DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Summaries of Arkansas Cotton Research 2014 Oosterhuis AAES

Summaries of
Arkansas Cotton Research
2014

Edited by Derrick M. Oosterhuis

DIVISION OF AGRICULTURE
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SUMMARIES OF ARKANSAS COTTON RESEARCH 2014

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2014 IN REVIEW

Arkansas cotton producers have set a record yield the last two years in a row. The previous record of 1133 pounds of lint per acre set in 2013, was surpassed in 2014, with an estimated 1193 pounds lint per acre. Arkansas ranked fourth in the nation for yield following California, Arizona, and Virginia. Total production ranked fifth in the nation while planted acres ranked sixth.

While the final outcome was excellent, many challenges presented themselves throughout the season. A much cooler than average winter and spring, resulted in the crop being planted later than normal (Fig. 1). Very little cotton was planted in April. Much of the state's cotton was planted the first full week of May. While this timeframe represents the heart of the optimum planting window, early May planted cotton still experienced nighttime temperatures in the 30s. Cooler than average temperatures persisted resulting in one of the coolest Julys on record. Essentially all the state's crop was delayed as a result of the cool temperatures. The crop statewide was 10 to 14 days behind target at first flower. This delay continued to express itself with cutout occurring 7 to 10 days behind target. Producers generally expect a yield penalty as a result of a late crop. An almost perfect fall with more normal temperatures and dryer than average rainfall patterns saved the day.

Lint yields in excess of 2,000 pound lint per acre were observed in various regions of the state. However, hardships did occur in other regions. An extended period of wet conditions capped with a single rainfall event of over 10 to 12 inches negatively impacted yields in the central portion of the Delta in St Francis and Crittenden counties. The extreme cool temperatures were blamed for disappointing yields in Clay and Greene counties. A series of early-morning storms containing hail, wind and excessive rainfall devastated 40,000 acres of cotton in Mississippi and Craighead counties 7 October 2014. A total of 65,000 acres received some damage. These two counties account for approximately 40% of the state's cotton acreage. Congressman Rick Crawford, Secretary of Agriculture Butch Calhoun, and various state representatives viewed the damage and visited with producers. Federal disaster declaration was made 22 October 2014 allowing producers access to federal assistance programs.

Bill Robertson
Professor, Cotton Extension Agronomist
University of Arkansas
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Newport, Ark.

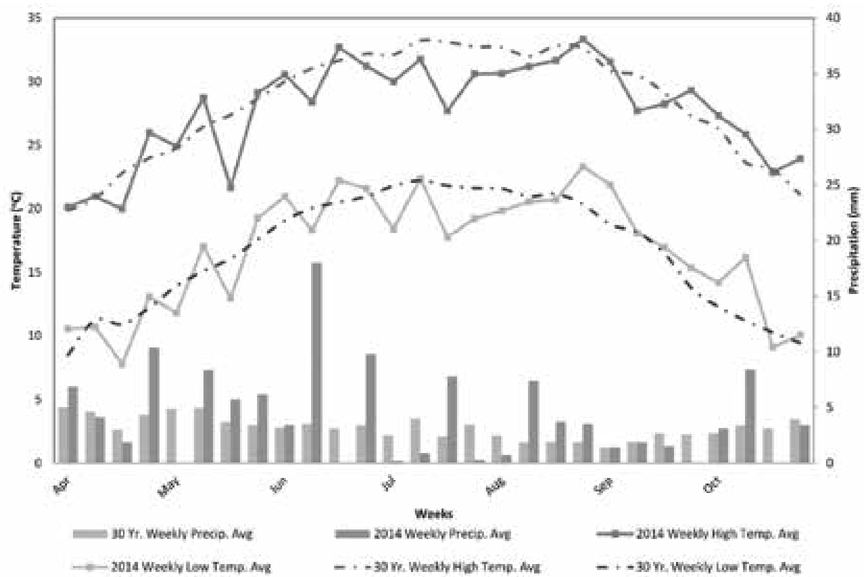

Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2014 compared with the long term 30 year averages in Eastern Arkansas.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research 2014* 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 2014.

		2013	2014
New Funds		$253,000	$247,000
Previous Undesignated		$55,359	$51,400
Total		$308,359	$298,400

Researcher	Short Title	2013	2014
Oosterhuis	Cotton Research In Progress	$5,000	$5,000
Lorenz	Rainfastness of Insecticides	$24,000	$0
Barber	Management of New Cultivars	$26,000	$0
Norsworthy	Modeling Glyphosate-Resistant Barnyardgrass	$12,251	$0
Barber	Replant Decisions	$13,500	$13,500
Lorenz	Herbicide, Insecticide Interactions	$31,000	$31,000
Barber	Verification	$74,208	$74,208
Bourland	Breeding	$26,000	$26,000
Henry	Irrigation	$31,500	$31,500
Burgos	Palmer amaranth Herbicide Resistance	$13,500	$13,500
Oosterhuis, Raper	Improving Cotton Fertility	$0	$9,800
Norsworthy	Cover Crops	$0	$32,782
Reba	Increasing yield through irrigation management	$0	$13,620
Uncommitted		$51,400	$47,490
Total		**256,959**	**$250,910**

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
— 2014 —

University of Arkansas Cotton Breeding Program: 2014 Progress Report

F.M. Bourland[1]

RESEARCH PROBLEM

The University of Arkansas 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 Cotton Breeding Program. Breeding lines are developed and evaluated in non-replicated tests, which include initial crossing of parents, individual plant selections from segregating populations, and evaluation of the progenies produced from seed of individual plants. Once segregating populations are established, each sequential test provides screening of genotypes to identify

[1] Director/Professor, Northeast Research and Extension Center, Keiser.

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 2008 through 2014 (F_1 through F_6 generations evaluated in 2014) 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 2014 was to combine lines having specific morphological traits, enhanced yield components and improved fiber characteristics. By special agreement, 10 crosses were made to specific lines from two private breeding companies. These crosses should help to widen the genetic base of the breeding program. The 2014 breeding effort also included evaluation of 24 F_2 populations, 24 F_3 populations, 24 F_4 populations, 655 1st year progeny, and 216 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 2015. From the 1st year progenies, 192 were advanced, and 72 F_6 advanced progenies were promoted to strain status. These 72 F_6 advanced progeny included 30 progenies derived from crosses with UA48 (Bourland and Jones, 2012a), 32 derived from crosses with UA222 (Bourland and Jones, 2012b), and 8 from a cross of UA48 and UA222.

Strain Evaluation

In 2014, 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 42 derived from crosses with UA48. Of these, 13 will be evaluated in 2015 New Strain Test—each showed improved yield and good fiber quality, but none had fiber quality equal to UA48.

Germplasm Releases

Germplasm releases are a major function of public breeding programs. Since 2004, a total of 49 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 APPLICATION

Genotypes that possess enhanced host-plant resistance, improved yield and yield stability, and good fiber quality are being developed. Improved host-plant resistance should decrease production costs and risks. Selection based on yield components may help to identify and develop lines having improved and more stable yield. Released germplasm lines should be valuable as breeding material to commercial 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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Evaluation of Cotton Variety Performance

B. Robertson[1], F. Bourland[2], N. Goodwin[3], and A. Free[3]

RESEARCH PROBLEM

Unbiased information regarding variety performance is critical in enabling producers to make informed seed buying decisions to increase their productivity and profits. Variety selection is one of the most important decisions a producer makes.

BACKGROUND INFORMATION

Variety selection and seed quality have a lasting effect on the crop's early-season vigor and on overall plant health which is critical in establishing high yield potentials. Some varieties are more susceptible to stresses caused by inadequate moisture, cool temperatures, thrips feeding, seedling diseases, nematodes and other pests. In addition, varieties exhibit varying levels of resistance or tolerance to high temperatures, diseases and pests, such as fusarium or verticillium wilt, root-knot nematode and bacterial blight. Producers consider planting resistant varieties, or those that have at least some tolerance when possible.

Producers should try new varieties on some of their acreage. However, planting the entire farm in new varieties is not recommended. Plantings of new varieties should be limited to no more than 10% of the farm. Acreage of a variety may be expanded slightly if it performs well the first year. Consider planting the bulk of the farm to three or four proven varieties of differing maturity to reduce the risk of weather interactions and to spread harvest timings. Caution is needed in terms of acres planted to newer varieties if multi-year testing is not available.

