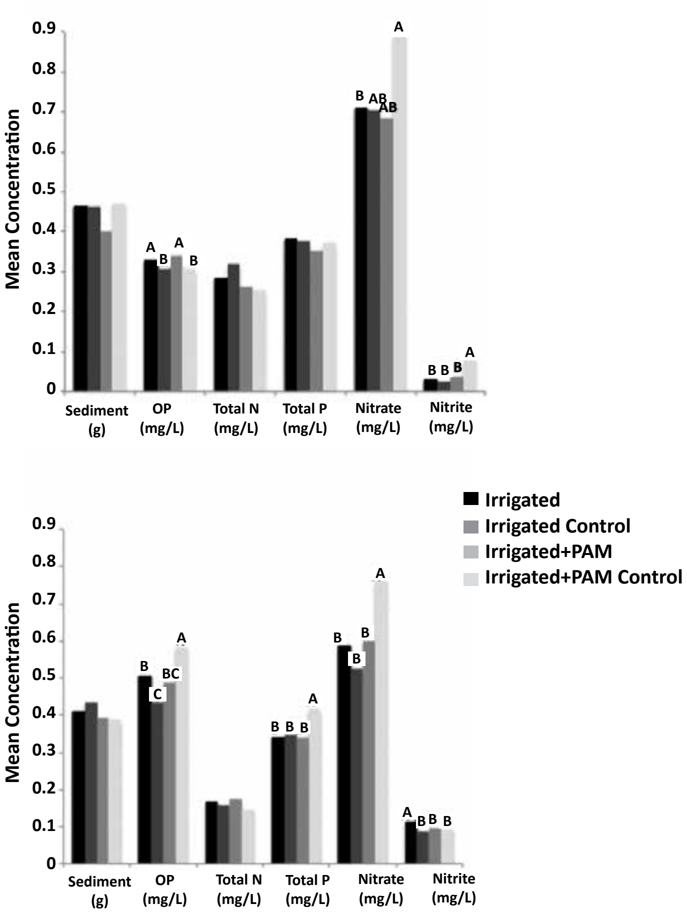

Fig. 3. Water quality results for irrigation events on 29 through 31 July (top) and 4 August (bottom). Different lettering indicates significant differences (P < 0.05). Control samples were collected at the beginning of each event directly from the polytubing. Irrigated and irrigated + polyacrylamide (PAM) samples were collected at the end of plots near field edge. OP = orthophosphate.

Evaluation of Post-Emergence Herbicide Options in Enlist™ Cotton

M.R. Miller[1], J.K. Norsworthy[1], C.J. Meyer[1], and M.P. Bararpour[1]

RESEARCH PROBLEM

Reliance on total post-emergence (POST) programs with a single mode of action (MOA) has resulted in the evolution of glyphosate-resistant weed species such as Palmer amaranth (*Amaranthus palmeri*). In a recent survey, glyphosate-resistant Palmer amaranth and barnyardgrass (*Echinochloa crus-galli*) were listed in the top ten most problematic weeds in cotton (Riar et al., 2013). As these and other herbicide-resistant and difficult-to-control weeds threaten cotton growers, new and effective control options are needed.

BACKGROUND INFORMATION

The introduction of a new herbicide-resistant trait technology available as Enlist™ cotton will allow over-the-top POST applications of 2,4-D, glyphosate, and glufosinate for difficult-to-manage weeds.

RESEARCH DESCRIPTION

A field experiment was conducted in 2015 at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center located in Keiser, Ark. The primary objective of this research was to evaluate the efficacy of utilizing various POST herbicides in Enlist cotton to control glyphosate-resistant Palmer amaranth and other difficult-to-manage weeds in cotton. The experimental design was a randomized complete block design with six herbicide programs plus a nontreated check. A multi-application approach was evaluated by utilizing Cotoran® (fluometuron) pre-emergence (PRE) followed by early POST (EPOST) and mid-POST (MPOST) herbicide applications. EPOST treatments consisted of Roundup® (glyphosate), Liberty® (glufosinate), or Enlist Duo® (2,4-D choline + glyphosate) applied alone or in combination with other herbicides

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[1] Graduate assistant, professor, graduate assistant, and post doctoral associate, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

(Refer to Table 1 for a complete treatment list). All herbicide treatments were applied with a CO_2-pressurized backpack sprayer with a 4-nozzle boom outfitted with 110015 AIXR nozzles calibrated to deliver 15 GPA at an application speed of 3 mph. The first application was made at planting, EPOST application at the 2- to 3-leaf growth stage of cotton, and MPOST application at the 5- to 6-growth leaf stage. Visual estimates of weed control were taken for Palmer amaranth and barnyardgrass 14 days after the MPOST application timing. Data were subjected to analysis of variance using JMP Pro 12 (SAS Institute, Inc., Cary, N.C.) and orthogonal contrast were used for program comparison.

RESULTS AND DISCUSSION

At the 14 days after MPOST evaluation timing, all programs that contained Enlist Duo provided a high level of glyphosate-resistant Palmer amaranth control (Table 1). Contrast analysis for Palmer amaranth indicated that as the number of effective modes of action increased, likewise weed control improved. Additionally, no significant differences were observed when comparing POST applications of Enlist Duo vs. Liberty, or Liberty + 2,4-D. This is consistent with previous research that reported Liberty and 2,4-D as effective POST options to control glyphosate-resistant Palmer amaranth (Culpepper et al., 2009; Norsworthy et al., 2008). However, due to the evolution of glyphosate-resistance, all POST programs provided a greater level of glyphosate-resistant Palmer amaranth control compared to Roundup alone.

High levels of barnyardgrass control were observed with all POST herbicide programs that contained Enlist Duo. Contrast analysis indicated that weed control improved as the number of effective modes of action increased. Additionally, all POST programs provided a high level of control with the exception of Liberty, which provided significantly lower control. Previous research has also reported annual grass control with Liberty as being less effective than that other herbicides (Gardner et al., 2006).

PRACTICAL APPLICATIONS

This research demonstrated that using Enlist on cotton will provide growers with a new tool that allows for improved weed control over current Roundup Ready systems in situations where glyphosate-resistant weeds persist. The herbicide programs evaluated in this research indicated that excellent weed control can be achieved with herbicide programs that contain multiple effective modes of action (Norsworthy et al., 2012). Furthermore, proper stewardship must be practiced to achieve the best protection of the Enlist technology, and it is vital that growers utilize PRE followed by POST residual herbicides as part of an integrated weed management program.

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Table 1. Influence of post-emergence (POST) herbicide programs on glyphosate-resistant Palmer amaranth and barnyardgrass controlab.

Treatment	Timing	Rate	Palmer amaranth control 14 days after MPOST	Barnyardgrass control 14 days after MPOST
		fl oz/A	--- % ---	--- % ---
Cotoran	PRE[†]	32	1 c[‡]	3 c
---	EPOST			
---	MPOST			
Cotoran	PRE	32	18 b	96 a
Roundup WeatherMAX	EPOST	22		
Roundup WeatherMAX	MPOST	22		
Cotoran	PRE	32	92 a	87 b
Liberty	EPOST	29		
Liberty	MPOST	29		
Cotoran	PRE	32	99 a	96 a
Enlist Duo	EPOST	75		
Eblist Duo	MPOST	75		
Cotoran	PRE	32	99 a	94 a
Liberty + 2,4-D	EPOST	29 + 32		
Enlist Duo	MPOST	75		
Cotoran	PRE	32	94 a	94 a
Enlist Duo	EPOST	75		
Liberty + 2,4-D	MPOST	29 + 32		
Cotoran	PRE	32	99 a	98 a
Liberty + 2,4-D + Dual Magnum	EPOST	29 + 32 + 16		
Enlist Duo	MPOST	75		
Contrasts[§]				
One mode of action vs. Two or more modes of action			***	***
Programs with Enlist Duo vs. Without			*	*
Enlist Duo EPOST vs. Enlist Duo MPOST			NS	NS

[†] PRE = Pre-emergence, EPOST = early post-emergence, MPOST = mid post-emergence.

[‡] Means within columns followed by different letters are significantly different using Fisher's least significant difference (α = 0.05).

[§] Contrasts were nonsignificant (NS) or significant at P ≤ 0.05 (*), P ≤ 0.01 (**), or P ≤ 0.001 (***) according to orthogonal contrasts.

Comparison of Brake Products to Cotoran Plus Caparol in Mid-South Cotton

M.L. Young[1], J.K. Norsworthy[1], L.T. Barber[1], and M.R. Miller[1]

RESEARCH PROBLEM

Reliance on total post-emergence (POST) programs with a single mode of action has resulted in evolution of glyphosate-resistant weed species such as Palmer amaranth, the most problematic weed in mid-South cotton (Riar et al., 2013). Recently, cases of fomesafen-resistant Palmer amaranth have been documented in Arkansas, Tennessee, Mississippi, and Kentucky, resulting in the need for new modes of action for weed control in cotton.

BACKGROUND INFORMATION

Fluridone, a group 12 herbicides, has been evaluated for several years as a pre-emergence (PRE) herbicide in cotton as it offers broad-spectrum control and long residual activity (Hill, 2015). SePRO Corporation (Carmel, Ind.) has recently developed two premix products for cotton that contain fluridone, including Brake F2® (fluridone + fomesafen (1.6 + 1.5 lb ai/gal)) and Brake FX® (fluridone + fluometuron (0.6 + 3.0 lb ai/gal)). These products offer multiple modes of action (MOA) and have a potential fit in cotton weed control programs across the mid-South.

RESEARCH DESCRIPTION

A field study was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Ark. on a silt-loam soil in 2015 to compare the newly developed Brake products to the current standard PRE cotton herbicides Cotoran (fluometuron) plus Caparol (prometryn). Following the three PRE herbicide applications of Brake F2, Brake FX, and Cotoran plus Caparol, applications of Liberty (glufosinate) were applied POST 14 days, 21 days, and 28 days, respectively (Table 1). Visual estimates of cotton injury and Palmer amaranth control were collected after three weeks after the final applica-

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[1] Graduate assistant, professor, post doctoral associate, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

tion (Fig. 1 and Table 1). The data were subjected to analysis of variance in JMP® Pro 12.1.0 (SAS Institute, Inc., Cary, N.C.) with means separated using Fisher's protected least significant difference test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The greatest level of injury (up to 41%) was caused by Brake F2 when assessed three weeks after final application, averaged over POST Liberty timings (Fig. 1). This injury significantly reduced cotton stand and height. This injury may have been intensified by the rainfall event that occurred during the PRE application. Brake FX caused only 8% injury to cotton, which was similar to the Cotoran plus Caparol standard used for comparison (Fig. 1). The treatments containing fomesafen applied PRE (Brake F2) resulted in the greatest amount of injury (Fig. 1). It has been previously reported that fomesafen can at times be injurious to cotton when applied PRE (Schrage et al., 2013); hence, all current fomesafen labels for cotton require applications be made prior to planting. All PRE herbicides that were followed by Liberty at 28 days after applying the PRE provided at least 98% control of Palmer amaranth (Table 1). Based on the results from this study, the fluridone-containing products do provide a high level of Palmer amaranth control and Brake FX is likely the preferred option in cotton due to the lower risk for injury to the crop compared to Brake F2.

PRACTICAL APPLICATIONS

This study showed that Brake FX provides a high level of Palmer amaranth control with minimal risk for injury to cotton. The integration of fluridone applied pre-emergence (PRE) into current herbicide programs aids in season long control of Palmer amaranth. Fluridone offers a solid foundation for cotton growers looking to integrate a new pre-emergence herbicide having an alternative MOA into their herbicide program.

ACKNOWLEDGMENTS

The authors thank the University of Arkansas System Division of Agriculture and SePRO for their support of this work.

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Table 1. Palmer amaranth control three weeks after final application.

Application Timing	Herbicide	Rate	Palmer amaranth control
		fl ounce/A	-----%-----
PRE	Brake F2	16	85d[†]
PRE	Brake FX	32	98ab
PRE	Cotoran + Caparol	32+32	92c
PRE	Brake F2	16	85d
14 d POST	Liberty	29	
PRE	Brake FX	32	98ab
14 d POST	Liberty	29	
PRE	Cotoran + Caparol	32+32	93bc
14 d POST	Liberty	29	
PRE	Brake F2	16	98a
21 d POST	Liberty	29	
PRE	Brake FX	32	98ab
21 d POST	Liberty	29	
PRE	Cotoran + Caparol	32+32	97abc
21 d POST	Liberty	29	
PRE	Brake F2	16	100a
28 d POST	Liberty	29	
PRE	Brake FX	32	99a
28 d POST	Liberty	29	
PRE	Cotoran + Caparol	32+32	98ab
28 d POST	Liberty	29	

[†] Means followed by the same letter are not significantly different according to Fisher's protected least significant difference test ($\alpha = 0.05$).

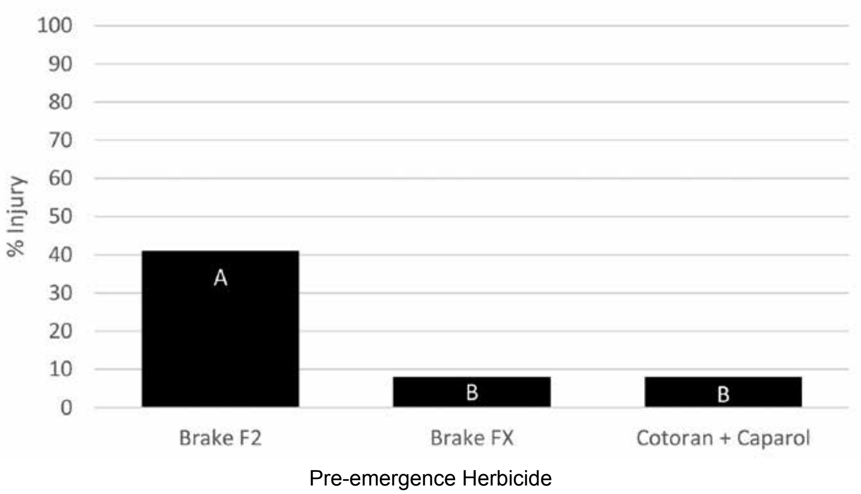

Fig. 1. Cotton injury 3 weeks after final application, averaged over post-emergence Liberty timing. Means with the same letter are not significantly different according to Fisher's protected least significant difference test (α = 0.05).

Identification of Antagonistic Tank-Mixtures in Enlist and Bollgard II® XtendFlex™ Cotton Systems

C.J. Meyer[1]*, J.K. Norsworthy*[1]*, M.T. Bararpour*[1]*, R.R. Hale*[1]*,*
S.M. Martin[1]*, and T. Barber*[2]

RESEARCH PROBLEM

The commercial release of Roundup Ready® Xtend and Enlist™ cropping systems will increase the number of herbicide products that can be applied post-emergence (POST) in soybean and cotton. As POST herbicide combinations of glyphosate, glufosinate, dicamba, and 2,4-D become more common, a greater understanding of how these herbicides are interacting in mixture is needed.