RESEARCH DESCRIPTION

Multiple locations were planted in replicated trials and reported to Cotton Incorporated, Seed Matrix, and published in the Arkansas Cotton Variety Test 2014 by Bourland et al. (2015) Sites were representative of soils for the state. Entries

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were managed for optimal yields. Site information collected included location, soil type, planting date, seeding rate and dates of defoliation and harvest. Quantitative data included: lint yield, turnout, and fiber quality (HVI).

RESULTS AND DISCUSSION

County large-plot variety evaluations provided an excellent companion to the Arkansas Cotton Variety Test 2014 program. Varieties that consistently performed well in the large-plot evaluations also did well in the 2014 Arkansas Cotton Variety Test (Table 1). The combined data in Table 1 provide an additional level of confidence for producers and others in the decision-making process in both data sets. As the life span of cotton varieties are short, it is often difficult to obtain long-term yield averages. Producers must look at data across multiple locations to best determine the fit of a variety for their farm.

PRACTICAL APPLICATION

Yield still is the ultimate measure for a cotton crop, although the ever-increasing demand for higher fiber quality makes this factor a close second in priority. When selecting varieties for planting, don't simply choose the top yielding variety at any single testing location or year, but look at the averages of several seasons. Varieties that consistently produce yields near the top are often easier to manage than those that produce at the top in some locations and in the middle or near the bottom at others. Also, some varieties perform more consistently across different seasonal conditions and locations. Particular attention should be paid to yield ranking in irrigated as well as dryland locations. This will help identify varieties that may tolerate stress better than others.

Each variety has strengths and weaknesses. The challenge is to identify these characteristics and adjust management strategies to enhance strengths while minimizing the weaknesses. Ultimately, the best experience is based on first-hand, on-farm knowledge. Evaluate yield and quality parameters of both university and other local unbiased testing programs to learn more about new varieties. Three-year averages are much more meaningful in evaluating the performance of a variety. If three-year averages do not exist for the varieties in which you are most interested, evaluation across locations can be useful.

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Bourland, F., A. Beach, C. Kennedy, L. Martin, A. Rouse, and B. Robertson. 2015. Arkansas Cotton Variety Test 2014. Arkansas Agricultural Experiment Station, Research Series 623, Fayetteville, Ark.

Table 1. Average ranking of lint yield for the top 16 of the 21 commercially available varieties in the Official Variety Trials (OVT) for the four locations reported compared to the average ranking for the 10 newer commercially available varieties planted in at least four of the seven county testing locations.

Variety	Average OVT rank	Average County rank
DP 0912 B2RF	1	
ST 4747GLB2	2	2
ST 4946GLB2	3	3
PHY 333 WRF	4	1
NG 1511 B2RF	5	6
DP 1321 B2RF	6	5
DP 1311 B2RF	7	7
PHY 495 W3RF	8	
ST 5032GLT	9	
SGS UA222	10	
Dyna-Gro 2570 B2RF	11	9
Dyna-Gro 2285 B2RF	12	4
PHY 339WRF	13	10
PHY 499 WRF	14	
ST 5289GLT	15	
FM 1944GLB2	16	8

Change in Arkansas Cotton Acreage During 2002-2010

A. Flanders[1]

RESEARCH PROBLEM

Arkansas cotton acreage has followed declining trends in U.S. acreage during the latter years of the previous decade. In Arkansas, the primary crops competing for cotton acreage are corn, soybeans, and rice. Long-term acreage allocations are mostly due to soil characteristics and crop rotation considerations that determine suitability for crops. Short-term acreage allocations are responses to economic considerations related to commodity prices and production costs. Results indicate consistent long-term acreage responses with a shift in response magnitude between cotton and rotation crops. The shift in magnitude is attributable to relative relationships among commodity prices that were less favorable to cotton for the period beginning in 2007. The objective of this research is to quantify Arkansas cotton acreage responses with rotation crops for two distinct economic periods.

BACKGROUND INFORMATION

Arkansas cotton acreage has declined during the latter years of the previous decade. Potential acreage shifts to competing crops varies by region and is dependent on localized agronomic conditions. Responsiveness of acreage reallocations to changes in economic considerations entail fundamental agronomic characteristics that vary by geographical production area. Economic conditions that determine acreage allocations include relative commodity prices for all crops that are potentially included in a desirable crop rotation program for maintaining agronomic viability.

RESEARCH DESCRIPTION

The major field crops in Arkansas consist of cotton, corn, soybeans, and rice. Soil characteristics that vary by geographical region influence long-term crop acreage decisions for Arkansas producers. Corn, cotton, soybeans, and rice production technologies have similar yield increases (USDA NASS, 2013). Produc-

[1] Assistant professor, Northeast Research and Extension Center, Keiser.

ers make short-term marginal adjustments in acreage determined by annual economic considerations while maintaining a long-term acreage base.

Arkansas cotton acreage can be categorized with a period of stable or increasing cotton acreage during 2002-2006, followed by a period of declining acreage during 2007-2010. These distinct periods of cotton acreage correspond to changes in relative prices received. All crop prices are increasing after 2006, but cotton price increases lag behind increases for other crops. Although the price index for rice is much greater than all other crops, rotation considerations with soybeans and compatibility of soil types with cotton is a limiting factor for the impacts that increased rice prices can have on cotton acreage. The objective of this empirical analysis is to quantify changes in acreage response among cotton and competing crops for the 2002-2006 and 2007-2010 time periods.

County level acreage data is applied to investigate acreage response among cotton and competing crops during 2002-2010 (USDA NASS, 2013). Data is collected for 18 counties producing the major field crops for a total of 162 observations. The panel data structure allows for repeated annual observations on counties producing cotton and competing crops. A fixed effects model for panel data captures all unobserved, time constant factors that affect a dependent variable. Changes in cotton acreage among competing crops can be represented by a first-differenced equation as:

$$\Delta Cotton_{it} = \beta_0 + \beta_1 \Delta Corn_{it} + B_2 \Delta Soybean_{it} + B_3 \Delta Rice_{it} + \Delta\mu_{it}, \qquad \text{Eq. (1)}$$

where *i* represents a county as a cross-sectional unit and *t* presents an annual observation of the change in crop acreage from the previous year. β_0,β_1,B_2, and B_3 are parameters to be estimated, and $\Delta\mu_{it}$ is an error term for the first-differenced equation. Assuming that the explanatory variables are strictly exogenous and not correlated with the error term, the first-difference method gives unbiased parameter estimates.

Potential change due to higher commodity prices for competing crops after 2006 can be quantified by restating Eq. (1) as:

$$\Delta Cotton_{it} = \beta_0 + \beta_1 \Delta Corn0306_{it} + \beta_2 \Delta Corn0710_{it} + B_3 \Delta Soybean0306_{it} + B_4 \Delta Soybean0710_{it} + B_5 \Delta Rice0306_{it} + B_6 \Delta Rice0710_{it} + \Delta\mu_{it}, \qquad \text{Eq. (2)}$$

where each explanatory variable in Eq. (1) is dichotomized to represent acreage changes for 2003-2006 and for 2007-2010. While Eq. (2) is not a price response model, the empirical model will investigate acreage responses for a period of constant agronomic conditions with increasing production technologies for all crops over two distinct periods of economic environments.

RESULTS AND DISCUSSION

Table 1 presents the parameter estimates for Eq. (2). Negative signs indicate that corn, soybeans, and rice acres are substitutes for cotton acres during both the 2003-2006 and 2007-2010 time periods. Producers continued similar rotation practices in both time periods, but cotton acreage declined relative to other crops in rotation programs. A coefficient greater than 1.0 for corn during 2007-2010 indicates that higher corn prices induced new corn acreage in addition to acreage that was exiting cotton for corn. Comparing estimates between the 2003-2006 and 2007-2010 time periods indicates that substitution increased for all competing crops after 2006. Increases in relative coefficient values for the later time period are 146% for corn, 151% for soybeans, and 131% for rice. Soybeans and rice are expected to substitute for cotton as rotation crops. The average coefficient change in the later period for soybeans and rice is 141%.

Results in Table 1 indicate shifts in acreage allocations among cotton and rotation crops. The shifts are attributable to relative relationships among commodity prices that were less favorable to cotton for the period beginning in 2007. Comparing returns per acre for the two periods is a means to estimate increases in cotton prices that are required to increase the profitability to relative levels that existed during the 2003-2006 period.