BACKGROUND INFORMATION

Cotton varieties with stacked herbicide-resistance traits granting resistance to 2,4-D, glyphosate, and glufosinate (Enlist™) and resistance to dicamba, glyphosate, and glufosinate (Bollgard II® XtendFlex™) are nearing commercial launch. However, prior research has demonstrated some mixtures of these products can lead to antagonism on various grass species such as glufosinate + 2,4-D (Craigmyle et al., 2013), glufosinate + dicamba (Merchant et al., 2013), glufosinate + glyphostate (Bethke et al., 2013) and glyphosate + dicamba (Meyer et al., 2015). Although antagonism has been reported using many of these tank mixtures, the results have been inconsistent and may be dependent upon the specific species evaluated. Therefore it is necessary to evaluate potential herbicide combinations of 2,4-D, dicamba, glyphosate, and glufosinate that could be used in Enlist and Xtend systems on hard-to-control weed species in the mid-South.

RESEARCH DESCRIPTION

Field experiments were conducted in 2015 at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center in Keiser, Ark., to evaluate potential herbicide interactions that could occur in

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[1] Graduate assistant, professor, post doctoral associate, graduate assistant, and graduate assistant, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

[2] Associate professor, Department of Crop, Soil, and Environmental Sciences. University of Arkansas System Division of Agriculture, Lonoke.

Enlist and Roundup Ready Xtend cropping systems. Various rates and combinations of glufosinate, glyphosate, dicamba, and 2,4-D were applied and evaluated for percent weed control (see Tables 1 and 2 for a complete list of treatments). Treatments were applied to large (25-30 cm) weeds. Control of Palmer amaranth, velvetleaf, prickly sida, and barnyardgrass by these herbicide treatments were evaluated 2 weeks after application (WAA) and analyzed for herbicide interactions based on Colby's method (Colby, 1967). To determine if a herbicide combination results in synergistic, additive, or antagonistic interaction, control values for the combination are compared to an expected value with a *t*-test ($\alpha = 0.05$). Expected values are calculated with the equation

$$E = (X + Y) - \left(\frac{X \times Y}{100}\right)$$

where *E* is the expected value, *X* is the control observed with herbicide 1 alone and *Y* is the control observed with herbicide 2 alone.

RESULTS AND DISCUSSION

In the Enlist experiment, glyphosate (dimethylamine salt) at 1120 g ae ha^{-1} controlled barnyardgrass 92%, whereas a premix of glyphosate (1120 g ae ha^{-1}) and 2,4-D (1065 g ae ha^{-1}) only controlled barnyardgrass 84% 2 WAA (Fig. 1). Similarly in the Roundup Xtend experiment, glyphosate (potassium salt) at 1540 g ae ha^{-1} controlled barnyardgrass 85% and glyphosate (1540 g ae ha^{-1}) + dicamba (560 g ae ha^{-1}) only controlled barnyardgrass 79%. (Fig. 2). In both experiments, control of Palmer amaranth was >85% for all mixtures, control of prickly sida was >80% for all mixtures, and control of velvetleaf was >80% for all mixtures (data not shown). For the broadleaf weeds, control with mixtures of two or more products was equal to or greater than control with either product alone.

PRACTICAL APPLICATIONS

Based upon these results, applying glyphosate with 2,4-D or dicamba on large (30 cm) barnyardgrass produces antagonism compared to glyphosate alone. If Roundup Xtend or Enlist cropping systems become widely adopted, herbicide applicators need to be aware of antagonistic interactions and the implications of antagonism on herbicide-resistance management.

ACKNOWLEDGMENTS

The authors thank Bayer Crop Science for funding this research. Support also provided by the University of Arkansas System Division of Agriculture.

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Table 1. Post-emergence herbicide programs for Enlist™ experiment including treatment number, herbicide common name, herbicide product name, and rate of herbicide applied.

Treatment	Common name	Product name	Rate
			g ai ha^{-1}
1	Glufosinate	Liberty	595
2	Glyphosate	Durango	1120[a]
3	2,4-D	Weedar	1065
4	Glyphosate + 2,4-D	Enlist Duo	1120[a] + 1065[a]
5	Glufosinate + glyphosate	Liberty + Durango	595 + 1120[a]
6	Glufosinate + 2,4-D	Liberty + Weedar	595 + 1065[a]
7	Glufosinate + glyphosate + 2,4-D	Liberty + Enlist Duo	595 + 1120[a] + 1065[a]

[a] Rate is in grams acid equivalent per hectare.

Table 2. Post-emergence herbicide programs for Xtend® experiment including treatment number, herbicide common name, herbicide product name, and rate of herbicide applied.

Treatment	Common name	Product name	Rate	Adjuvant[a]
			g ai ha^{-1}	
1	Glufosinate	Liberty	595	
2	Glyphosate	Roundup Powermax	1260[b]	
3	Dicamba	Clarity	560[b]	NIS
4	Glyphosate + dicamba	Roundup Powermax + Clarity	1260[b] + 561[b]	
5	Glufosinate + dicamba	Liberty + Clarity	595 + 560[b]	NIS
6	Glufosinate + glyphosate	Liberty + Roundup Powermax	595 + 1262[b]	
7	Glufosinate + glyphosate + dicamba	Liberty + Roundup Powermax + Clarity	595 + 1260[b] + 561[b]	

[a] NIS, nonionic surfactant.

[b] Rate is in grams acid equivalent per hectare.

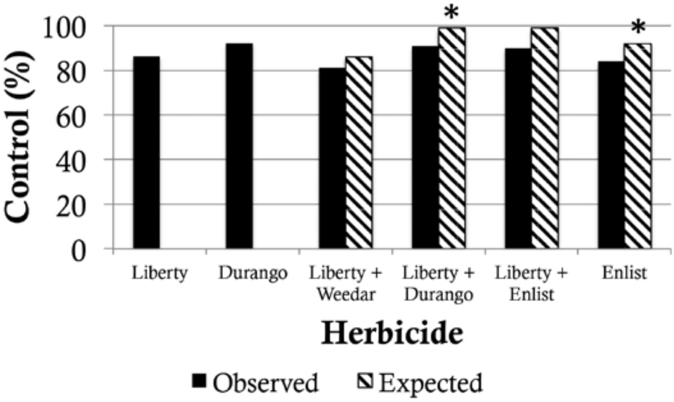

Fig. 1. Barnyardgrass control 2 weeks after treatment in the Enlist™ experiment. Expected values with a * over the bar indicate it is significantly different from the observed value according to a *t*-test.

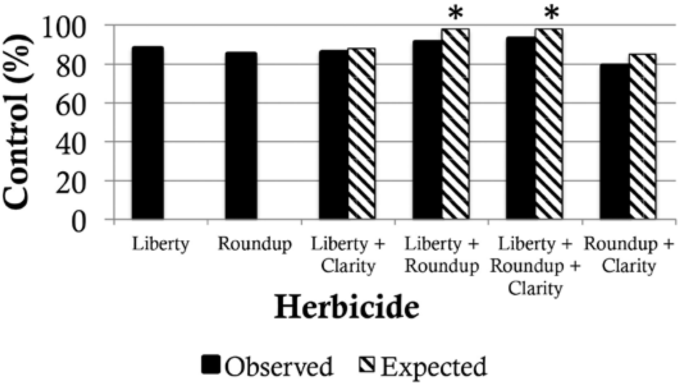

Fig. 2. Barnyardgrass control 2 weeks after treatment in the Xtend® experiment. Expected values with a * over the bar indicate it is significantly different from the observed value according to a *t*-test.

Residual Weed Control of Palmer Amaranth in Cotton with Brake Premixes

Z. Hill[1]*, T. Barber*[2]*, L. Collie*[2]*, R. Doherty*[1]*, and A. Ross*[2]

RESEARCH PROBLEM

Since 2006, herbicide-resistant Palmer amaranth (*Amaranthus palmeri*) has been considered the most troublesome broadleaf weed in Arkansas crops; including corn (*Zea mays*), cotton (*Gossypium hirsutum*), and soybean (*Glycine max*). Currently, Palmer amaranth has been confirmed to be resistant to five herbicide mechanisms of action (MOA), those being microtubule assembly inhibitors, photosystem (PS) II-inhibitors, acetolactate synthase (ALS) inhibitors, 5-enolpyruvyl shikimate-3-phosphate synthase (EPSPS) inhibitors, and protoporhyringon oxidase inhibitors (Heap, 2016). These five herbicide MOAs were frequently used for control of Palmer amaranth prior to the onset of resistance (Young, 2006). Without the development and commercialization of a new MOA in the foreseeable future, the need for a different yet currently commercialized herbicide MOA is greatly needed.

BACKGROUND INFORMATION

Fluridone, a Weed Science Society of America Group 12 herbicide, inhibits phytoene desaturase in plants and was found to provide extended residual control of an *Amaranthus* spp. when applied pre-emergence (PRE). Additionally, a high tolerance to fluridone been observed in cotton (Waldrep and Taylor, 1976). Fluridone was reported to remain in the soil for extended periods of time, which is highly dependent upon soil texture, organic matter, and pH (Banks et al., 1979). As a result of fluridone's favorable characteristics, utilizing fluridone in an Arkansas cotton herbicide program could be highly beneficial in controlling this troublesome weed. In recent years, fluridone has been incorporated into a pre-mixed formulation with fomesafen and fluometuron to aid in controlling herbicide-resistant Palmer amaranth as well as providing an additional mechanism of action (MOA) to reduce further resistance evolution.

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[1] Weed program associates, University of Arkansas System Division of Agriculture, Southeast Research and Extension Center, Monticello.

[2] Associate professor and program technicians, respectively, Weed Science, Department of Crop, Soil, and Environmental Science, University of Arkansas System Division of Agriculture, Lonoke Extension Center, Lonoke.

RESEARCH DESCRIPTION

An experiment was conducted at two University of Arkansas System Division of Agriculture locations in 2015: the Lon Mann Cotton Research Station in Marianna, Ark. and the Rohwer Research Station in Rohwer, Ark. The experiment was setup as a randomized complete block design, with four replications. Herbicide treatments included fluridone+fomesafen (Brake F2) applied PRE at 0.325 lb ai/acre, fluridone+fluometuron (Brake FX) applied PRE at 0.9 lb ai/acre, fluometuron (Cotoran) + prometryn (Caparol) both applied PRE at 0.5 lb ai/acre, and fomesafen (Reflex) applied PRE at 0.25 lb ai/acre; all of which were applied alone or followed by glufosinate (Liberty 280) applied post-emergence (POST) at 0.53 lb ai/acre at 14, 21, and 28 days after application A (PRE). Herbicide treatments were applied with a CO_2-pressurized sprayer calibrated to deliver 12 gal/acre. Weed control and crop injury (data not shown) was taken on a scale of 0% to 100%, with 0% being no control or injury and 100% being complete control or death of the plant. Data were subjected to analysis of variance and means were separated using Fisher's protected least significant difference test ($\alpha = 0.05$). Data were analyzed separately by location.

RESULTS AND DISCUSSION

Upon initial evaluation, all treatments provided comparable control of Palmer amaranth, regardless of the location (Fig. 1). At 3 weeks after application (WAA), control of Palmer amaranth remained >90% from all treatments at the Marianna location. Palmer amaranth control decreased drastically at the Rohwer location, with no treatment providing >83% (Fig. 2). The drastic decrease in control at Rohwer is likely attributed to receiving higher levels of rainfall than Marianna, which may have resulted in the loss of the herbicides sooner. It was evident that the POST application of glufosinate increased the control of Palmer amaranth over that of treatments lacking a POST application, with the fluridone+fomesafen, fluridone+-fluometuron, and fluometuron + prometryn followed by (fb) glufosinate applied 14 days after application (DAA) providing 83%, 83%, and 80% control, respectively. By 5 WAA, Palmer amaranth control had diminished for most of the evaluated treatments at Marianna; albeit, the PRE fb POST at 14 and 21 DAA treatments continued to provide >90% control (Fig. 3). The PRE fb POST at 28 DAA treatments all provided <80% control of Palmer amaranth, which is likely attributed to the POST application of glufosinate being applied to large Palmer amaranth plants. By 5 WAA at Rohwer, most of the PRE fb POST at 21 DAA treatments provided ≥85% control of Palmer amaranth, whereas all remaining treatments provided <85% control (Fig. 3).

PRACTICAL APPLICATIONS

This data suggests that fluridone can provide good control of Palmer amaranth for an extended period of time; however, this is highly dependent upon location and environmental conditions. In order to overcome this issue, premixing fluridone with common cotton PRE herbicides can be beneficial in controlling this weed; however, an extensive program with multiple POST applications will be required for providing excellent control of Palmer amaranth.

ACKNOWLEDGMENTS

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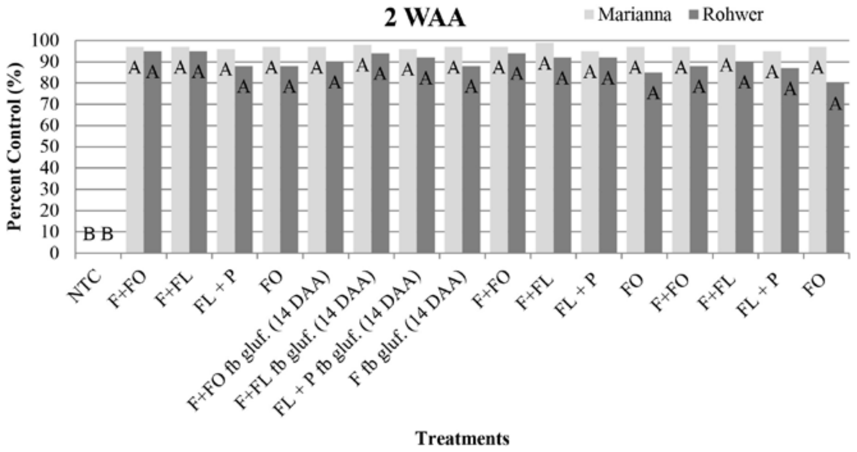

Fig. 1. Palmer amaranth control 2 weeks after application A (WAA) at the Lon Mann Cotton Research Center at Marianna, Ark., and the Rohwer Research Station at Rohwer, Ark., in 2015. Abbreviations: nontreated control (NTC), fluridone (F), fomesafen (FO), fluometuron (FL), prometryn (P), glufosinate (gluf.), days after application (DAA).

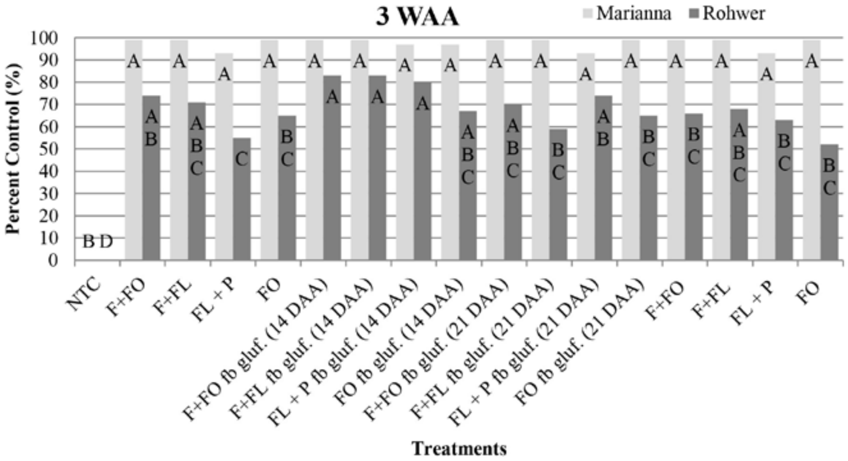

Fig. 2. Palmer amaranth control 3 weeks after application A (WAA) at the Lon Mann Cotton Research Center at Marianna, Ark., and the Rohwer Research Station at Rohwer, Ark., in 2015. Abbreviations: nontreated control (NTC), fluridone (F), fomesafen (FO), fluometuron (FL), prometryn (P), glufosinate (gluf.), days after application (DAA).

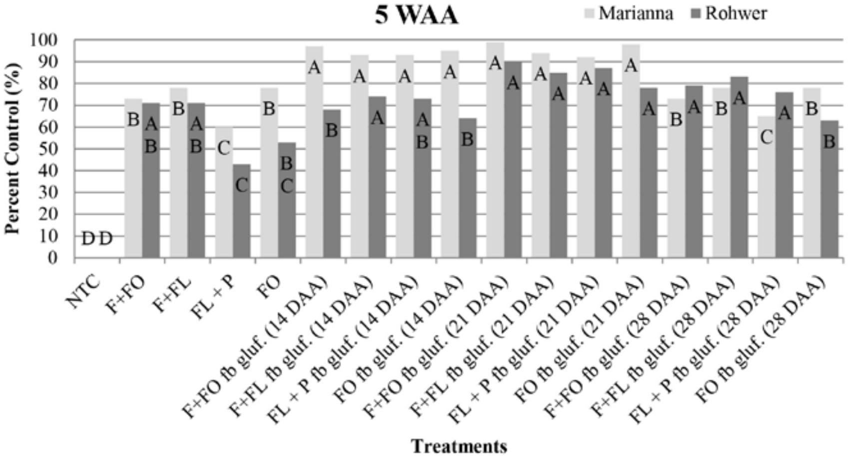

Fig. 3. Palmer amaranth control 5 weeks after application A (WAA) at the Lon Mann Cotton Research Center at Marianna, Ark., and the Rohwer Research Station at Rohwer, Ark., in 2015. Abbreviations: nontreated control (NTC), fluridone (F), fomesafen (FO), fluometuron (FL), prometryn (P), glufosinate (gluf.), days after application (DAA).

Effect of Cereal Rye, Seeding Rate, and Planting Method on Weed Control in Cotton

M. Palhano[1], J. Norsworthy[1], T. Barber[2], and M. Barарpour[1]

RESEARCH PROBLEM

Recently, cotton growers have struggled with weed management mainly due to herbicide-resistant weeds (Sosnoskie and Culpepper, 2014). The recent confirmation of protoporphyrinogen oxidase inhibitor (PPO)-resistant Palmer amaranth in the mid-South has increased the concern about sustainability of weed management in cotton production systems. Relying only on herbicides, especially on one mode of action, is no longer a sustainable option for controlling weeds. Hence, integrating herbicide programs with cultural practices is extremely necessary to preserve the existing technologies and herbicides available for an extended period of time.

BACKGROUND INFORMATION

The use of cover crops in conservation tillage has become a major topic for those growers who intend to capitalize federal conservation payments and incorporate sustainable practices in the agricultural system. Long-term effects such as increased organic matter, reduced soil erosion and carbon sequestration are often overlooked because they are cumulative and difficult to measure. In contrast, the short-term effects such as weed control, nitrogen credits and yield improvement are frequently used as parameter of cover crop effectiveness. Cover crops can reduce weed emergence, by physical and allelochemical suppression and increase yields (Creamer et al., 1996; Bauer and Roof, 2004).

RESEARCH DESCRIPTION

A field experiment was conducted at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. in 2014 and 2015 to determine the effect of cereal rye seeding rate, and planting method on weed control in cotton. Cereal rye was sown in the

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[1] Graduate assistant, professor, and post doctoral associate, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

[2] Associate professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Little Rock.

early fall of 2013 and 2014 and chemically terminated 21 days before cotton planting in the spring of 2014 and 2015. At cotton planting, aboveground cereal rye biomass was collected from 2 random 0.5 m^2 quadrats in each plot. The cotton (*Gossypium hirsutum*) cultivar used in the studies was ST 4946 GLB2 planted on a 91-cm row spacing at a seeding rate of 123,000 seeds ha^{-1}. Experimental design was a randomized completely block with a split plot where the main plot was cereal rye seeding rates of 0, 56, 112, and 168 kg ha^{-1} in the absence or presence of a standard herbicide program. Subplots consisted of drilled and broadcasted planting methods. The herbicide program utilized in this study was fluometuron (1.1 kg ai ha^{-1}) applied at cotton planting, glufosinate (0.6 kg ai ha^{-1}) plus S-metolachlor (1 kg ai ha^{-1}) at 14 and 28 days after planting (DAP) and flumioxazin (0.07 kg ai ha^{-1}) plus MSMA (2.2 kg ai ha^{-1}) as layby application 56 DAP. Palmer amaranth emergence and visual weed control were evaluated throughout the growing season and seedcotton yield data were also collected. All data were subjected to analysis of variance with MIXED procedures in JMP 12 PRO (SAS Institute, Inc., Cary, N.C.).

RESULTS AND DISCUSSION

No significant differences were observed between planting methods in any parameter evaluated, with an exception of the biomass production at the seeding rate of 56 kg ha^{-1} in 2015. Cereal rye biomass production increased as seeding rate increased in both years (Table 1). Cereal rye biomass influenced the weed control obtained each year in absence of herbicides. When herbicides were not applied, cereal rye at 56 kg/ha provided the least weed control. Cereal rye at 112 and 168 kg ha^{-1} provided comparable levels of weed control. Cereal rye by itself was more effective on Palmer amaranth suppression than broadleaf signalgrass. All plots treated with a standard herbicide program had Palmer amaranth control greater than 98% regardless of the seeding rate (Table 2). Yields from plots with the standard herbicide program were significantly higher than from plots without herbicides, independent of seeding rates (data not shown). Yield improvement was observed due to use of cereal cover crop in the system compared to no cover crop in 2014; whereas no differences were observed in 2015.

PRACTICAL APPLICATIONS

Based on the results observed in these studies, it can be concluded that greater amounts of cover crop residues are required to achieve a higher level of weed control when herbicides are not applied. Thus, increased seeding rate can increase the biomass produced by cereal rye. Weed control provided by cereal rye itself is considerable, but still not acceptable. Hence, integrating herbicides into the system is needed to obtain an acceptable level of weed control and higher yields. The long-term effect of cover crop was not measured in this study due to the short period of the research. Nevertheless, it is important to understand that even though most of the time these effects are overlooked, they ought to be considered along with short-term effects when using cover crops.

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Table 1. Cover crop biomass in kg ha^{-1} prior to cotton planting in 2014 and 2015.

Seeding rate (kg ha^{-1})	Planting method	Year 2014	Year 2015
56	Broadcast	3109 c[†]	2429 c
	Drill	3008 c	2609 d
112	Broadcast	3941 b	3299 b
	Drill	4049 b	3229 b
158	Broadcast	4439 a	3735 a
	Drill	4476 a	3603 a

[†] Numbers within a column followed by the same letter are not significantly different at $P = 0.05$.

Table 2. Palmer amaranth control (%) in absence and presence of herbicide program as influenced by cereal rye seeding rate at 56 DAP in 2014 and 2015.

Seeding rate (kg ha^{-1})	Herbicide program	Year 2014	Year 2015
No cover crop	No herbicide	-	-
	Herbicide	100 a[†]	100 a
56	No herbicide	73 c	60 c
	Herbicide	99 a	100 a
112	No herbicide	82 b	64 c
	Herbicide	98 a	100 a
158	No herbicide	83 b	74 b
	Herbicide	100 a	100 a

[†] Numbers within a column followed by the same letter are not significantly different at $P = 0.05$.

Pethoxamid Weed Control Systems in Arkansas Cotton

R.C. Doherty[1], L.T. Barber[2], L.M. Collie[3], Z.T. Hill[2] and A.W. Ross[3]

RESEARCH PROBLEM

Controlling troublesome weeds such as, glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), remains a major concern for cotton (*Gossypium hirsutum*) growers in Arkansas. The ever increasing Palmer amaranth herbicide tolerance to protoporphyrinogen oxidase inhibitor (PPO) herbicides proves the need for new herbicide options and the use of multiple modes of action in season. These herbicide systems must be applied timely to control this evasive weed. Pethoxamid provides an opportunity and the flexibility to use multiple modes of action pre-emergence or over-the-top of cotton for improved control of many weeds including Palmer amaranth and barnyardgrass. The objective of this study was to evaluate pethoxamid for crop response and weed control.

BACKGROUND INFORMATION

Palmer amaranth being resistant to glyphosate and acetolactate synthase (ALS) and showing tolerance to PPO herbicides continues to force evolution in Arkansas cotton weed control programs. Jursik et al. (2013) found that pethoxamid provided good control of redroot pigweed and barnyardgrass when applied pre-emergence in sunflower. Presently no single herbicide will provide adequate control of Palmer amaranth; full-season herbicide systems must be used (Scott et al., 2016). More information is needed on crop tolerance and weed control provided by pethoxamid.

RESEARCH DESCRIPTION

One trial was conducted in 2015 at the University of Arkansas System Division of Agriculture Rohwer Research Station in Rohwer, Ark. The trial was estab-

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[1] Program associate, University of Arkansas System Division of Agriculture Southeast Research and Extension Center, Monticello.

[2] Associate professor, program associate, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Little Rock.

[3] Program technicians, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture Lonoke Extension Center, Lonoke.

lished in a Desha silt loam soil. The design was a randomized complete block with four replications. Treatments were applied at five timings pre-emergence, 2-leaf, 4-leaf, or 8-leaf cotton and Layby. Herbicides used were pethoxamid, diuron, acetochlor, S-metolachlor, glyphosate, glufosinate, flumioxazin, and monosodium methanearsonate (MSMA). These herbicides were applied alone and in combination to create a complete weed control system. All treatments were applied using a compressed air sprayer calibrated to deliver 12 gallons per acre. Means were separated using Fishers protected least significant difference test ($P = 0.05$). Weed control and cotton injury were recorded on a 0-100 scale with 0% being no control or crop injury and 100% being complete control or death of the crop.

RESULTS AND DISCUSSION

Cotton injury was 13% or less with all treatments 14 days after the 1st application. At nine days after the 2nd application, cotton injury was 3% or less, and at 21 days after the 2nd application, cotton injury was undetectable (data not shown). At fifteen days after the 4th application, Diuron followed by (fb) S-metolachlor plus glyphosate fb S-metolachlor plus glyphosate and Diuron fb pethoxamid plus glufosinate fb pethoxamid plus glufosinate provided 94 and 95% control of Palmer amaranth, respectively (Fig. 1). All other treatments provided 73% or less control. Diuron fb S-metolachlor plus glyphosate fb S-metolachlor plus glyphosate, Diuron fb pethoxamid plus glufosinate fb pethoxamid plus glufosinate, Diuron fb pethoxamid plus glyphosate fb pethoxamid plus glyphosate all provided 84% control of morningglory (*Ipomoea lacunosa*). All other treatments provided 78% or less control. All treatments provided 95% or greater control of barnyardgrass (*Echinochloa crus*-galli) (Fig. 1). Diuron fb S-metolachlor plus glyphosate fb S-metolachlor plus glyphosate fb flumioxazin plus MSMA and Diuron fb pethoxamid plus glufosinate fb pethoxamid plus glufosinate fb flumioxazin plus MSMA provided 92 and 94% control of Palmer amaranth, respectively 20 days after emergence (DAE); Fig. 2. All other treatments provided 73% or less control. At 20 DAE, Diuron fb S-metolachlor plus glyphosate fb S-metolachlor plus glyphosate fb flumioxazin plus MSMA and Diuron fb pethoxamid plus glufosinate fb pethoxamid plus glufosinate fb flumioxazin plus MSMA both provided 84% control of morningglory, while all other treatments provided 81% or less control. Diuron fb S-metolachlor plus glyphosate fb S-metolachlor plus glyphosate fb flumioxazin plus MSMA, Diuron fb pethoxamid plus glufosinate fb pethoxamid plus glufosinate fb flumioxazin plus MSMA, and Diuron fb pethoxamid plus glyphosate fb pethoxamid plus glyphosate fb flumioxazin plus MSMA all provided 99% control of barnyardgrass, while all other treatments provided 94% or less control. In this study herbicide systems that contained three separate applications of residual herbicides, in season, provided better weed control than those that contained two. Systems that contained multiple modes of action in the 2-, 4-, or 8-leaf cotton applications also provided better weed control (Fig. 2).

PRACTICAL APPLICATIONS

Pethoxamid systems can provide good control of Palmer amaranth, morningglory, and barnyardgrass, while causing minimal injury to the cotton crop. The addition of pethoxamid into Arkansas cotton herbicide systems will provide an additional mode of action and may increase our success over ever-growing herbicide resistant weeds, such as Palmer amaranth. These data will be used to make weed control recommendations across the state.

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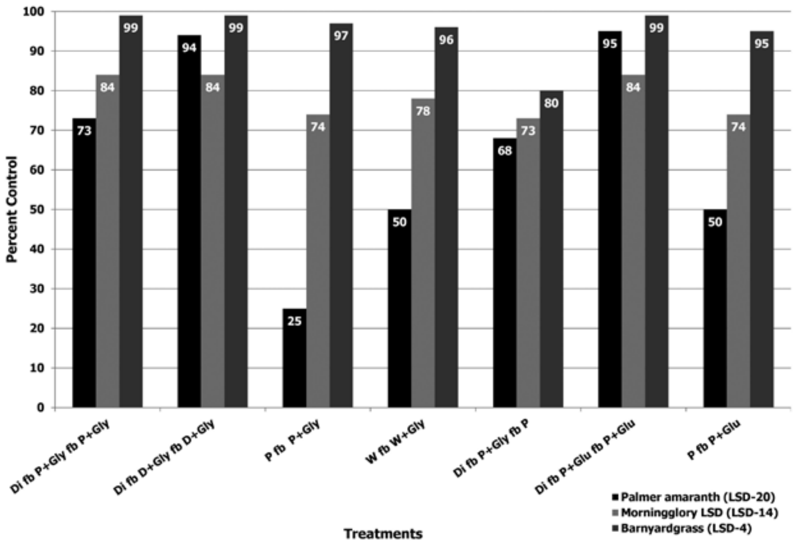

Fig. 1. 2015 Weed Control 15 days after 4th application at the University of Arkansas System Division of Agriculture Rohwer Research Station, in Rohwer, Ark. Di-Diuron 0.75 lb ai/acre, P-Pethoxamid 1 lb ai/acre, D-Dual Magnum 1 lb ai/acre, W-Warrant 1.13 lb ai/acre, Gly-Glyphosate 0.75 lb ae/acre, Glu-Glufosinate 0.53 lb ai/acre, LSD-least significant difference.