PRACTICAL APPLICATION

Public policies and global economic conditions related to agriculture have a potential to cause shifts in acreage allocations. Producers may maintain fundamental relationships in crop rotation practices, but shift acreage concentrations in order to capture increased profits. There are approximately 6.0 million annual acres of cotton, corn, soybeans, and rice in Arkansas. Arkansas cotton acreage can be categorized with a period of stable or increasing cotton acreage during 2002-2006, followed by a period of declining acreage during 2007-2010. These distinct periods of cotton acreage correspond to changes in relative prices received that favor alternative crops over cotton. Results of this analysis indicate shifts in acreage allocations among cotton and rotation crops. Producers continued similar rotation practices in both time periods, but cotton acreage declined relative to other crops in rotation programs. With increasing production technologies for all crops, the shifts are attributable to relative relationships among commodity prices that were less favorable to cotton for the period beginning in 2007.

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Table 1. Regression coefficients[a] for acreage change, cotton and major field crops, Arkansas, 2002-2010.

Variable	Coefficient[b]	Std. Error	t Statistic	Prob. > |t|
Intercept	481.997	528.100	0.910	0.3630
Corn0306	-0.804*	0.172	-4.680	<0.0001
Corn0710	-1.172*	0.126	-9.300	<0.0001
Soybean0306	-0.464*	0.075	-6.210	<0.0001
Soybean0710	-0.702*	0.076	-9.270	<0.0001
Rice0306	-0.448*	0.088	-5.090	<0.0001
Rice0710	-0.587*	0.177	-3.320	0.0012
R-Square	0.6997			

[a] Data are pooled, and ordinary least squares is applied for heteroscedasticity-consistent covariance matrix estimation of the model.
[b] Values followed by * are significant at $P < 0.01$.

Nitrogen Losses and Uptake Efficiency of Foliar Nitrogen Applications in Cotton

J. Burke, D.M. Oosterhuis, and T. FitzSimons[1]

RESEARCH PROBLEM

Nitrogen (N) fertilizers may be lost from the soil or foliage in numerous ways, and an understanding of these fates is essential in order to improve plant nitrogen use efficiency. However, research into the amount and rates of leaf foliar-N uptake and losses over time from various foliar-N fertilizers has been rare. Furthermore, examinations and comparisons of foliar-N fertilizers regarding N loss mechanisms such as surface runoff and volatilization are also scarce. Therefore, in order to assess the efficacy of a variety of foliar-N fertilizer sources, their respective leaf uptake potentials along with their primary N loss mechanisms upon contact with the cotton leaf surface need to be quantified.

BACKGROUND INFORMATION

Foliar nitrogen (N) fertilization of cotton is viewed as a reliable method in which to provide N to cotton plants that may experience N deficiencies within a growing season (Craig Jr., 2002; Oosterhuis and Weir, 2010). Soil-incorporated N fertilizers can be lost from the soil by processes such as leaching, ammonia volatilization and surface runoff (Barber, 1984), and foliar-N fertilizers can also suffer a variety of losses that can severely reduce their efficacy (Wiedenfeld et al., 2009). Maintaining an adequate and available supply of N during the fruiting period is vital in order to insure proper reproductive development and guarantee productive yields (Zhu and Oosterhuis, 1992). Therefore it is essential to understand and quantify the ways in which foliar-applied N can be lost.

RESEARCH DESCRIPTION

The study employed a complete randomized design consisting of 12 treatments and 3 replications using cotton (*Gossypium hirsutum* L.) cultivar Stoneville 4288 B2RF. Plants were grown in a growth chamber programmed at 32/24 °C (day/

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night) temperatures, 14-h photoperiods, and at 60% relative humidity. Treatments included a no-foliar-fertilizer-applied control, foliar-applied urea (1%), Nitamin (1%) and urea ammonium nitrate (UAN 32; 0.4%). All foliar treatments were applied at rates equivalent to 11.23 kg N/ha using a micron pipette and spread with a metal spatula on the leaf surface of the first fully expanded main-stem leaf at the fourth main-stem node from the top of each plant. Leaves were sampled at time intervals of 4, 8, and 16 h after foliar applications.

Leaves for sampling were covered with a 3.785 L clear plastic Ziploc bag containing a 10 ml solution of 1.5 M H_2SO_4 in order to capture NH_3 volatilizing off of the leaf surface and convert it to NH_4^+. Rinsate samples were obtained by placing each harvested leaf in a 50 ml tube containing 10 ml of deionized water. The tube was then gently shaken in order to remove any foliar fertilizer still adhering to the leaf surface. Measurements of adsorbed N samples were made by immersing the leaf in 10 ml of chloroform in order to extract the leaf cuticle. Rinsate, gas capture and chloroform samples were then collected and frozen along with foliar-N treated and control sampled leaves, oven-dried. The total amount of N (TN) lost through rinsate, ammonia volatilization or adsorbed onto the leaf surface was expressed in terms of the percentage of TN lost per the amount of TN applied. This calculation gave an estimate of the amount of foliar-applied N absorbed through the leaf surface. The no-fertilizer-applied control was excluded from rinsate and gas capture graphs and analyses. Analysis of variance methods and Student's *t*-tests were used to determine any significant differences between foliar treatments, sampling times and/or possible interactions between foliar treatments and sampling times in a 4 × 3 full factorial arrangement at the $P \leq 0.05$ by using the "Fit Model" platform provided by JMP Pro 11.0 and 11.2 (SAS Institute Inc., Cary, N.C.).

RESULTS AND DISCUSSION

The nitrogen budgets for foliar-applied urea, UAN 32 and Nitamin concerning all measured response variables at each sampling time are displayed in Table 1. Both the foliar treatment ($P < 0.0001$) and sampling time main effects ($P = 0.0010$) were significant in the total nitrogen budget (%TN) lost via rinsing. At the 4-, 8- and 16-h sampling times, foliar urea lost more N than Nitamin and UAN 32. The %TN lost through NH_3 volatilization was only significant for the foliar treatment ($P < 0.0001$). The amount of %TN lost through volatilization was greatest for UAN 32 and was significantly higher than Nitamin and urea at all sampling times. Nitamin, in turn, was significantly higher than foliar urea in each sampling interval. The %TN adsorbed to the leaf surface for all foliar treatments was significant at $P < 0.0001$. However, the %TN adsorbed between foliar urea, UAN 32 and Nitamin was non-significant. The %TN absorbed by cotton leaves was significant between the foliar treatment ($P < 0.0001$) and sampling time main effects ($P = 0.0014$). At the 4- and 8-h sampling times, Nitamin and UAN 32 had a significantly higher %TN absorbed than foliar urea and in turn, were not significantly different. At the 16-h sampling time, foliar urea had a significant increase in the %TN absorbed but was not significantly different than Nitamin and UAN 32.

PRACTICAL APPLICATION

In this trial, the main foliar-N loss pathway for foliar urea was shown to be through leaf surface runoff and the main loss pathway for UAN 32 was determined to be through ammonia volatilization. However, Nitamin's viscous nature most likely reduced leaf surface runoff while enhancing foliar-N absorption. These results demonstrate the variability of different foliar-N fertilizers regarding their respective N loss pathways along with their relative effectiveness in cotton leaf uptake potential.

ACKNOWLEDGMENTS

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Table 1. Total nitrogen budget (%TN) means per foliar treatment. Sampling times indicate hours (h) after foliar applications.

Foliar Treatment	Sampling Time (h)	%TN Lost (Rinsate)	%TN Lost (Volatilization)	%TN Adsorbed	%TN Absorbed
Foliar Urea	4	10.19 a[†]	0.01 c	0.73 a	88.60 b
UAN 32	4	3.98 b	1.11 a	0.98 a	94.80 a
Nitamin	4	4.48 b	0.20 b	0.77 a	94.88 a
Foliar Urea	8	8.71 a	0.01 c	0.83 a	89.92 b
UAN 32	8	2.74 b	1.52 a	0.75 a	95.35 a
Nitamin	8	3.09 b	0.21 b	0.75 a	96.27 a
Foliar Urea	16	5.37 a	0.01 c	0.87 a	94.99 a
UAN 32	16	1.65 b	1.39 a	0.71 a	96.60 a
Nitamin	16	2.02 b	0.25 b	0.64 a	97.37 a

[†] Columns for foliar and individual sampling time treatments sharing a common letter are not significantly different ($P \leq 0.05$).

Effect of Urea and a Controlled-Release Nitrogen Fertilizer on Cotton Yield in Arkansas

M. Mozaffari, C.G. Herron, and S.D. Carroll[1]

RESEARCH PROBLEM

In many Arkansas soils, cotton (*Gossypium hirsutumn* L.) yield can be optimized by nitrogen (N) fertilization. However, soil and fertilizer N can be lost by processes such as runoff, leaching and denitrification. Improving N-use efficiency will increase the growers' profit margin and reduce potential environmental risks of excessive N application.