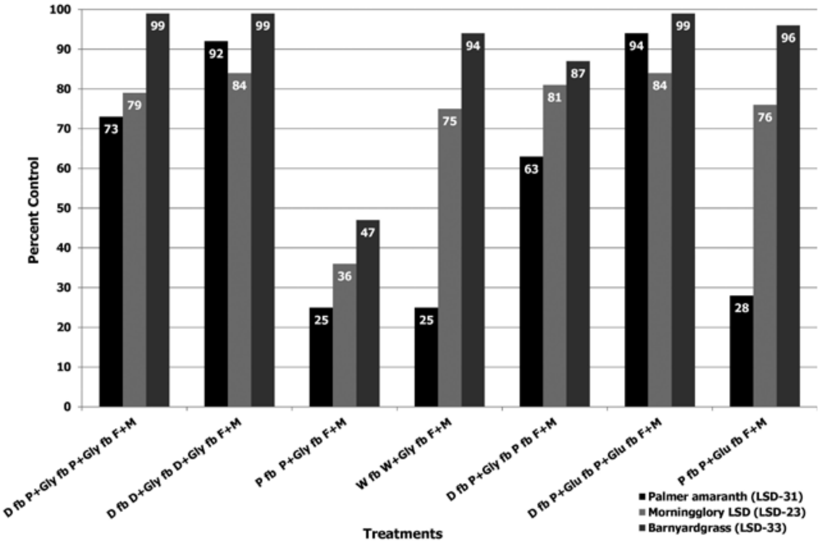

Fig. 2. 2015 Weed Control 20 days after emergence at the University of Arkansas System Division of Agriculture Rohwer Research Station, in Rohwer, Ark. Di-Diuron 0.75 lb ai/acre, P-Pethoxamid 1 lb ai/acre, D-Dual Magnum 1 lb ai/acre, W-Warrant 1.13 lb ai/acre, Gly-Glyphosate 0.75 lb ae/acre, Glu-Glufosinate 0.53 lb ai/acre, F-Flumioxazin 0.064 lb ai/acre, monosodium acid methanearsonate 2 lb ai/acre, LSD-least significant difference.

Weed Control Programs Using Engenia™ in XtendFlex™ Cotton

L.M. Collie[1], L.T. Barber[1], R.C. Doherty[2], Z.T. Hill[2], and A.W. Ross[1]

RESEARCH PROBLEM

Palmer amaranth *(Amaranthus palmeri)* is a devastating weed in Arkansas crop production and is confirmed to be resistant to four modes of action including acetolactate synthase (ALS), dinitroanaline (DNA), 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), and most recently, resistance to protoporphyrinogen oxidase (PPO) herbicides. Resistant Palmer amaranth is the most problematic weed in mid-South cotton (Riar et al., 2013). Herbicides such as Engenia™ could offer a new mode of action in controlling resistant Palmer amaranth when paired with dicamba resistant cotton cultivars such as XtendFlex™ cotton.

BACKGROUND INFORMATION

The BASF company recently announced the development of Engenia™, a new formulation of dicamba, for use in the fight against herbicide-resistant Palmer amaranth and other difficult-to-control broadleaves. This new formulation of dicamba has reduced volatility characteristics due to the development of the new salt formulation of dicamba: N, N-Bis (3-aminopropyl) methylamine (BAPMA) salt (Norsworthy et al., 2015). This product will be intended for use in dicamba-resistant crops, such as XtendFlex™ cotton, and can be applied both pre-emergence or post-emergence (POST) in crop, with the majority of the activity from POST applications. Under a prolonged period without rainfall following application, dicamba may provide some residual control of broadleaf weeds.

RESEARCH DESCRIPTION

This trial was conducted to evaluate Engenia when applied in a full program approach in conjunction with PRE and other POST herbicides. These trials were

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[1] Program technician, associate professor, and program technician, respectively, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Lonoke Extension Center, Lonoke.

[2] Program associates, University of Arkansas System Division of Agriculture, Southeast Research and Extension Center, Monticello.

conducted in 2015 on 38-inch rows at the University of Arkansas System Division of Agriculture Lon Mann Cotton Research Center, Marianna, Ark. and at the University of Arkansas System Division of Agriculture Rohwer Research Station, Rohwer, Ark. Palmer amaranth and Pitted Morningglory (*Ipomoea lacunose*) were overseeded at planting to provide a consistant weed population. The trial consisted of 8 herbicide programs comprised of pre-emergence (PRE), early post-emergence (EPOST), and late post-emergence (LPOST) applications.

RESULTS AND DISCUSSION

Greatest control of Palmer amaranth at two weeks after the EPOST application was observed in treatments 2, 3, and 4, and contained a PRE followed by an EPOST application regardless of which PRE was used. Control was maintained in treatments using PRE herbicides 14 days after the LPOST applications (Fig. 1). Delaying POST applications to later timings greatly decreased control of Palmer amaranth with Engenia. No differences were observed 2 weeks after LPOST applications and end-of-season control ratings of morningglory (Fig. 2). Less than 10% injury was observed at 14 days after EPOST application, resulting in no significant differences. Treatments containing PRE applications produced the highest yields. The greatest yield reduction was a result of POST only applications made later in the season (Fig. 3).

PRACTICAL APPLICATIONS

When used in XtendFlex™ cotton, Engenia, provided better control of Palmer amaranth and morningglory in a full herbicide program. Residual herbicides at planting and early post-emergence are crucial in making Engenia successful in the XtendFlex system. Future research will be conducted to explore Engenia tank-mixes and determine efficacy on difficult to control broadleaves.

ACKNOWLEDGMENTS

Support provided by the University of Arkansas System Division of Agriculture.

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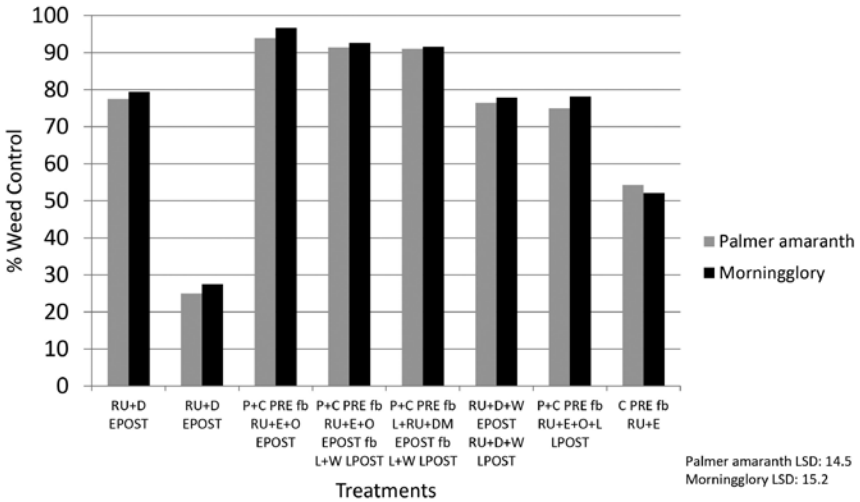

Fig. 1. Palmer amaranth (PA) and Morningglory control at the University of Arkansas System Division of Agriculture, Rohwer Research Station, in Rohwer, Ark. 14 days after the early post (EPOST) application. Abbreviations: Late post application (LPOST), Roundup Powermax (RU), Dicamba (D), Prowl H_2O (P), Cotoran (C), Engenia (E), Outlook (O), Liberty (L), Warrant (W), and Dual Magnum (DM).

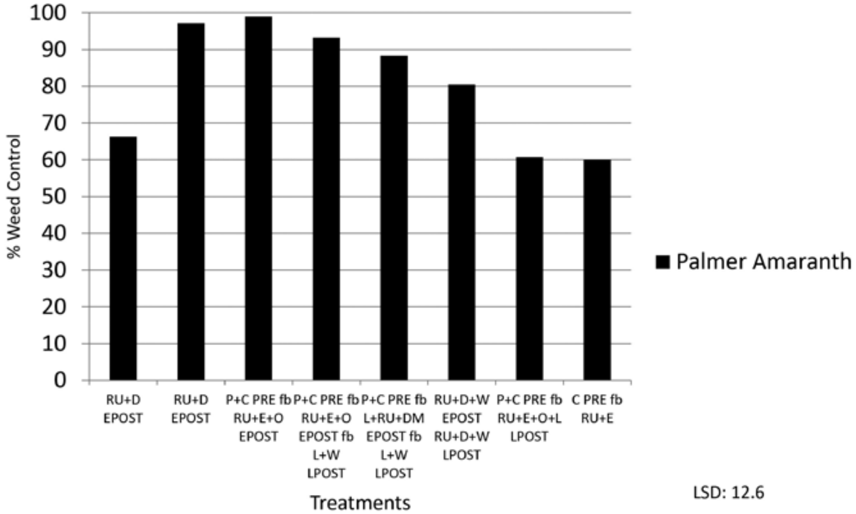

Fig. 2. Visual estimates of Palmer amaranth control at the University of Arkansas System Division of Agriculture, Rohwer Research Station, in Rohwer, Ark. 14 days after the late post (LPOST) application. No differences were observed in Morningglory control. Abbreviations: Late post application (LPOST), Early post application (EPOST), Roundup Powermax (RU), Dicamba (D), Prowl H_2O (P), Cotoran (C), Engenia (E), Outlook (O), Liberty (L), Warrant (W), and Dual Magnum (DM).

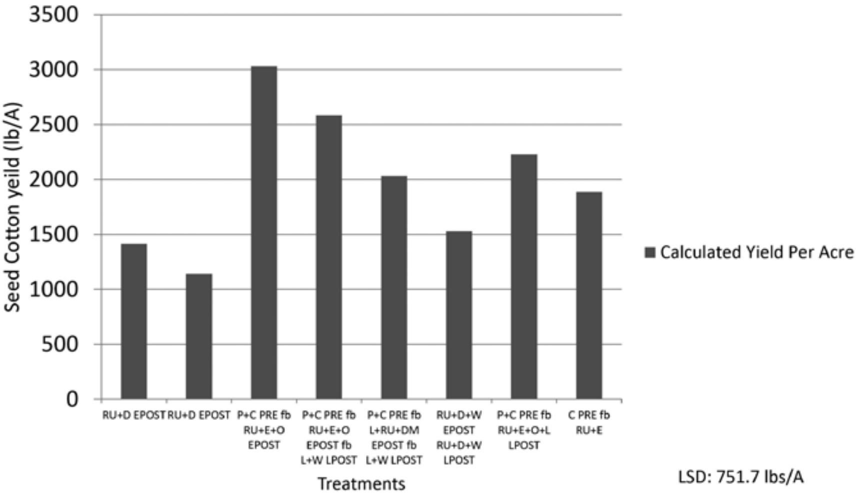

Fig. 3. Influence of herbicide program on seed cotton yield at the University of Arkansas System Division of Agriculture, Rohwer Research Station, in Rohwer, Ark. Abbreviations: Late post application (LPOST), Early post application (EPOST), Roundup Powermax (RU), Dicamba (D), Prowl H_2O (P), Cotoran (C), Engenia (E), Outlook (O), Liberty (L), Warrant (W), and Dual Magnum (DM).

Looking for Better Ways to Control Thrips

W.A. Plummer[1], G.M. Lorenz III[1], N.M. Taillon[1], H.M. Chaney Jr[1], and J. Black[1]

RESEARCH PROBLEM

With the potential banning of the neonicotinoid class of insecticides, there is a need to look at alternatives for thrips control. Efficacy data on new and currently labeled products will help in proper selection of treatments for consultants and producers. A trial was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. to evaluate the efficacy of insecticide seed treatments (IST), and in-furrow (IF) sprays for thrips management in cotton.

BACKGROUND INFROMATION

Thrips are an early-season cotton pest that have the potential to cause delayed maturity and yield loss in cotton. Typical symptoms of thrips damage on young cotton include ragged crinkled leaves that curl upward, "burnt" edges, and a silvery appearance. The level of damage varies from year to year based on the population of thrips (Hopkins et al., 2001). Thrips are the second most damaging cotton pest, infesting 100% of all Arkansas cotton acreage from 2006 to 2014, and the average cost of control and economic loss was around 8 million dollars (Williams et al., 2006-2015). In the last several years, thrips have become an increasingly difficult pest to control. Insecticide seed treatments followed by a foliar application are commonly needed to achieve control which makes it one of the most economic pests in Arkansas. Neonicotinoid insecticide seed treatments have been the standard for controlling thrips in Arkansas; however, recent studies have indicated that tolerance/resistance has developed to thiamethoxam (Cruiser/Avicta) (Plummer et al., 2014).

RESEARCH DESCRIPTION

A trial was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. Plot size was 12.5

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[1] Program associate, associate department head, program associate, program associate, and program technician respectively, Department of Entomology, University of Arkansas System Division of Agriculture, Lonoke Extension Center, Lonoke.

ft by 40 ft in a randomized complete block with 4 replications. Insecticide seed treatments (IST) consisted of Fortenza (cyantraniliprole) 0.2 mg ai/seed, Dermacor (chlorantraniliprole) 11.35 oz/cwt, Orthene (acephate) 15 oz/cwt, and Aeris Seed Applied System (imidacloprid) 21.32 oz/cw; in-furrow (IF) treatments were Orthene (acephate) 1lb/acre, Blackhawk (spinosad) 3.3 oz/acre, Dermacor (chlorantraniliprole) 2.13 oz/acre, and Verimark (cyantraniliprole) 13 oz/acre. All treatments, including the untreated check (UTC), had a base fungicide of Trilex Advanced 1.6 oz/cwt. Insecticide seed treatments were applied using a small batch seed treater. In-furrow treatments were applied at planting using an in-furrow sprayer fitted with a Tee Jet 9001VS flat fan nozzle. Spray volume was 10 gal/acre, at 40 psi. Insect density was determined by collecting 5 plants per plot at 19 and 26 days after planting (DAP) in jars with a 70/30 alcohol solution. Plants were washed and filtered in the lab at the Lonoke Extension Center, Lonoke, Ark., and thrips were counted using a dissecting scope (Burris et al., 1990). Thrips damage ratings were taken at 21 and 28 DAP using the scale: 0 = no damage, 5 = plant loss. Data was processed using Agriculture Research Manager Version 9 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted and Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

RESULTS AND DISCUSSION

At 19 DAP, all treatments had fewer thrips than the UTC except Fortenza, Dermacor, and Blackhawk (Fig. 1), while Verimark and Aeris Seed Applied System had fewer thrips than Blackhawk. At 26 DAP, the only treatments with fewer thrips than the UTC were Verimark and Aeris Seed Applied System (Fig. 2). At 21 DAP, all treatments reduced damage compared to the UTC except for Dermacor; and Aeris Seed Applied System reduced damage below all treatments (Table 1). Verimark, Aeris Seed Applied System, and Blackhawk reduced damage below the UTC at 28 DAP. Verimark and Aeris Seed Applied System had less damage than Blackhawk. Dermacor was the only treatment with a yield higher than the UTC, but did not differ from Dermacor, Verimark, Fortenza, or Blackhawk (Fig. 3).

PRACTICAL APPLICATIONS

Verimark can achieve the same level of control as today's standards such as Aeris Seed Applied System; however, it would be impractical for growers to implement this method of application compared to using a neonicotinoid IST. With the possible loss of the neonicotinoid class of insecticide, further evaluation of non-neonicotinoid ISTs and IF sprays should be conducted to find alternative ways to control thrips.

ACKNOWLEDGMENTS

Appreciation is expressed to Claude Kennedy, Clayton Treat, and Chris Pruitt at Lon Mann Cotton Branch Experiment Station. Support also provided by the University of Arkansas System Division of Agriculture.

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Table 1. Thrips damage rating at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 21 and 28 days after planting. Damage Rating (scale: 0 = none – 5 = worst).

	Days After Planting	
Treatments	**21**	**28**
Untreated check	1.8 a[§]	3.5 a
Orthene 15 oz/cwt[†]	1.0 b	3.0 ab
Orthene 1 lb/acre[‡]	1.0 b	3.0 ab
Fortenza 0.2 mg ai/seed[†]	1.3 b	3.5 a
Verimark 13 oz/acre[‡]	1.0 b	2.0 c
Dermacor 11 oz/cwt[†]	1.0 b	3.0 ab
Dermacor 2.13 oz/acre[‡]	1.8 a	3.3 ab
Blackhawk 3.3oz/acre[‡]	1.3 b	2.8 b
Aeris Seed Applied System 21.32 oz/cwt[†]	0.5 c	1.5 c

[†] Insecticide Seed treatment.

[‡] In-furrow.

[§] Means followed by same letter do not significantly differ ($P = 0.10$, Duncan's New Multiple Range Test). Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

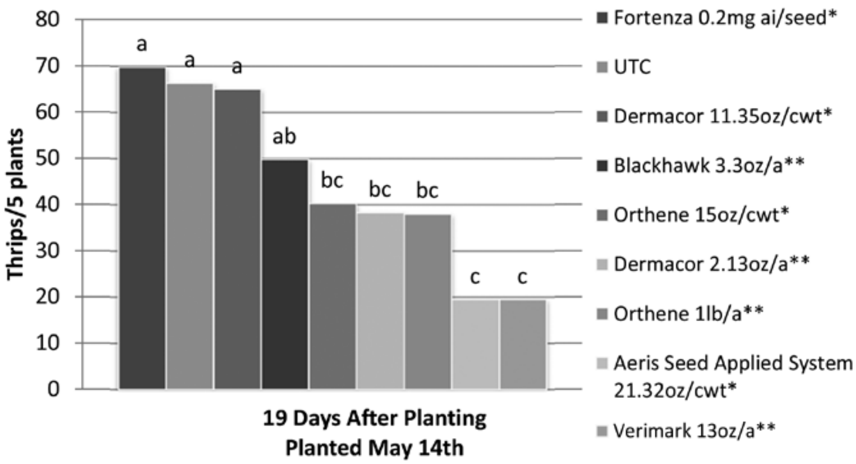

Fig. 1. Thrips totals at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 19 days after planting. *indicates insecticide seed treatment. **indicates in-furrow. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test). Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

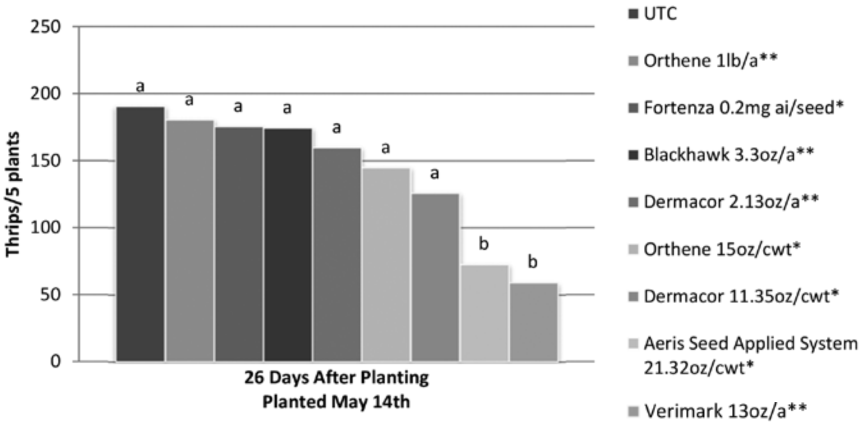

Fig. 2. Thrips totals at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 26 days after planting. *indicates insecticide seed treatment. **indicates in-furrow. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test). Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

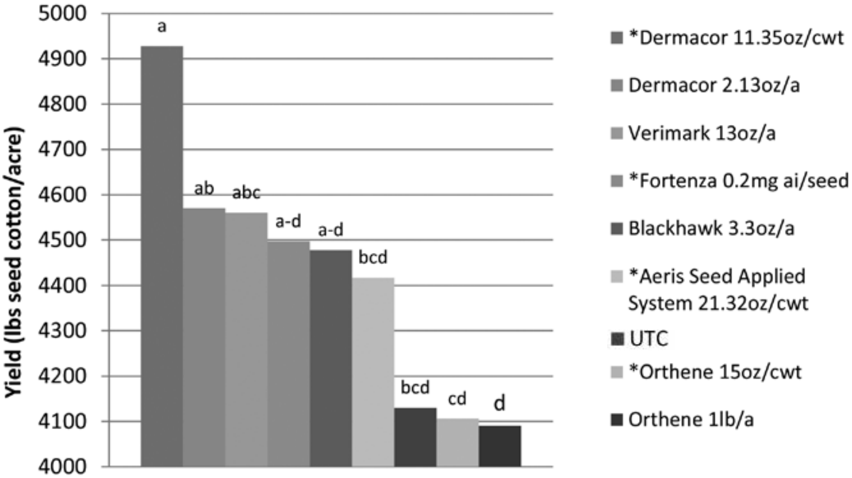

Fig. 3. Yield lbs seed cotton/acre at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. *indicates insecticide seed treatment. **indicates in-furrow. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test). Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

Impact of Foliar Applications for Control of Heliothines in Cotton

N. Taillon[1], G. Lorenz[1], A. Plummer[1], M. Chaney[1], J. Black[1]

RESEARCH PROBLEM

When bollworm populations are high in cotton, dual gene transgenics such as WideStrike™ and Bollgard® II cotton may not provide adequate protection to maintain yield potential. In these situations, supplemental foliar applications may be needed to provide additional yield protection. In 2014, growers treated 65% of total acres for lepidopteran pests, 57% were for bollworm, and losses were estimated at over $4 million. The objective of this study was to evaluate the impact and efficacy of foliar oversprays on conventional, dual-gene and triple-gene cottons, specifically Bollgard II, WideStrike, WideStrike™ III and TwinLink®, for control of cotton bollworm, (*Helicoverpa zea*).

BACKGROUND INFORMATION

While plant bugs are considered the number one pest in Arkansas cotton, caterpillar pests can be equally or even more devastating economically for our producers. In 2014, 97% of the cotton acreage in Arkansas was planted with dual gene *Bt* cultivars and every acre was infested by the bollworm, *Helicoverpa zea* (Williams et al., 2015). TwinLink® cotton and WideStrike™ III became available in 2014; other third generation technologies will be commercially available within the next few years.

RESEARCH DESCRIPTION

A trial was conducted on a grower field in Jefferson County, Ark. in 2015. Plot size was 12.5 ft (4 rows) by 40 ft, in a randomized complete block with 4 replications of sprayed and 4 replications of unsprayed plots. Treatments consisted of a conventional cultivar (PHY315RF); WideStrike cultivar (PHY499WRF); TwinLink cultivar (ST5289TL); Bollgard II cultivar (ST5288B2RF); and a WideStrike III cultivar (PHY495W3RF). Sprayed plots were treated with a foliar application

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[1] Program associate, associate department head, program associate, program associate, and program technician respectively, Department of Entomology, University of Arkansas System Division of Agriculture's Lonoke Extension Center, Lonoke.

of Prevathon (20 oz) in the second week of bloom on 21 July. Application was made using a Mudmaster fitted with 80-02 dual flat fan nozzles at 19.5 inch spacing with a spray volume of 10 gal/acre, at 40 psi. Damage ratings were taken 3, 7, 13 and 20 days after application by sampling 25 squares, blooms, and bolls per plot. Plots were harvested using a John Deere two-row plot picker. The data was processed using Agriculture Research Manager V.9 (Gylling Data Management, Inc., Brookings, S.D.) and Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

RESULTS AND DISCUSSION

In the unsprayed portion of the test, cumulative damage in the conventional cultivar was high compared to the unsprayed transgenics (Fig. 1). WideStrike had more damage compared to all other unsprayed transgenics. In the sprayed portion of the test, cumulative damage was higher in the conventional cultivar than the sprayed transgenic cultivars (Fig. 2). Foliar applications did not reduce cumulative damage fruit number for TwinLink and WideStrike III (Fig. 3). All other treatments had less damage when sprayed. Conventional unsprayed had more total damaged fruit than all other treatments. However, one application of Prevathon (20 oz/acre) reduced damage for the conventional cultivar similar to the unsprayed trangenics. A reduction in damaged fruit was also observed in WideStrike and Bollgard II when foliar applications were made. Yields indicated that the unsprayed conventional cultivar had significantly lower yield than all other treatments (Fig. 4). When sprayed, the conventional cultivar had similar yield to all unsprayed transgenic cultivars as well as the sprayed TwinLink and Bollgard II. Conventional, WideStrike, and WideStrike III cultivars had higher yields when they were sprayed compared to unsprayed. There were no differences in sprayed versus unsprayed for TwinLink and Bollgard II. WideStrike and WideStrike III sprayed treatments had higher yield compared to all other sprayed and unsprayed treatments.

PRACTICAL APPLICATIONS

Yield results from previous studies (Lorenz et al., 2012; Taillon et al., 2014; Orellana et al., 2014), show the impact of foliar applications on transgenic cultivars varies from year to year. In 2012, foliar applications increased yield in Bollgard II and WideStrike but in 2013 and 2014 yields did not increase with foliar applications. These studies suggest that in some years when a conventional cultivar is sprayed with insecticides it can yield similarly to current *Bt* cultivars. Secondly, *Bt* cotton can benefit from an insecticide application in years when cotton fields are under high bollworm pressure. Further studies will be conducted to determine the impact of supplemental foliar applications on second and third generation *Bt* cottons as well as to monitor for tolerance.

ACKNOWLEDGMENTS

Appreciation is expressed to Chuck Hooker. We would also like to thank Bayer, Dow, and Monsanto for their support. Support also provided by the University of Arkansas System Division of Agriculture.

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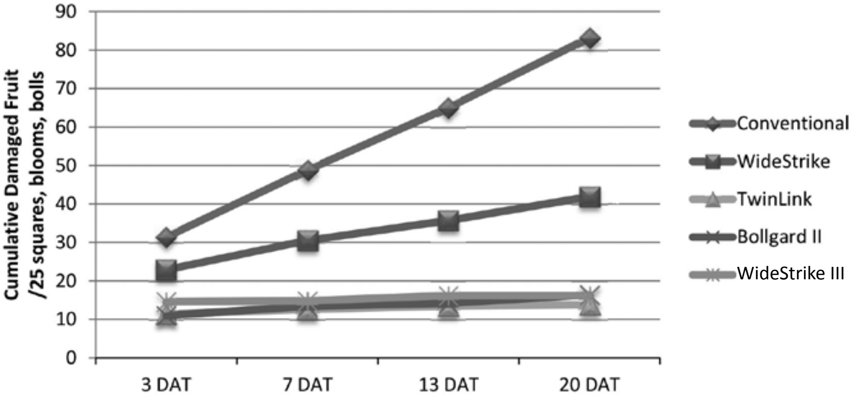

Fig. 1. Conventional and transgenic variety comparison trial, 2015 at a grower field in Jefferson County, Ark. Season totals for percent total damage in unsprayed portion of test. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test) Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

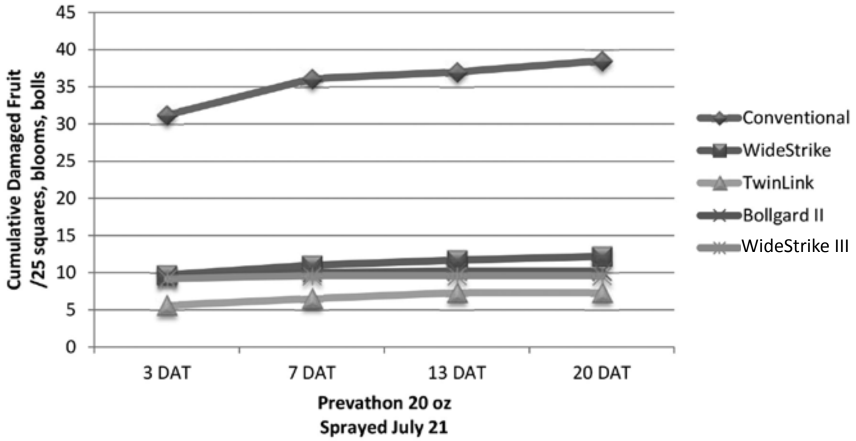

Fig. 2. Conventional and transgenic variety comparison trial, 2015 at a grower field in Jefferson County, Ark. Season totals for percent total damage. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test) Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

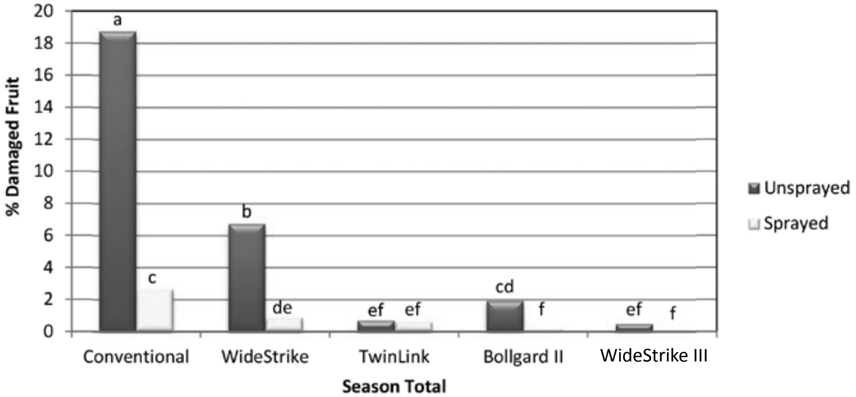

Fig. 3. Conventional and transgenic variety comparison trial, 2015 at a grower field in Jefferson County, Ark. Season totals for percent total damage. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test) Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

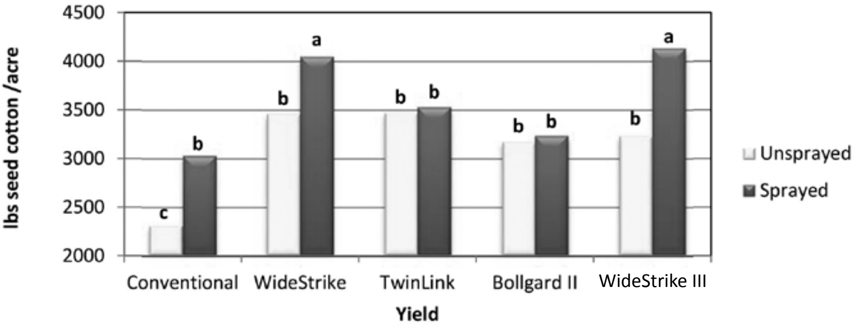

Fig. 4. Yield for conventional and transgenic variety comparison trial, 2015 at a grower field in Jefferson County, Ark. Means followed by same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test) Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

Impact of Season-Long Control of High Populations of Tarnished Plant Bug in Cotton

M. Chaney[1], G. Lorenz[1], N. Taillon[1], A. Plummer[1], and J. Black[1]

RESEARCH PROBLEM

In 2014 the tarnished plant bug cost growers $78.14/acre in treatments and yield loss, and was responsible for 79% of Arkansas' cotton yield loss by insect (Williams et al., 2014). A trial was conducted to determine when insecticide applications can be terminated while still giving growers season-long control.