BACKGROUND INFORMATION

Polymer coated controlled-release (slow release) N fertilizers may provide the cotton growers with the opportunity to increase their N-use efficiency (Oosterhuis and Howard, 2008). A polymer-coated urea (44% N, Agrium Wholesales, Loveland, Colo.) is currently being marketed in Arkansas under the trade name of Environmentally Smart Nitrogen or ESN[2]. The objective of this study was to evaluate furrow irrigated cotton response to ESN and urea fertilizers in a representative Arkansas soils used for cotton production.

RESEARCH DESCRIPTION

The effect of pre-plant application of urea, ESN and their combinations on cotton yield in a Loring silt loam (Oxyaquic Fragiudalfs) at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station (LMCRS) in Marianna, Ark. was investigated. Soil samples were collected from the 0-to 6-inch depth and composited by replication before fertilizer application. Selected soil properties were measured by standard methods. Average soil properties in the 0-to 6-inch depth were: 1.8%, soil organic matter 12 ppm NO_3-N, 28 ppm P, 121 ppm K, and 6.2 pH. Selected agronomic information is presented

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[2] 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.

in Table 1. Current Cooperative Extension Service soil-test based irrigated-cotton fertility guidelines recommended an application of 90 lb N/acre. The experimental design 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. All other fertilizers were applied as recommended by soil test results. All fertilizers (including the N-fertilizer treatments) were hand applied onto the soil surface and mechanically incorporated immediately. Standard cultural practices for production of furrow- irrigated cotton were followed. Each cotton plot was 40-ft long and 12.6-ft wide allowing for four rows of cotton planted in 38-inch wide rows. The two center rows of cotton in each plot were harvested with a spindle-type picker equipped with an electronic weight measuring device. We obtained monthly precipitation data from the weather station at LMCRS (Table 2). Analysis of variance (ANOVA) was performed by using the GLM procedure of SAS. The data from the control (0 lb N/acre) were not included in the ANOVA. When appropriate, means were separated by the least significant difference (LSD) method and interpreted as significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

The main effect of N source and N rate both significantly ($P \leq 0.0530$) influenced seedcotton yield, but the N source × N rate interaction did not influence seedcotton yield ($P > 0.10$, Table 3). The significant N source effect suggests that ESN-N was more available for plant uptake than conventional urea in 2014 when the amount of earlyseason rainfall was above normal and conducive to early-season N loss. Seedcotton yield for the cotton that received no N was 1990 lb/acre, which was numerically (25%) lower than the yield of cotton that received the lowest N rate of 30 lb N/acre, averaged across N sources (Table 3). Averaged across the five N rates, cotton fertilized with 100%-urea-N produced significantly lower seedcotton yield (2675 lb/acre) than cotton fertilized with 25%-urea-N plus 75% ESN-N (2892 lb/acre) or cotton that received 100%-ESN-N (2815 lb/acre). Averaged across the four urea and ESN blends, application of 90 lb N/acre significantly maximized seedcotton yield. When urea was the sole N source, maximal numeric seedcotton yield was produced by application of 120 lb N/acre; but when ESN was the sole source of N, maximal numeric yield was produced with application of 90 lb N/acre. Similar to the 2013 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 APPLICATION

The amount of early-season precipitation during the 2014 growing season was above long-term average (Table 2) and was conducive for possible loss of the preplant-applied N. Seedcotton yields were maximized by application of 90 lb N/

acre and treatments that included 25% to 100% of the N applied as ESN produced greater yield than those fertilized preplant with urea. Averaged across N rates, yield of cotton fertilized with more than 50% ESN-N was significantly higher than cotton fertilized with 100% urea. These results suggest that preplant-incorporated ESN is a suitable alternative to urea for irrigated cotton production in Arkansas.

ACKNOWLEDGMENTS

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Table 1. Selected agronomically important information for a cotton N fertilization trial established at the Lon Mann Cotton Research Station in Marianna, Ark. during 2014.

Previous crop	Soil series	Cultivar	Planting date	N application date	Harvest date
wheat	Loring silt loam	ST4946	5-June	23-May	21-Oct

Table 2. Rainfall received by month in 2014 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) ---------------------				
2014 [a]	6.32	9.77	2.55	4.67	1.33	24.64
Average[b]	5.90	3.90	3.90	2.80	3.20	19.70

[a] Cotton was planted on 5-June and harvested on 21 Oct.
[b] Long-term average for 1960-2007.

Table 3. Seedcotton yield as affected by the significant (P < 0.10) N source (averaged across N rates) and N rate (averaged across N sources) main effects and the non-significant N source × N rate interaction (P > 0.10) for a cotton fertility experiment conducted at the Lon Mann Cotton Research Station in Lee County Ark. during 2014.

	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 mean	N-fertilizer source	N source mean
lb N/acre	---------- Seedcotton yield (lb/acre) ----------						lb/acre
0		1900[b]				None	1900[b]
30	2361	2555	2695	2593	2543	100% Urea-N	2675
60	2569	2607	2767	2787	2682	50%Urea-N, 50%ESN-N	2748
90	2767	3000	3030	2949	2937	25% Urea-N,75% ESN-N	2892
120	2888	2873	3010	2841	2903	100% ESN-N	2815
150	2787	2705	2917	2903	2828		
LSD 0.10		NS[c] (interaction)			137[d]	LSD 0.10	123
P-value		0.9683			<0.0001	*P*-value	0.0530

[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] Least significant difference compares the yield of treatments that received N, averaged across N sources.

Evaluation of Foliar Fertilizer Products in Cotton

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

RESEARCH PROBLEM

Cotton producers are looking for ways to improve production and increase yield to help offset 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 in northeast Arkansas.

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 yield 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 nitrogen loss through leaching can result in a reduction of nitrogen 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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RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutumn* L.) cultivar Stoneville 5288 B2R was planted at the Manila Airport Research Field on 8 May 2014. Production inputs were based on weekly field inspections and followed University of Arkansas Cooperative Extension Service recommendations for cotton production. All practices, with the exception of foliar-applied products were consistent across all plots in this study. Based on recommendations of the manufacturer, all foliar-fertilizer applications (including application rates) were made during the first 10 days of flower.

Treatments were established on 17 July 2014, approximately 10 days after first flower, and included four 38-in rows 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 gallons per acre. Plots were machine harvested on 21 October 2014 and converted to a per acre yield (Table 1).

RESULTS AND DISCUSSION

Yields from the 2014 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 (Tables 1 and 2). Soil test levels (data not presented) 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 effects. Future plans are to evaluate these and similar products on field areas expressing historically low yields and in areas of varying soil texture.

PRACTICAL APPLICATION

Although high soil nutrient levels may have masked any expected effects of foliar-applied fertilizer on yield in this study, the evaluation of their effects in different soil type/management zones is warranted. Evaluation of foliar-fertilizer products can help producers identify which fertilizer source provides the most cost effective option for meeting the fertility requirements of cotton. Expanded testing of foliar products on field areas with historically low yields may help develop crop fertilizer strategies which improve the efficiency of cotton production in Arkansas.

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Table 1. Yields for foliar fertilizer treatments, Manila, Ark., 2014.

Foliar Product	Product Rate (acre/oz)	Lint yield (acre/lbs)
NOVUS K	128	1575
Quick Ultra with Awaken	32	1539
Coron 25-0-0	192	1526
NOBUS B	128	1502
Utilize	8	1480
Deliverek K plus	128	1468
N-Pact 26-0-0	128	1461
Coron Full BOR	16	1458
Control – No Treatment	--	1441
Re-Nforce	192	1405
Boost-it	32	1402
VitaBor	8	1386
Bloom Pro	32	1343
NUTRA – K	32	1314
		P >F (0.49)
		NS

Table 2. Analysis of variance for foliar demonstration, 2014.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	243533.6071	16235.5738	0.97	0.5109
Error	26	435828.5376	16762.6361		
Corrected Total	41	679362.1448			
rep[a]	2	28065.1490	14032.5745	0.84	0.4443
trt	13	215468.4581	16574.4968	0.99	0.4878

[a] rep = replication, trt = treatment.