BACKGROUND INFORMATION

The tarnished plant bug (TPB) (*Lygus lineolaris*) is the most damaging insect pest in cotton. It causes yield loss by feeding on squares, blooms, and young bolls. It is imperative for growers to have tools available to them to combat this pest and maintain the upper hand before increasing populations grow beyond their control (Thrash et al., 2013). In 2013 and 2014, growers in Arkansas made six insecticide applications per growing season for the control of TPB alone (Williams et al., 2014, 2015). Determining when insecticide applications can be terminated and still give growers season-long control can help growers determine when to make cost effective applications.

RESEARCH DESCRIPTION

A trial was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. during the 2015 growing season. Plot size was 12.5 ft. (4 rows) by 40 ft. with a 2 row buffer between plots, in a randomized complete block with 4 replications. Insecticide treatments were applied with a MudMaster fitted with 80-02 dual flat fan nozzles at 19.5 inch spacings. Spray volume was 10 gal/acre, at 40 psi. Applications were made weekly starting at bloom using the following spray schedule: treatments included an untreated check (UTC), all other treatments were sprayed with Transform at 2.25 oz/acre the first week of bloom followed by Orthene 97 at 1 lb/a +

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[1] Program associate, associate department head, program associate, program associate, and program technician respectively, Department of Entomology, University of Arkansas System Division of Agriculture's Lonoke Extension Center, Lonoke.

Bifenthrin at 6.4 oz/acre the second week of bloom. Treatments 3, 4, and 5 were sprayed with Bidrin at 5 oz/acre + Bifenthrin at 5 oz/acre the third week of bloom. Treatments 4 and 5 were sprayed with Transform at 2.25 oz/acre the fourth week of bloom. Treatment 5 was sprayed with Orthene 97 at 1 lb/acre + Bifenthrin at 6.4 oz/acre the fifth week of bloom. Plant bug numbers were determined by taking 2 shakes per plot with a 2.5 ft. drop cloth, for a total of 10 row ft. The data was processed using Agriculture Research Manager V. 9 (Gylling Data Management, Inc., Brookings, S.D.) and Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

RESULTS AND DISCUSSION

All treatments reduced plant bug numbers below the UTC after the first and second application. At 5 days after treatment 3 (DAT3) all treatments reduced plant bug numbers below the UTC, and all other treatments were lower than treatment 2 which received only 2 applications (Fig. 1). At 7 DAT4 plant bug numbers rebounded in treatment 2 and were higher than the UTC, and treatment 3 which had been terminated after the third application was no different than the UTC; treatments 4 and 5 had fewer plant bugs than all other treatments (Fig. 2). At 7 DAT5, treatments 2 and 3 had higher plant bug numbers than the UTC and treatments 4 and 5 had fewer plant bug numbers. Treatment 5, receiving 5 applications had fewer plant bugs than treatment 4 (Fig. 3). Season totals indicated the UTC and treatments 2 and 3 were not different and treatment 4 was lower than the UTC but had more plant bugs than treatment 5 (Fig. 4). Harvest data revealed that 5 applications had a significantly higher yield than the UTC and 2 applications; 3 and 4 applications had a higher yield than the UTC (Fig. 5). There was a trend for increased yield with increased number of applications.

PRACTICAL APPLICATIONS

Early in the season, 2 or 3 applications were sufficient for control of tarnished plant bug. As the season progressed more applications were required to maintain control due to the constant influx of TPB to the testing area from surrounding crops and wild hosts. These migrating TPB tended to be attracted to the plots that had been protected and had more fruit than the UTC, and were able to remain in treatments 2, 3, and to some extent, 4, due to the loss of plant bug control as the season progressed. This study shows the importance of maintaining a season-long approach to tarnished plant bug management. We will continue studies to determine when growers can stop spraying for TPB without impacting yield.

ACKNOWLEDGMENTS

Appreciation is expressed to Claude Kennedy, Clayton Treat, and Chris Pruitt at the Lon Mann Cotton Research Station. Support also provided by the University of Arkansas System Division of Agriculture.

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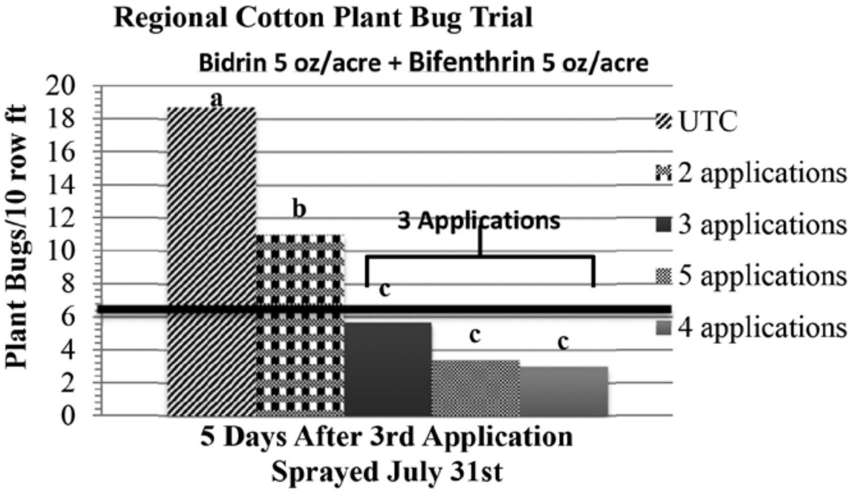

Fig. 1. Plant bug counts at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 5 days after 3rd application, regional cotton plant bug trial. TPB, tarnished plant bug. Line indicates University of Arkansas System Division of Agriculture's Cooperative Extension Service threshold of 6 TPB/10 row ft. Means within a column followed by the same letter are not significantly different (*P* = 0.10).

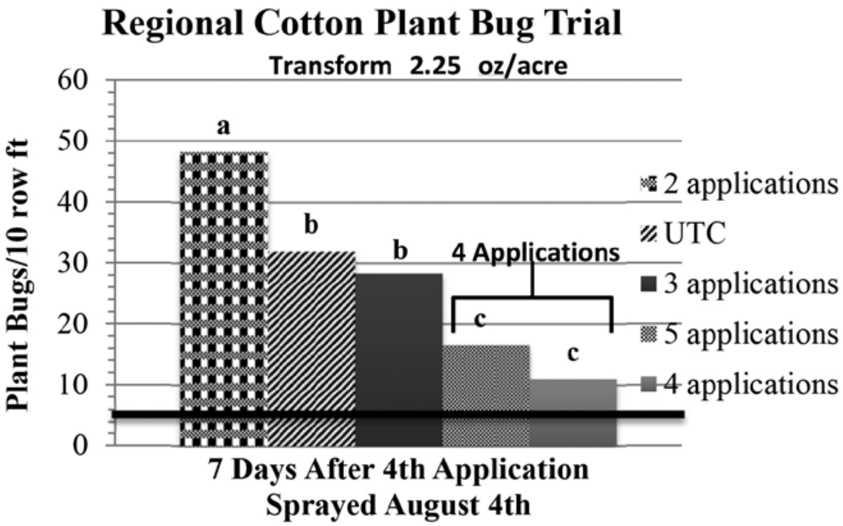

Fig. 2. Plant bug counts at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 7 days after 4th application, regional cotton plant bug trial. TPB, tarnished plant bug. Line indicates University of Arkansas System Division of Agriculture's Cooperative Extension Service threshold of 6 TPB/10 row ft. Means within a column followed by the same letter are not significantly different (*P* = 0.10).

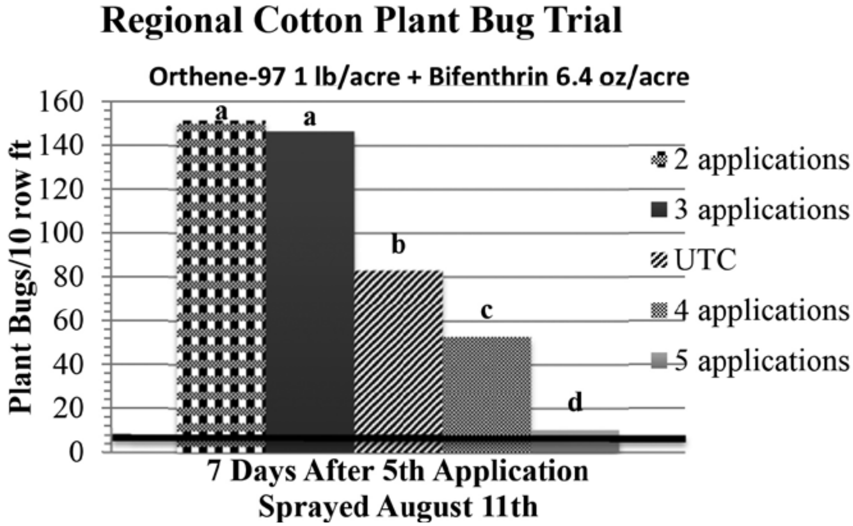

Fig. 3. Plant bug counts at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark. 7 days after 5th application, regional cotton plant bug trial. TPB, tarnished plant bug. Line indicates University of Arkansas System Division of Agriculture's Cooperative Extension Service threshold of 6 TPB/10 row ft. Means within a column followed by the same letter are not significantly different (*P* = 0.10).

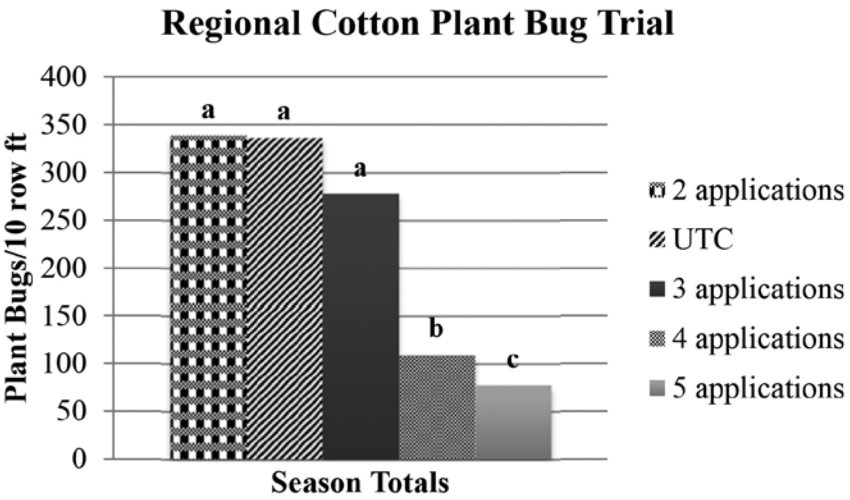

Fig. 4. Plant bug season totals at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark., regional cotton plant bug trial. TPB, tarnished plant bug. Means within a column followed by the same letter are not significantly different (*P* = 0.10).

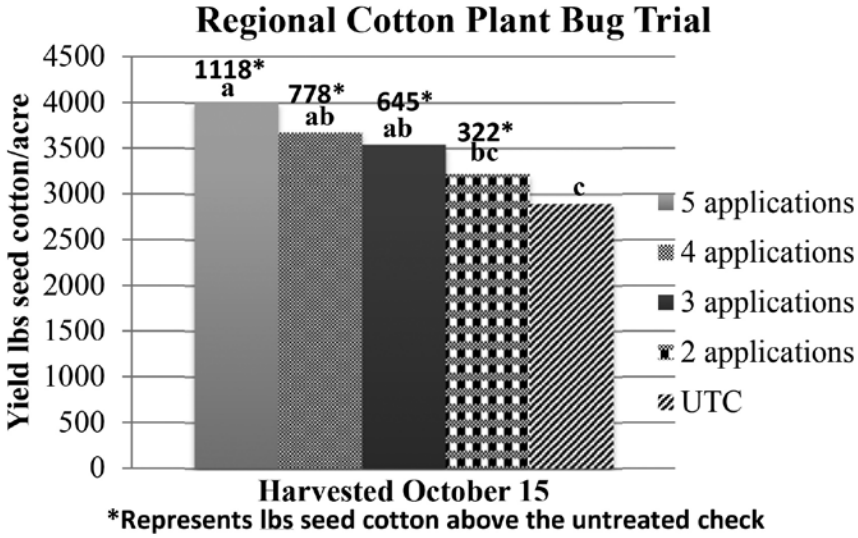

Fig. 5. Yield data at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Ark., regional cotton plant bug trial. TPB, tarnished plant bug. Means within a column followed by the same letter are not significantly different (*P* = 0.10).

Tobacco Thrips Infestations and Effects on Different Cotton Varieties

G. E. Studebaker[1] *and L. Towles*[1]

RESEARCH PROBLEM

Resistance to thiamethoxam in the tobacco thrips has raised concern that the usefulness of other insecticide seed treatments may also be in jeopardy. Loss of efficacious in-furrow insecticides and lack of adequate control of foliar insecticide applications, plus their associated problems of flaring other pests, leaves growers with few options other than seed treatments to manage thrips on seedling cotton. Host-plant resistance is an option that has not been adequately investigated in the past. The purpose of this research was to measure the level of thrips resistance in popular commercially available cotton varieties.

BACKGROUND INFORMATION

The tobacco thrips, *Frankliniella fusca* (Hinds), is the predominant species found in mid-South cotton (Stewart et al., 2013). The preferred method for thrips management is applying insecticide seed treatments containing either imidacloprid or thiamethoxam (Studebaker, 2016). Resistance to thiamethoxam was detected in 2013 and has all but eliminated this product as a choice for thrips management in the mid-South, leaving growers with fewer options. Because imidacloprid and thiamethoxam are both in the neonicotinoid class of chemistry, there are concerns that resistance to imidacloprid is not far behind. Foliar applications are an option, but growers often have difficulty getting applications out on time and also run the risk of flaring secondary pests such as spider mites and aphids. Host-plant resistance to thrips has been detected in some varieties in the past (Zhang et al., 2013). Therefore, it is important to investigate host-plant resistance as a potential management option.

RESEARCH DESCRIPTION

A small plot trial examining eight commercially available cotton varieties was conducted at the University of Arkansas System Division of Agriculture's North-

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[1] Extension entomologist, program technician, respectively, University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser.

east Research and Extension Center located in Keiser, Ark. Plots were 4 rows wide by 13.7 meters long, arranged in a randomized complete block design with 4 replications. Each variety had a no insecticide seed treatment (fungicide only) and an imidacloprid + fungicide treatment. Thrips were collected from each plot weekly for 4 weeks following emergence by clipping 5 plants from each plot and washing thrips from plants using alcohol. All plots were taken to yield by harvesting the 2 rows that were not sampled. All data were analyzed using Agriculture Research Manager (Gylling Data Management, Inc., Brookings, S.D.) version 2015 software.

RESULTS AND DISCUSSION

The total number of thrips counted across all four sampling dates in untreated plots are reported as the seasonal total and are shown in Fig. 1. Yields were taken from the two rows that were not sampled for thrips. Yield from the plots that were not treated with imidacloprid seed treatment were compared to the yields in the imidacloprid treated plots and reported as yield loss due to thrips in Fig. 2.

PRACTICAL APPLICATIONS

Differences in tobacco thrips numbers were detected between varieties (Fig. 1). Variety DP1522GLBT had significantly fewer thrips throughout the sampling period than other varieties tested. The Stoneville varieties tested also had lower thrips populations through the early season, indicating they are either less attractive or thrips survival may be lower on these varieties. Varieties PHY444WRF and DP1518B2XF had significantly higher populations of thrips indicating they are more attractive to tobacco thrips.

Yield loss associated with thrips infestations are reported in Fig. 2. Yield loss was determined by measuring the differences in yield between the imidacloprid treated plots and the untreated plots. Variety DP1522GLBT had no measurable yield loss associated with thrips. The Stoneville varieties that had lower thrips poplulations also had less yield loss as expected. Variety DP1518B2XF also had higher yield loss (as well as higher thrips numbers). However, PHY444WRF which had the highest thrips populations, also had very little yield loss resulting from thrips. This may indicate that PHY444WRF, although obviously attractive to thrips, may have some tolerance to thrips, or may be able to successfully recover from thrips damage with little yield loss.

ACKNOWLEDGMENTS

Support provided by the University of Arkansas System Division of Agriculture.

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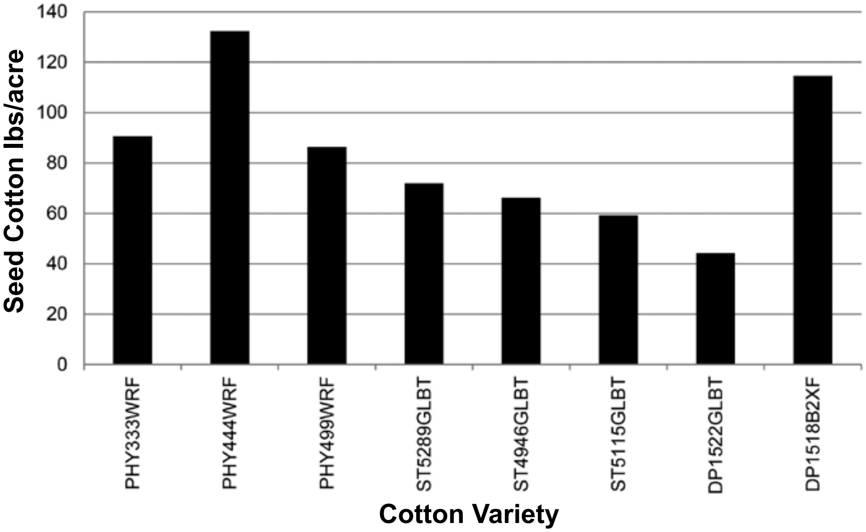

Fig. 1. Season-long total for tobacco thrips per 5 plants in untreated plots at University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser, Ark.

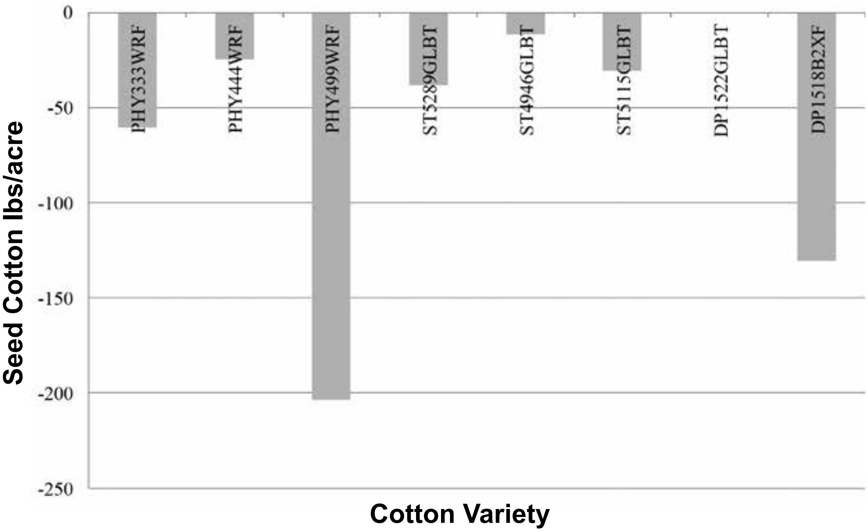

Fig. 2. Yield loss (lbs/acre) due to tobacco thrips at University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser, Ark.

Evaluation of Harvest Aid Programs in Cotton

B. Robertson[1] *and R. Benson*[2]

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. The tank mixture of Folex, thidiazuron (Dropp and others), and ethephon (Prep and others) is the standard by which all new products are evaluated.

BACKGROUND INFORMATION

New harvest aid products come onto the market continually 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 regrowth control. 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 evaluation was to compare the efficacy of protoporphyrinogen oxidase inhibitor (PPO) products, evapotranspiration (ET) and Display™, integrated into area standard harvest aid programs

RESEARCH DESCRIPTION

The cotton (*Gossypium hirsutum* L.) cultivar ST 4946 B2GT was planted at the University of Arkansas System Division of Agriculture's Manila Airport

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[1] Professor, cotton agronomist, University of Arkansas System Division of Agriculture, Newport Extension Center, Newport.

[2] County cooperative extension agent, University of Arkansas System Division of Agriculture, Cooperative Extension Service, Blytheville.

Research Field on 8 May 2015. Production inputs were based on weekly field inspections and followed Cooperative Extension Service recommendations for cotton production. All practices, with the exception of harvest aid products were consistent across all plots in this study. Treatments were initiated on 4 September 2015, approximately 750 heat units beyond cutout. Cotton was approximately 10% open at the time of initial application. The early timing was utilized in an effort to synchronize the opportunity to demonstrate results with a scheduled field day. The initial application was 100 heat units earlier than our earliest recommendation. Yield loss is commonly experienced with such an early harvest aid treatment, but treatment differences between products are much easier to separate utilizing this timing. All harvest aid products were applied using a self-propelled plot sprayer calibrated to deliver 10 gal/acre. Multiple visual ratings were used to evaluate treatments.

RESULTS AND DISCUSSION

One measure of an effective harvest aid program is to have a performance rating greater than 85% at 14 days after initial treatment (DAIT). The performance rating 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.

The initial harvest aid application in this evaluation was made 4 September. The follow-up treatment was made 7 days later. The performance rating in this evaluation was collected 17 DAIT (10 days after the follow-up treatment) and 28 DAIT.

All treatments with thidiazuron in the initial treatment exhibited a performance rating in excess of 90% with the exception of the treatment containing Aim (7) and treatment 9 which received no follow-up application (Table 1). Enhancing the rate of thidiazuron in the initial treatment (5) did not provide additional basal or terminal regrowth inhibition 28 DAIT.

Evapotranspiration with the addition of nonionic surfactant (NIS) used as a replacement for Folex in the follow-up application provided excellent results. Evapotranspiration will be added to the list of recommended harvest aids for the second application of a two-application harvest aid program.

Display plus NIS (treatment 8) used as a replacement for Folex provided similar results to the standard (treatment 1). While leaf defoliation was slightly slower compared to the standard, performance ratings were very good at 17 DAIT and excellent at 28 DAIT. More research is needed in very lush or stressed cotton evaluating the effect of Display used in the initial application of a two-application harvest aid program on leaf desiccation.

PRACTICAL APPLICATIONS

As harvesting practices improve with larger and faster machines, the need for effective use of harvest aids has intensified. Improvements in ginning have also emphasized the need for proper preparation of the crop prior to harvest. The use of new products in our standard harvest aid programs opens the door to options for lower program costs without sacrificing quality.

ACKNOWLEDGMENTS

The authors express appreciation to the area agribusiness who supplied product for this study. We also acknowledge the Manila Airport Committee and Costner Farms for their support of this project. Support also provided by the University of Arkansas System Division of Agriculture.

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Table 1. Harvest aid evaluation at 7, 17, and 28 days after initial treatment (DAIT) for percent open bolls, percent defoliation (Def), terminal (TRG) and basal regrowth (BRG) ratings, and overall performance.

Treatment	Products	Rate (oz/A)	7 DAIT % Open	7 DAIT % Def	17 DAIT % open	17 DAIT % Def	17 DAIT TRG	17 DAIT BRG	17 DAIT Perform	28 DAIT TRG	28 DAIT BRG	28 DAIT Perform
1	Folex ethephon thidiazuron fb[†] (7 days) Folex ethephon	6.4 5.3 2.1 8.0 32	70	72	99	99	0	7	99	0	80	100
2	Finish thidiazuron fb (7 days) Finish ethephon	5.3 2.1 10.6 21.3	75	81	99	99	0	2	99	0	70	100
3	Folex ethephon fb (7 days) Folex ethephon thidiazuron	6.4 5.3 8.0 32 2.1	80	49	90	94	0	5	79	0	85	90
4	Folex ethephon thidiazuron fb (7 days) Folex ethephon thidiazuron	6.4 5.3 2.1 8.0 32 2.1	80	70	100	99	0	3	95	0	60	100
5	Folex ethephon thidiazuron fb (7 days) Folex ethephon	6.4 5.3 3.2 8.0 32	85	70	95	95	0	5	90	0	75	100
6	Folex ethephon thidiazuron fb (7 days) ET + NIS ethephon	6.4 5.3 2.1 1.5 32	85	64	99	99	0	5	95	0	80	100
7	Folex ethephon thidiazuron fb (7 days) Aim + NIS ethephon	6.4 5.3 2.1 1.0 32	80	73	65	81	20	5	60	50	50	60
8	Display + NIS ethephon thidiazuron fb (7 days) Display + NIS ethephon	0.3 5.3 2.1 0.4 32	83	53	99	94	0	5	95	0	80	100
9	Folex ethephon thidiazuron	6.4 5.3 2.1	85	58	85	84	30	10	65	40	50	50
10	ethephon thidiazuron fb (7 days) Folex	32 2.1 8.0	80	62	85	96	10	5	70	20	50	70

[†] fb = followed by.

Identifying Spatial Distributions of Seedling Disease Pressure in Cotton Fields

K.D. Wilson[1], C.S. Rothrock[2], and T.N. Spurlock[1]

RESEARCH PROBLEM

Seedling diseases are important factors in cotton stand establishment and are widespread in fields in Arkansas. However, little is known about the variability of seedling disease pressure within fields. As planting rates decrease to reduce input cost, predicting seedling disease pressure becomes of greater importance to cotton growers. This report summarizes results from a study being conducted to characterize the risk of seedling diseases on a site-specific basis within fields.

BACKGROUND INFORMATION

The cotton seedling disease complex is made up of the soilborne pathogens *Thielaviopsis basicola*, *Rhizoctonia solani*, *Pythium* spp., and *Fusarium* spp. (DeVay, 2001; Rothrock and Buchanan, 2015). These pathogens can survive in soil for long periods and act individually or in combination to cause a range of symptoms on seed, roots and hypocotyls which affect germination, emergence, and early-season growth and development of the crop when the environment is conducive. Cool and wet soils are known for being favorable for disease, which are often the conditions many cotton growers encounter at planting.

Seedling diseases reduce stands and cause the crop to be more variable, creating issues with timing of inputs and reduced yields. The cost of seed due to technology fees and products applied to the seed has increased making planting one of the highest input costs. Increasing seeding rate in order to compensate for seedling losses due to disease and environmental factors is often recommended. This strategy is expensive and does not consider field variability. Site-specific planting prescriptions currently used by some growers consider field variability, but they do not consider seedling disease pressure. The ability to predict seedling disease potential would be beneficial for site-specific planting and producers wanting to reduce seeding rate.

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[1] Graduate assistant, and extension plant pathologist, respectively, Plant Pathology, University of Arkansas System Division of Agriculture's Southeast Research and Extension Center, Monticello.

[2] Professor, Plant Pathology, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.

RESEARCH DESCRIPTION

The objectives of this study were to characterize variation in seedling disease incidence and severity within fields, and to elucidate abiotic factors that explain spatial differences including soil temperature, water, strength, electrical conductivity, texture, and cultural practices. Spatial analyses were used to find associations between the spatial aggregation of seedling pathogens and disease and soil environmental or physical factors in order to predict seedling diseases pressure. To accomplish these objectives, trials at the Judd Hill Foundation Cooperative Research Station, in Poinsett Co., a grower's field in Mississippi Co. farmed by David Wildy, and another grower's field in Ashley Co. farmed by Bruce Bond were chosen. Results from a field at the Judd Hill Foundation Cooperative Research Station will be presented.

At Judd Hill in 2014 and 2015, 15.24-m (50 ft) long four-row plots were established across a cotton field with each row having one of four seed treatments; (1) Vortex + Spera + Allegiance + Evergol Prime + Evergol Energy, (2) Allegiance FL, (3) RTU-PCNB, and (4) no fungicide. For each plot, minimal soil temperature, moisture, and strength were recorded 1 and 5 days after planting along with soil electrical conductivity, and soil texture. Seedlings were recovered from each sampling point to assess seedling disease, root and hypocotyl discoloration. Stand counts, skip indices, and plant height were recorded 21 days after planting. Yield for each row also was determined. Spatial data exploration was performed using Moran's I to determine distributions of observations within the field. Regression was used to determine the relationships between the spatial clustering of seedling pathogens and disease and soil environmental or physical factors in order to predict seedling diseases on cotton.

RESULTS AND DISCUSSION

From analyses using one of the field locations at Judd Hill, the fungicide responses showed treatment 1, the broad-spectrum combination fungicide seed treatment, significantly improved stands over non-treated seed by 17% in 2014 and 12% in 2015 (Table 1). Soil temperature was shown to be significantly aggregated in both years in this field by Moran's I ($P < 0.001$, Table 2). The minimum soil temperature ranged from 20.0–21.4 °C (68.0–70.5 °F) in 2014 and 20.7–21.7 °C (69.3–71.1 °F) in 2015 for the first day after planting. Stand improvement was found to be aggregated, and through spatial regression models, positively correlated with sites with higher temperatures for all seed treatments in 2014 (Table 3) but not in 2015. Regression of spatial correlation of soil temperature and hypocotyl disease severity indices showed a higher degree of symptoms in areas with lower soil temperatures for both 1 and 5 days after planting for both years. Root disease severity also increased in the areas of the field with lower soil temperatures (Table 4).

Soil environment, temperature and rainfall, are important factors in stand establishment and seedling disease severity for cotton in any field or year (Rothrock et al., 2012). However, within-field variation has not been characterized. As site-specific planting prescriptions are developed, it is critical to include an assessment of seedling disease pressure as a result of seedling diseases being the primary cause of stand reduction in many situations. This study suggests that seedling disease does vary across a field as indicated by the stands for various fungicide seed treatments and severity of disease symptoms expressed on seedlings. Seedling disease losses are aggregated in a field and are associated with soil temperature and water. In this field study, as little as 1.4 °C (2.5 °F) was associated with changes in plant population density and severity of symptoms on seedlings across the field examined. Understanding factors that influence stand establishment and seedling diseases should allow growers to minimize losses from seedling diseases on cotton.

PRACTICAL APPLICATIONS

These results suggest that predictive maps for seedling disease risk are possible. With the addition of seedling disease pressure, efficacy of site-specific prescription planting strategies could improve the likelihood of achieving a uniform and adequate stand to ensure potential maximum yields.

ACKNOWLEDGMENTS

Support provided by the University of Arkansas System Division of Agriculture.

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Table 1. Stand counts for fungicide seed treatments across 50 sites for a field at Judd Hill.[†]

Seed treatment[‡]	Rate (oz/cwt)	Plant stand 2014		Plant stand 2015	
Vortex + Spera + Allegiance + Evergol Prime + Evergol Energy	0.08 + 1.8 + 1.5 + 0.32 + 2.0	105.6[§]	A	108.7	A
Metalaxyl	1.5	92.6	B	102.0	AB
PCNB	14.5	90.3	BC	96.4	B
None		87.4	C	95.76	B

[†] Tests were planted at the Judd Hill Plantation on 6 May 2014 and 7 May 2015.
[‡] Gaucho applied to all seed, 0.375 mg ai/seed.
[§] Plant stand/15.24 m (50 ft) of row planted at 3 seed/0.305 m (1 ft). Means within a column and main effect followed by the same letter are not significantly different, $P = 0.05$.