Effect of Potassium Fertilization and Cultivar on Potassium Partitioning

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

RESEARCH PROBLEM

Potassium (K) is involved in numerous physiological processes (Oosterhuis et al., 2013) and a deficiency can affect a number of plant characteristics such as reductions in lint yield and biomass production (Yang et al., 2011; Pettigrew and Meredith, 1997). The last major K partitioning study was published in 1990, with lower yielding, nontransgenic cultivars (Mullins and Burmester, 1990). With the advancement in transgenic technologies in cotton, there is need for a more recent K partitioning study involving modern cotton cultivars.

BACKGROUND INFORMATION

Potassium is the most abundant cation in plant cells but is not a constituent of any single plant component (Szczerba et al., 2009). Understanding the uptake and distribution of K by the cotton (*Gossypium hirsutum* L.) plant during the season is essential for efficient and profitable fertility management. Whole cotton plant K accumulation patterns have been documented for traditional non-transgenic cultivars (Mullins and Burmester, 1990). The K uptake curve somewhat mirrors that of dry matter production, however dry matter production continues after K uptake has reached a maximum at approximately 112 days after planting (Oosterhuis et al., 2014). Whole plant K accumulation generally follows a curve that has a maximum uptake around 112 days after planting. However K is a highly mobile element and moves throughout the plant, and K concentrations in individual plant parts shift throughout the growing season (Gerardeaux et al., 2010). According to Mullins and Burmester (1990), mature non-transgenic cotton took up an average of 99-108 kg K ha^{-1} with 24.8% of K in the shoots, 20% of K in the leaves, 36.5% of K in the capsule walls, and 18.4% of K in the seed. In another study, Leffler (1986) found that of the K accumulated by the boll, 60% is in the capsule wall, 27% is in the seed, and 10% is in the fiber at maturity. There has been much research concerning K partitioning in older, non-transgenic cultivars, but no studies

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[3] Extension soil scientist, Department of Crop, Soil, and Environmental Sciences, Little Rock.

looking at modern, transgenic cultivars. Plant dry matter can have as much as 10% K by weight (Szczerba et al., 2009), but the optimum amount for cotton is 2-5% (Oosterhuis et al., 2013). Cotton bolls can accumulate K to concentrations above 40 mg/g of the dry weight (Kafkafi and Xu, 1996). Potassium uptake is slow during the seedling stage, increases rapidly at flowering, and slows after the maximum is reached at maturity (Oosterhuis, 2002). Cotton's K needs are highest during boll set because bolls are a major K sink. During the development of a boll, K concentration in plant tissue increases from 10 g kg^{-1} to 55 g kg^{-1} at maturity (Oosterhuis, 2002).

RESEARCH DESCRIPTION

This study took place during the 2014 growing season at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Center in Marianna, Ark. The study was a completely randomized design with four K rates (0, 30, 60, and 90 lb K_2O/acre) and three cultivars (Phytogen 499, Stoneville 5458, and Delta Pine 0912) replicated four times. Plots were four rows wide and forty-five feet long. Potassium was applied pre-plant as KCl. At pinhead square (PHS), first flower (FF), and three weeks after first flower (FF+3), one meter of whole plant samples were taken from the middle rows of plots. Plants were then divided into stems, petioles, leaves, and reproductive components. Dry matter and K concentrations of these plant parts were recorded, as well as yield components at the end of season.

RESULTS AND DISCUSSION

For this summary, only cultivars PHY499 and DP0912 with 0 and 90 lb K_2O/acre applied in the leaf and reproductive component plant parts will be discussed.

Potassium Partitioning Results

Major K shifts occurred in the leaves and reproductive component from PHS to FF+3. The proportion of total K in the leaves significantly decreased throughout the season in every treatment; however, there were no differences between any treatments at each growth stage ($P < 0.05$; Fig. 1). Regardless of treatment, the proportion of total K in reproductive components significantly increased throughout the season ($P < 0.05$; Fig. 2). At growth stage PHS, DP0912 with 90 lb K_2O/acre had a significantly higher proportion of total K in reproductive components than DP0912 with 0 lb K_2O/acre and PHY499 with 0 and 90 lb K_2O/acre ($P < 0.05$). DP0912 had significantly higher proportion of K than PHY499 at FF, but no significant interaction between cultivar and K level was found ($P < 0.05$). Although the proportion of total K in reproductive components increased drastically over the growing season, the overall concentration of K in reproductive components decreased due to the increase in biomass from PHS to FF3 (not shown).

Yield Results

Comparing the four K and cultivar treatments, DP0912 with both 0 and 90 lb K_2O/acre had significantly higher yields than PHY499 with both 0 and 90 lb K_2O/acre ($P < 0.05$) (Fig. 3). However, there was no significant yield differences between cultivars when K was not included as a variable ($P < 0.05$).

PRACTICAL APPLICATION

The increased translocation of K to reproductive units in DP0912 could have led to the higher yields as compared to PHY499. There were no differences in leaf K partitioning in low- or high-K environments or between cultivars. Over the growing season, K in reproductive components increased as leaf K decreased. In low-K situations, DP0912 yielded higher and partitioned more K into reproductive components than did PHY499, indicating a higher tolerance to K deficiency.

ACKNOWLEDGMENTS

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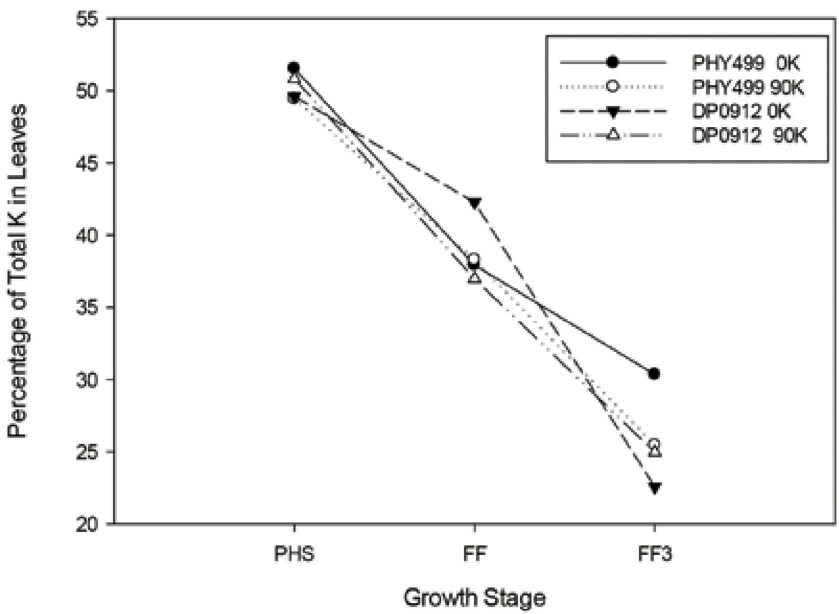

Fig. 1. Proportion of total potassium located in leaves at three growth stages by varying K treatments and cultivars.

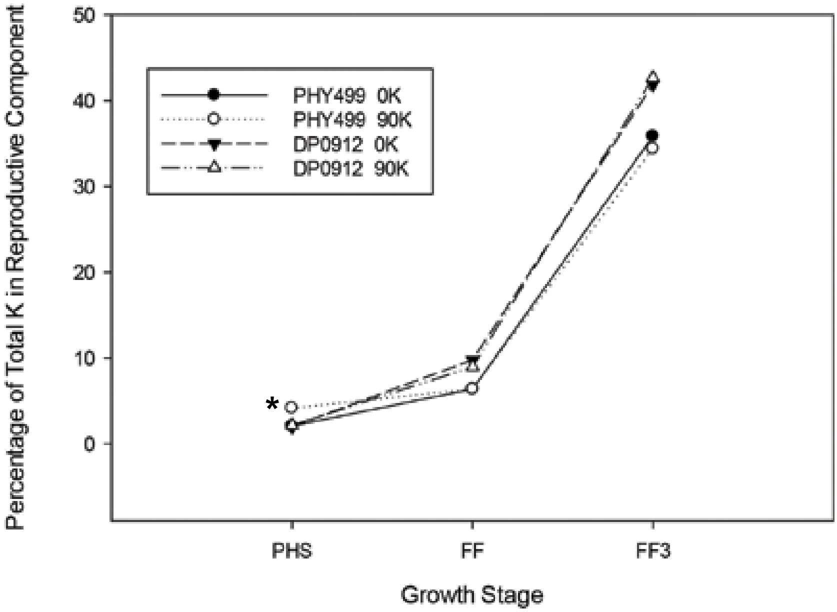

Fig. 2. Proportion of total potassium located in reproductive components at three growth stages by varying K treatments and cultivars. Significant cultivar and potassium interaction within each growth stage marked by a star ($P < 0.05$).