Table 2. Spatial distributions of soil temperature and soil water content across 50 sites for a field at Judd Hill.[†]

Parameter	Soil temp. 1 day after planting (20.2–21.4 °C)	Soil temp. 5 days after planting (21.7–22.6 °C)	Soil water 1 day after planting (9.4–16.2%)	Soil water 5 days after planting (12.0–20.1%)
2014				
Moran's I	0.730	0.490	0.500	0.700
Distribution[‡]	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
2015				
Moran's I	0.570	0.7860	0.440	0.430
Distribution[‡]	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.003$

[†] Tests were planted at the Judd Hill Plantation on 6 May 2014 and 7 May 2015 at 3 seed/0.305 m (1 ft). of row.
[‡] Moran's I statistic gives a value ranging between -1 and 1. As value approaches 1, distribution is more aggregated. As value approaches -1, distribution is more uniform.

Table 3. Regression of spatial correlation of soil temperature and soil water content with plant stand in 2014.[†]

	Plant stand	
Parameter	No seed treatment	Vortex + Spera + Allegiance + Evergol Prime + Evergol Energy
Soil temperature 1 day after planting	(+) $P < 0.008$[‡]	(+) $P < 0.016$[‡]
Soil Temperature 5 days after planting	(+) $P < 0.038$[‡]	(+) $P < 0.0375$[§]
Soil water 5 days after planting	(+) $P < 0.013$[‡]	(+) $P < 0.156$[§]

[†] Test was planted at the Judd Hill Plantation on 6 May 2014.
[‡] P-value for spatial lag regression model.
[§] P-value for ordinary least squares regression.

Table 4. Regression of spatial correlation of soil temperature and soil water content with hypocotyl and root disease assessments.[†]

	Disease severity	
Parameter	**Hypocotyl rating**	**Root rating**
2014		
Soil temperature 1 day after planting	(-) $P < 0.03$[§]	(-) $P < 0.43$[§]
Soil temperature 5 days after planting	(-) $P < 0.05$[§]	(-) $P < 0.08$[§]
2015		
Soil temperature 1 day after planting	(-) $P < 0.001$[‡]	(-) $P < 0.002$[‡]
Soil temperature 5 days after planting	(-) $P < 0.005$[‡]	(-) $P < 0.003$[‡]

[†] Tests were planted at the Judd Hill Plantation on 6 May 2014 and 7 May 2015.
[‡] *P*-value for spatial lag regression model.
[§] *P*-value for ordinary least squares regression.

Cotton Research Verification/Sustainability Program: 2015 Progress Report

A. Free[1], B. Robertson[1] and A. Flanders[2]

RESEARCH PROBLEM

The Cotton Research Verification/Sustainability Program works with producers in an effort to increase efficiency and hence become more sustainable in an effort to improve profitability. As cost of production continue to increase, producers are looking for ways to produce cotton more efficiently. The program seeks to accomplish many goals. The primary goal is to demonstrate to producers that the University of Arkansas System Division of Agriculture cotton recommendations developed from small-plot research are applicable to field-scale operation and provide optimum yields and economic returns. The Cotton Research Verification/Sustainability Program expands beyond that of the traditional verification program by measuring the producers' environmental footprint for each field and evaluating the connection between profitability and sustainability.

BACKGROUND INFORMATION

The University of Arkansas System Division of Agriculture has been conducting the Cotton Research Verification Program (CRVP) since 1980. This is an interdisciplinary effort in which recommended best management practices and production technologies are applied in a timely manner to a specific farm field. Since the inception of the CRVP in 1980, there have been 269 irrigated fields entered into the program. The success of the cotton program spawned verification programs in rice, soybeans, wheat and corn in Arkansas and other states in the mid-South.

RESEARCH DESCRIPTION

Eight fields at two locations comprised the Cotton Research Verification/Sustainability Program locations in 2015. Each field was entered into the Field to

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[1] Cotton research verification/sustainability program coordinator, and professor/cotton extension agronomist, respectively, University of Arkansas System Division of Agriculture's Newport Extension Center, Newport.

[2] Associate Professor, University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser.

Market Fieldprint Calculator. Sustainability metrics from the 2015 season will help serve to establish a benchmark for successive years as sustainability efforts will be a major part of the program for 2016.

The Cotton Research Verification/Sustainability Program worked along with Discovery Farms in Southeast Arkansas on 5 of the 8 fields in the program. Discovery Farms main focus is to monitor edge-of-field water quality. Fields are watered in two sets. The split-field arrangement provides the opportunity to compare two production strategies. The farmer standard tillage and cover crop usage was compared to a no-till system with a cereal rye cover crop. The remaining three fields had no cover crop planted in 2015. Irrigation methods were composed of either furrow or pivot irrigation on the eight fields. This program was conducted under various farmers' standard tillage systems, irrigation regimes, soil types and environmental conditions. The diversity of fields in the program reflected cotton production in Arkansas.

Field records were maintained and economic analyses were conducted at seasons end to determine net return/acre for each field in the program. All fields were also entered into Fieldprint Calculator, to evaluate fields' environmental footprint.

RESULTS AND DISCUSSION

The 2015 growing season began with a wetter than normal April and May, which delayed planting across the state. First cotton was planted in Arkansas around May 1st. The vast majority of the crop in the state was planted the first half of May. However, many producers who had planned to plant cotton were unable to get cotton in the ground due to rainfall that occurred during the favorable planting window. Plant bug numbers were moderate this year, fields in the Verification/Sustainability program were treated an average of 3.1 times for plant bugs. Each field had an average of 1.9 burndowns, and 2.9 herbicide applications for the 2015 season. Two of the eight verification fields had one treatment for worms. Average costs for herbicides and insecticides were \$57.14 and \$33.41, respectively. Pest control represents a significant expense and can impact yield greatly. Insecticides, herbicides, and plant growth regulators represented 26% of the producers input costs. Planting seed with technology fees are 24% and fertilizers are 28% of input costs. All energy costs including diesel fuel for tillage, irrigation, and harvest represented 13% of input costs. These items represent approximately 91% of the producers input costs to grow the crop.

Records of field operations on each field provide the basis for estimating expenses. Production data from the 8 fields were applied to determine costs and returns above operating costs, as well as total specified costs. Operating costs and total costs per pound indicate the commodity price needed to meet each costs type. Operating costs, total costs, costs per pound, and returns are presented in Table 1. Costs in this report do not include land costs, management, or other expenses and fees not associated with production. Budget summaries for cotton are in Table 2. Price received for cotton of \$0.65/lb. is the estimated Arkansas annual average for the 2015 production year. Average cotton yield for all verification fields was 1182.6 lb/acre. Value of cottonseed is set equal to total post-harvest expenses for each field.

Average operating costs for cotton in Table 1 and Table 2 are $539.99 per acre. Table 2 indicates that fertilizer and nutrient costs average 23% of operating expenses and are $126.84/acre. Chemicals average $117.80/acre, and are 22% of the operating expenses. Seed and associated technology fees average $109.76/acre, 20% of operating expenses, and include two fields planted with a cover crop.

With yield average of 1182.6 lb/acre, average operating costs are $0.46/lb. in Table 1. Operating costs range from a low of $503.62 in the Weaver (No-till with cover crop), to a high of $582.69 in the Shop (No-Till with cover crop). Returns to operating costs average $228.71/acre. The range is from a low of $108.04 in the Weaver (farmer standard) to a high of $383.17 in the St. Francis Conders Field. Average fixed costs are $152.46. Which leads to average total cost of $692.46/acre. The average returns to total specified cost is $76.24/acre. The low is -$54.12 in the Shop (farmer standard), and the high is $236.51 in the St. Francis Conders field. Total specified costs average $0.60/lb.

PRACTICAL APPLICATIONS

This program has become a vital tool in the educational efforts of the University of Arkansas System Division of Agriculture. It continues to serve a broad base of clientele including cotton growers, consultants, researchers, and county extension agents. The program strives to obtain its goals and provide timely information to the Arkansas cotton community.

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Table 1. Operating costs, total costs, and returns for cotton research verification program, 2015

Field	Operating Costs	Operating Costs per Pound	Returns to Operating Costs	Total Fixed Costs	Total Costs	Returns to Total Costs	Total Costs per Pound
				$			
Weaver (Farmer Standard)	518.95	0.54	108.04	157.60	676.54	-49.55	0.70
Weaver (No-Till/ Cover Crop)	503.62	0.45	215.99	151.05	654.67	64.94	0.59
Shop (No-Till/ Cover Crop	582.69	0.46	239.53	157.89	740.58	81.65	0.59
Shop (Farmer Standard)	576.39	0.55	110.89	165.00	741.40	-54.12	0.70
Desha Homeplace	565.81	0.41	336.59	155.97	721.77	180.62	0.52
St. Francis Conders	528.13	0.38	383.17	146.66	674.79	236.51	0.48
St. Francis Norris	506.45	0.50	146.46	146.66	653.11	-0.20	0.65
St. Francis Westside	537.90	0.42	289.00	138.89	676.79	150.11	0.53
Average	539.99	0.46	228.71	152.46	692.46	76.24	0.60

Table 2. Summary of revenue and expenses per acre.

	Field								
Revenue	**Weaver (Farmer Standard)**	**Weaver (No-Till/ Cover Crop)**	**Shop (No-Till/ Cover Crop)**	**Shop (Farmer Standard)**	**Desha Homeplace**	**St. Francis Conders**	**St. Francis Norris**	**St. Francis Westside**	**Average**
Yield (lb)	964.6	1107.1	1265.0	1057.4	1388.3	1402.0	1004.5	1272.2	1182.6
Price ($/lb)	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Total Crop Revenue	626.99	719.62	822.22	687.28	902.40	911.30	652.91	826.90	768.70
Cottonseed Value	116.38	133.57	152.62	127.57	167.50	169.15	121.19	153.49	142.68
Expenses									
Seed	98.67	108.87	108.87	98.67	98.67	121.44	121.44	121.44	109.76
Fertilizers & Nutrients	82.16	80.60	131.24	131.24	131.24	153.27	153.27	151.68	126.84
Herbicides	63.06	44.68	61.80	61.80	81.50	56.98	44.50	42.78	57.14
Insecticides	51.19	51.19	35.27	35.27	35.27	13.35	13.35	32.38	33.41
Other Chemicals	25.30	25.30	25.30	25.30	25.30	30.50	30.50	30.50	27.25
Custom Applications	35.00	35.00	42.00	42.00	35.00	6.00	6.00	6.00	25.88
Other Inputs	3.45	3.45	3.45	3.45	3.45	30.68	21.98	31.28	12.65
Diesel Fuel	33.45	30.80	31.11	33.34	33.11	23.32	23.32	27.70	29.52
Irrigation Energy Costs	31.87	31.55	48.01	48.01	27.89	11.20	11.20	9.34	27.38
Input Costs	424.16	411.44	487.05	479.08	471.42	446.73	425.56	453.11	449.82
Fees	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Repairs & Maintenance[a]	40.67	39.43	40.82	41.98	39.80	38.96	38.96	38.92	39.94
Labor, Field Activities	24.08	23.07	23.31	23.96	23.46	12.19	12.19	15.39	19.71
Production Expenses	506.91	491.94	569.17	563.02	552.68	515.88	494.70	525.42	527.47
Interest	12.04	11.68	13.52	13.37	13.13	12.25	11.75	12.48	12.53
Post-harvest Expenses	116.38	133.57	152.62	127.57	167.50	169.15	121.19	153.49	142.68
Operating Expenses	518.95	503.62	582.69	576.39	565.81	528.13	506.45	537.90	539.99
Returns to Operating Expenses	108.04	215.99	239.53	110.89	336.59	383.17	146.46	289.00	228.71
Capital Recovery & Fixed Costs	157.60	151.05	157.89	165.00	155.97	146.66	146.66	138.89	152.46
Total Specified Expenses[b]	676.54	654.67	740.58	741.40	721.77	674.79	653.11	676.79	692.46
Returns to Specified Expenses	-49.55	64.94	81.65	-54.12	180.62	236.51	-0.20	150.11	76.24
Operating Expenses/lb	0.54	0.45	0.46	0.55	0.41	0.38	0.50	0.42	0.46
Total Expenses/lb	0.70	0.59	0.59	0.70	0.52	0.48	0.65	0.53	0.60

[a] Includes employee labor allocated to repairs and maintenance.

[b] Does not include land costs, management, or other expenses and fees not associated with production.

APPENDIX I

STUDENT THESES AND DISSERTATIONS RELATED TO COTTON RESEARCH IN PROGRESS IN 2015

Benson, Ray. Spatial analysis methods for agronomic, economic, and environmental evaluations of implementing management zones in agricultural fields in the lower Mississippi River Basin in northeast Arkansas. (PhD., advisor: Teague)

Berlangeiri, Sole. Temperature gradients in the canopy and the influence on cotton bolls growth. (M.S., advisor: Oosterhuis)

FitzSimons, Toby. Cotton plant response to high temperature stress during reproductive development. (Ph.D., advisor: Oosterhuis)

Greer, Amanda. Relationship between Telone II and nitrogen fertility in cotton in the presence of reniform nematodes. (M.S., advisor: Kirkpatrick)

Hannam, Josh. Pathogens of the tarnished plant bug, *Lygus lineolaris*, in Arkansas. (M.S., advisor: Steinkraus)

Kelly, Erin. Spatial and temporal variability of cotton grown on heterogeneous soils with cereal cover crops. (M.S., advisor: Teague)

Lewis, Austin. Field validation of irrigation tools in major Arkansas row crops. (M.S., advisors: Reba and Teague)

Mann, Amanda. Irrigation initiation timing, cultivar and plant bug feeding interactions in cotton grown in three different tillage systems in northeast Arkansas. (M.S., advisor: Teague)

Meyer, Christopher. Utilization of tank mixtures and application technology to improve efficiency of herbicide applications on glyphosate-resistant weeds. (M.S., advisor: Norsworthy)

Palhano, Matheus. Value of cover crop on palmer amaranth control in cotton and impact of herbicide carryover on cover crop establishment. (M.S., advisor: Norsworthy)

Pilon, Cristiane. Effect of early water-deficit stress on reproductive development in cotton. (Ph.D., advisor: Oosterhuis)

Rose, James. Sensitivity of Enlist™ and Roundup Ready 2 Xtend™ technologies to auxin herbicides and comparison of tolerance to susceptible cotton and soybean cultivars. (M.S., advisor: Norsworthy)

Straitt, Nadine. Impacts conservation practices have on water resources from production size agricultural fields in northeast Arkansas. (M.S., advisors: Reba and Teague)

van der Westhuizen, Mathilda. High temperature tolerance in cotton. (Ph.D., advisor: Oosterhuis)

Wilson, Kyle. Spatial variability of seedling pathogens and diseases on cotton; influence of soil environmental factors and cultural practices. (M.S. advisor: Rothrock)

APPENDIX II

RESEARCH AND EXTENSION 2015 COTTON PUBLICATIONS

BOOKS AND CHAPTERS

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