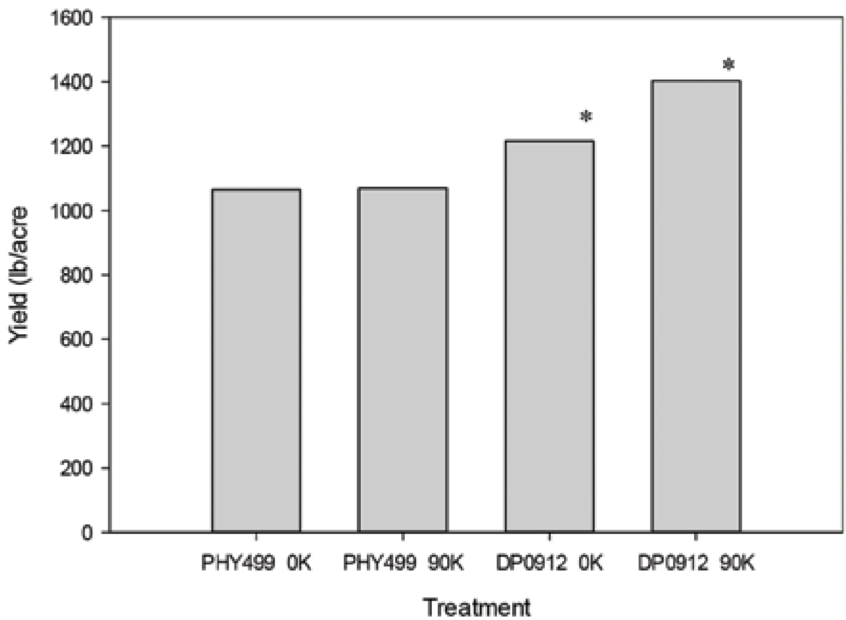

Fig. 3. Seedcotton yield response to varying K treatments and cultivars. Significant differences marked with a star ($P < 0.05$).

The Fate of Nitrogen and Phosphorus Fertilizer in Cotton Production

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RESEARCH PROBLEM

Arkansas cotton farmers are under increasing pressure from environmental groups and retailers alike to operate with environmental sustainability. To help agricultural producers take ownership of documenting environmental impact and water-related sustainability, the University of Arkansas System Division of Agriculture in conjunction with many stakeholder groups launched the Arkansas Discovery Farm (ADF) program in 2011 and established a Cotton Discovery Farm in 2013 on the C.B. Stevens farm in Desha County. This program utilizes a unique approach based on agriculture producers, scientists and natural resource managers working jointly to collect economic and environmental data from real, working farms to better define sustainability issues and find solutions that promote agricultural profitability and natural resource protection.

BACKGROUND INFORMATION

Within the Mississippi River drainage basin, large-scale, basin-wide, water quality modeling efforts by the United States Geological Service projects agriculture in States along the Mississippi River corridor as the leading source of nitrogen and phosphorus delivery to the Gulf of Mexico where excessive nutrients are thought to be the cause of large hypoxic (waters with low dissolved oxygen) zones within the Gulf. This has led to concern among environmental groups to increase nutrient efficiency in crop production. In an independent effort but with similar goals, Field to Market is an important component of the Cotton LEADS™ program. Field to Market, a diverse alliance of industry and retailers, is working to create opportunities across the agricultural supply chain for continuous improvement, environmental quality, and human well-being. However, little data exists that quantifies edge-of-field losses from agricultural operations and tracks

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these losses through drainage pathways to streams and rivers. One objective of the Cotton Discovery Farm was to quantify sediment and nutrient losses in runoff generated from precipitation and irrigation and use this information to evaluate sustainability metrics.

RESEARCH DESCRIPTION

The Arkansas Discovery Farm is located in Desha County near Rowher, Ark. on the C.B. Stevens farm. Four fields in cotton and corn rotations, Shopcot (22 acres; cotton), East Weaver (38 acres; Corn) Homeplace (39 acres; Cotton) and Welcot (41 acres; Cotton), were selected for monitoring the quantity and quality of both inflow (precipitation and irrigation) and outflow (runoff). Cotton was planted in late May while the corn in East Weaver Field was planted in early May. A cereal rye cover crop was utilized in the Shopcot field. Stale seed bed with minimum tillage was utilized in all fields. For the three cotton fields, 89 lbs of N as liquid URAN was applied on 18 June with 22 lbs of urea broadcast on 22 June and 30 pounds of P were broadcast on 22 June. For the corn, 92 lbs of N as pre-plant was applied on May 5 with additional 177 lbs as liquid incorporated on 22 May on North half and 161 lbs of N as agrotain broadcast on South half. Forty-five pounds of P were applied on 5 May.

At the lower end of each field, automated, runoff-water-quality monitoring stations were established to: 1) measure runoff flow volume, 2) to collect water quality samples of runoff for water quality analysis and 3) measure precipitation. The ISCO 6712 (Teledyne Isco, Lincoln, Neb.) automated portable water sampler was utilized to interface and integrate all the components of the flow station. Runoff flow volume (discharge) was collected with a trapezoidal flume especially designed to measure flow in agricultural drainage channels. Discharge data were utilized to trigger flow-paced, automated collection of up to 100, 100-mL subsamples which were composited into a single 10-liter sample.

A subsample of the 10-liter sample was collected, processed in the field for preservation and shipped in insulated shipping vessels to keep samples chilled to meet EPA guidelines for prepping and handling samples. Samples were shipped to the University of Arkansas System Division of Agriculture's Water Resources Lab (certified by the Arkansas Department of Environmental Quality) to determine concentration of ortho-Phosphorus, nitrite-nitrate-Nitrogen, total nitrogen, total phosphorus and total solids according to handling, prepping and analytical methods outlined by EPA (AWRC, 2014).

RESULTS AND DISCUSSION

Total N loss ranged from 1% to 6% in runoff while P losses were similar across fields at 2% of the P applied (Tables 1 and 2). This indicates relatively low loss relative to application. The sum of estimated nutrient uptake and losses in runoff was similar to the application rate, which indicates an efficient use of N and P applied as fertilizer. The corn crop in East Weaver actually had to remove N and P stored in the soil to meet the crop demand. Average N and P losses per event were less than 1% and less than 0.1% for N and P respectively across all fields (Table 3). Nitrogen losses in 2014 were slightly lower than in 2013, while P losses were essentially the same across years with the exception of the Shopcot field where there was considerable reduction in P loss for 2014 (Tables 4 and 5).

PRACTICAL APPLICATION

The data collected during the first two years indicates low nutrient losses in runoff to off-farm water bodies, which provides encouragement that our cotton production systems are efficient in terms of nutrient loss to runoff. It is still preliminary as it is generally accepted by the scientific community that runoff studies should be conducted for a minimum of five years to account for climatic and hydrological response variability.

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Table 1. Seasonal total nitrogen loss as compared to nitrogen applied.

Field	Crop/ Yield	N-Applied	N-Loss	N-Loss	Removal + Loss
		---------- lb/A	----------	%	lb/A
ShopCot	Cotton 1304 lb/A	111	4.41	4.0	109
WellCot	Cotton 1376 lb/A	111	6.57	5.9	117
Homeplace	Cotton 1440 lb/A	111	1.19	1.1	116
E. Weaver	Corn 219 bu/A	260	5.87	2.3	213

Table 2. Seasonal total phosphorus loss in runoff compared to phosphorus applied.

Field	Crop/ Yield	P-Applied	P-Loss	P-Loss	Removal + Loss
		------------ lbs/A ------------		%	lb/A
ShopCot	Cotton 1304 lb/A	30	0.68	2.3	27
WellCot	Cotton 1376 lb/A	30	0.66	2.2	28
Homeplace	Cotton 1440 lb/A	30	0.71	2.4	30
E. Weaver	Corn 219 bu/A	48	0.88	1.8	87

Table 3. Average loss per runoff event.

Field	Events	N-Loss (lb/A)	P-Loss (lb/A)
ShopCot	11	0.40	0.062
WellCot	12	0.55	0.055
Homeplace	9	0.13	0.079
E. Weaver	20	0.29	0.044

Table 4. Nitrogen losses by year.

Field	Year/Crop	N-Applied lb/A	N-Loss lb/A	N-Loss %
Shopcot	2013 Cot	108	11.4	10.5
	2014 Cot	111	4.4	4.0
Weaver	2013 Cot	108	11.4	10.5
	2014 Corn	260	4.41	4.0
Homeplace	2013 Cot	108	1.8	1.7
	2014 Cot	111	1.2	1.1
Wellcot	2013 Corn	275	--	--
	2014 Cot	111	6.57	5.9

Table 5. Phosphorus losses by year.

Field	Year	P-Applied lb/A	P-Loss lb/A	P-Loss %
Shopcot	2013 Cot	27	2.2	8.1
	2014 Cot	30	0.7	2.3
Weaver	2013 Cot	27	0.5	1.9
	2014 Corn	48	0.9	1.8
Homeplace	2013 Cot	27	0.8	3.0
	2014 Cot	30	0.7	2.4
Wellcot	2013 Corn	34	--	--
	2014 Cot	111	6.6	5.9

Temperature Gradients in the Canopy and Effects on Boll Growth

M.S. Berlangieri, D.M. Oosterhuis, and T.R. FitzSimons[1]

RESEARCH PROBLEM

Temperature is one of the most important factors affecting cotton boll growth and development. Environmental conditions fluctuate considerably from year to year and have an effect on ultimate yield. Most data involving temperature and yield that rely upon the effects of temperature stress use ambient air temperatures. However the temperature profile in the field can be considerably different than temperatures above the canopy. Thus, the relationship between ambient temperatures and those inside the canopy, and the possible effects on cotton bolls growth must be addressed. This research provides an insight into potential microclimate effects within the canopy that may influence boll growth.

BACKGROUND INFORMATION

According to Reddy et al. (1991b) cotton grown under supra-optimal temperatures exhibited reduced growth, lowered CO_2 fixation, and reduced sink strength. Similar studies also determined that supra-optimal temperatures affected cotton's phenology, leaf expansion, and assimilate partitioning (Reddy et al., 1991a). Cotton's optimal temperature has been established at 28 ± 3 °C (Burke and Wanjura, 2010), while Bibi et al. (2008) indicated that 33 °C was the optimum for photosynthesis. One of the principal problems with research in environmental stress physiology is that either ambient air temperatures or temperatures at the top of the canopy are used to characterize a stress and its effects on yields; however, actual temperatures in the canopy where bolls develop are different (Gonias et al., 2010). The effect of that temperatures on leaf and boll development at different depths in the canopy has not been addressed. Additionally, internal boll temperatures and its relationship with temperature and mid-canopy growth is unknown.

Little to no work has been performed on canopy microclimate effects within the past 50 years for cotton. Most of the papers are very old and out of date, such as Jarman (1959) and Stanhill and Fuchs (1968). However, they found that there is evidence that less dense cotton canopies experience higher temperatures at the

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mid-canopy early in the growing season, although the comparisons were between different canopy structures and not related to ambient air temperature (Jarman 1959; Marois et al., 2004). To the contrary, in corn, it has been suggested that upper canopies experience higher temperatures and lower water potential (Liu and Song, 2012). However, Liu and Song (2012) iterated that temperatures are higher when the canopy is closer to the soil surface.

RESEARCH DESCRIPTION

A field experiment was carried out at the University of Arkansas System Divison of Agriculture's Agricultural Experiment Station, in Fayetteville, Ark. during the summer of 2014. The experiment consisted of two planting dates: 20 May and 4 June 2014 for allowances for a cumulatively longer flowering period when heat may impact plants. Crop management was performed according to cotton recommended practices, with a double nitrogen application (40 lb N/acre at planting and 40 lb N/acre at pinhead square), and furrow irrigation as needed based on soil moisture. The cotton (*Gossypium hirsutum* L.) cultivar used was DP0912 B2RF. Weekly measurements were performed at noon, beginning one week after first flower. Temperature measurements were recorded using type K thermocouple thermometers at both lower canopy position (main-stem node 7 ± 1) and upper canapy (main-stem node 11 ± 1) for internal boll, boll surface, air next to the boll, ambient air above the canopy, subtending leaf, and soil temperatures. Relative humidity (%) and wind (m/s) within the different canopy profiles were also recorded. Ambient conditions from the closest weather station were recorded for the entire growing season as a control check. Statistical analyses were performed in JMP11.

RESULT AND DISCUSSION

To summarize the results, only the first planting will be discussed. Lower canopy air around cotton 7th node, resulted in significantly ($\alpha = 0.05$) warmer temperatures than ambient air in the first, second, and third weeks after first flower (Fig. 1). Differences between the ambient air above the canopy and inside the canopy reached a maximal of 7 and 8 °C for both the upper and lower canopy, respectively. Those values appeared early in the boll development stage and are supported by the literature since less dense canopies experienced warmer temperatures in the interior of the canopy (Marois et al., 2004). Both canopy positions, upper (not shown) and lower did not present differences between the ambient air and the air inside the canopy for the 4th and 5th weeks after first flower, respectively. This may indicate that denser canopies (i.e. more advanced into the season with higher leaf area index) reduce the temperature gradient, producing a more stable air profile.

Air inside the canopy was warmer for the 3 consecutive weeks after first flower. One of the possible reasons may be that evapotranspiration may have slowed due to measurements taken at noon; however, the temperatures for the 2014 season were relatively cool, and not potentially sufficient to cause under well-watered conditions. Conversely, evapotranspiration may be reduced due to smaller leaf size at early stages of reproductive development causing the inside of the canopy to be warmer compared to the ambient air. Finally, according to the literature, less dense canopies experience higher temperatures which due to solar insolence affect a greater proportion of both the air and soil when compared to later season effects.

PRACTICAL APPLICATION

The research related to microclimate and temperature gradients present a wide spectrum of practical applications for crop physiology research. The specific findings of these experiments will allow for a better understanding of the temperature dynamics within the canopy. The finding that earlier in the season, cotton displays significantly warmer temperatures inside the canopy leads us to question the usefulness of ambient temperature as an indicator of stress. Additionally, this may indicate the existence of differential heat stresses between different parts of the canopy.

ACKNOWLEDGMENTS

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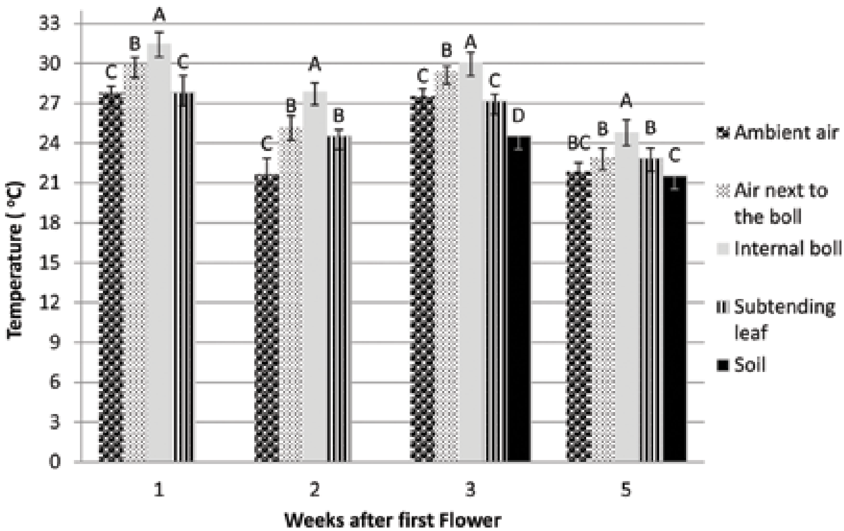

Fig. 1. Temperature gradients over time for the lower canopy first planting date for the air next to the boll, internal boll, subtending leaf, and soil temperatures. Within each week, columns not connected by the same letter are significantly different at an α level of 0.05 student's *t*-test. Errors bars indicate 95% confidence interval.

Evaluation of Screening Methods to Detect Heat Stress in Four Cotton Cultivars Grown in a Growth Chamber

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

RESEARCH PROBLEM

Elevated carbon dioxide-induced climate change will affect cotton production practices due to more frequent occurrence of extreme weather events such as heat waves (Oosterhuis, 2013). Warmer temperatures in some agricultural production areas caused by global warming will have a negative effect on sustainable crop production. This is an increasing agricultural problem in many areas in the world as high temperature stress reduces yield in cotton.

BACKGROUND INFORMATION

High temperature has a strong negative correlation with cotton lint yields and quality (Oosterhuis, 2002; Rawson, 1992; Hodges et al., 1993; Singh et al., 2007). Plant physiological functions during reproductive stages are affected negatively with elevated temperatures. Bibi et al. (2008) found that high day temperatures of 36 °C and above caused significant decreases in the photosynthesis, leaf extension growth and quantum yield of photosystem II. Their research showed non-significant changes when temperature was increased from 30 to 35 °C, but found a 49% decrease when temperature was increased to 40 °C indicating high-temperature stress. Plant responses to high temperature vary with plant species and developmental stages. In most plants, the reproductive processes are markedly affected by high temperatures, which ultimately affect the fertilization processes leading to reduced crop yield (Snider et al., 2009). There is a need to screen different cotton cultivar's physiological (metabolism) responses for the repressing effect of heat (Bibi et al., 2008). The objective of this study was to investigate the effect of high-temperature stress on the physiological processes of four contrasting cotton cultivars grown in a growth chamber using different screening methods.

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RESEARCH DESCRIPTION

A growth chamber study was conducted at the University of Arkansas System Division of Agriculture's Altheimer Laboratory, Fayetteville, Ark. during May 2014. Cotton (*Gossypium hirsutum* L.) was planted on 1 April 2014 in 2-L pots in nutrient-free Sungro Horticultural potting mix and placed into two Conviron PG15 growth chambers. Plants were watered daily to soil capacity with half strength Hoagland's solution. Four diverse cultivars were evaluated: VH260 (Heat tolerant), and Arkot 9704 (Moderately tolerant), DP 393 (Heat sensitive) and DP210 BRF (a cultivar of unknown tolerance planted commercially in South Africa). Two heat treatments were compared; 30/24 °C and 40/24 °C (day/night). High-temperature stress was imposed at the onset of first flower. Temperatures were increased the day of stress beginning at 8:00 AM in 3 °C increments hourly until maximum temperatures had been achieved. The experimental design was organized as a randomized block design with 15 replications. Membrane leakages (ML), fluorescence, and electron transport rates were measured 2, 4 and 6 h following the onset of heat stress.

RESULTS AND DISCUSSION

The effect of heat stress on membrane leakage on cultivars with time after heat stress treatment differed significantly (Fig. 1). The only cultivar that leaked less electrolytes at all three measuring times was Arkot. At 2 h after heat stress, Arkot's ML decreased from 85.2% to 81.2%. After 4 and 6 h of heat stress, Arkot 9704 had a mean leakage decrease from 84.1 to 82.3%, respectively.

Fluorescence (ΦPSII) with time after heat stress treatment and cultivars differed significantly. Four hours after heat stress, fluorescence was the lowest (0.64 ΦPSII; Fig. 2a). Cultivar VH260 had the highest fluorescence of 0.7 quantum yield at photosystem II. Although not significantly Fig. 2b shows that when a heat stress was experienced, all cultivars except DP393 resulted in lower fluorescence..

Electron transport rate differed significantly with time after heat stress treatment and cultivars. Figure 3a shows that electron transport rate was detrimentally affected when 4 h of heat stress was experienced. The highest electron transport rates were found with cultivars Arkot 9704 and DP393. Figure 3b indicated that electron transport rates decreased when a heat stress was experienced with cultivars VH260, Arkot9704 and DP393, but not DP210.

It seems as if the 4 h heat stress application did the most damage as ML was higher and fluorescence and electron transport rates were the lowest, indicating a recovery or acclimation of plants when heat stress persists for 6 hours.

PRACTICAL APPLICATION

Quantification of the detrimental effects of high temperature stresses is possible by using membrane leakages, fluorescence and electron transport rate as screening methods. These methods are easy, inexpensive and rapid. This is an ongoing project to evaluate cotton cultivars in order to find cultivars with heat tolerance with the aim of aiding cotton plant breeders in selection and also for recommending to cotton producers tolerant cultivars as well as adopted management practices to reach optimal yields.

ACKNOWLEDGMENTS

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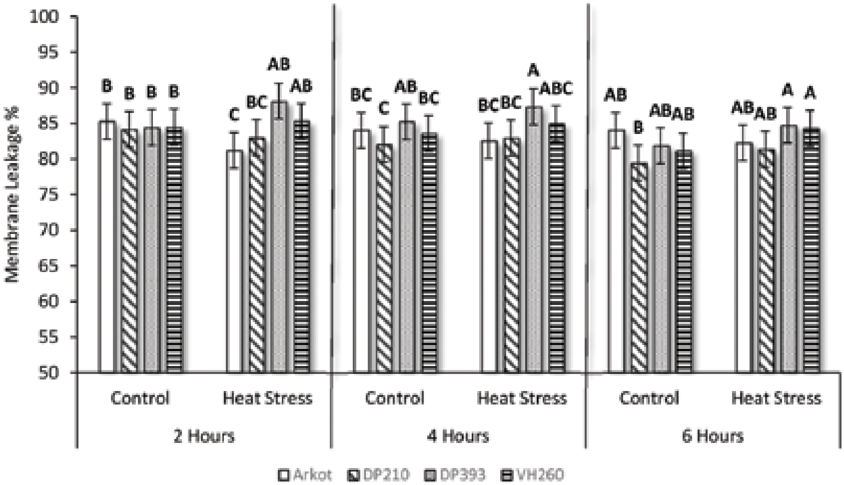

Fig. 1. Membrane leakage of four genotypes; VH260, Arkot 9704, DP393 and DP210 measured at 2, 4 and 6 hours after heat stress as an indication of the effect of heat stress on cell integrity. Measurements were made in the control temperature (30 °C) and in the elevated high temperature (40 °C) on the day of the heat stress treatment at the first flower stage. Error bars represent ±5% of the mean. Shared capital letters within each time period are not significantly different (*P* = 0.05).

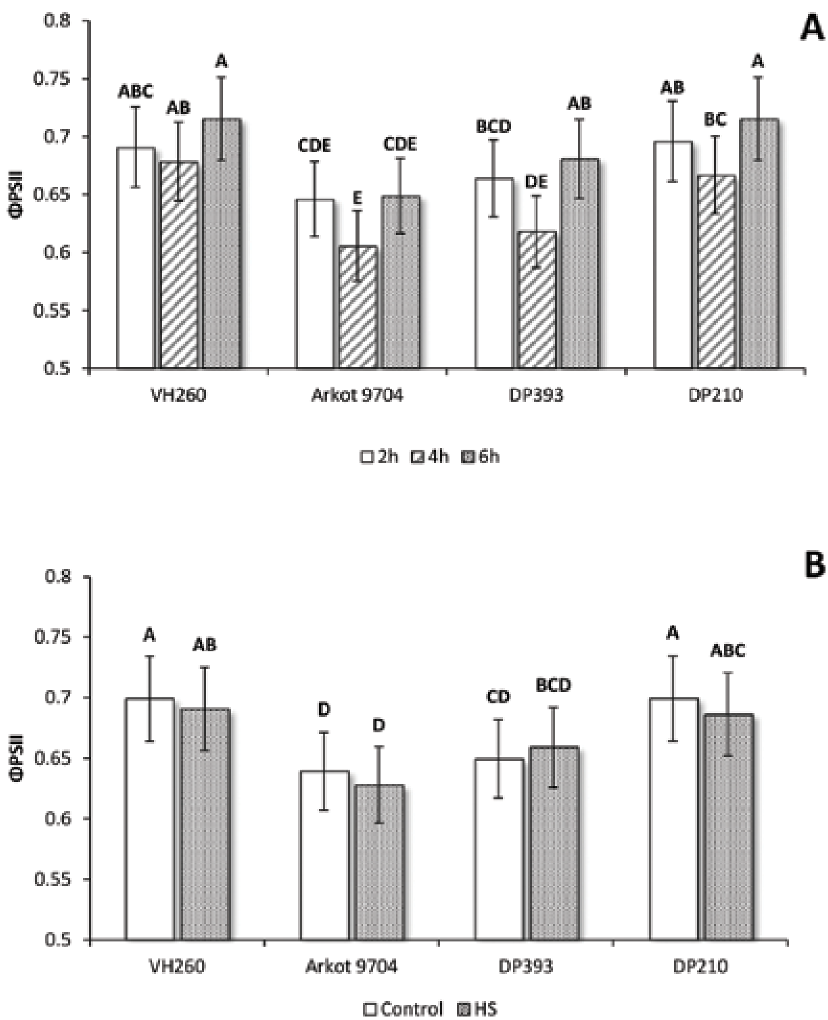

Fig. 2. A) Fluorescence (ΦPSII) of four genotypes: VH260, Arkot 9704, DP393 and DP210 measured at 2, 4 and 6 hours after heat stress (HS) as an indication of the effect of heat stress on fluorescence. B) Fluorescence of four genotypes: VH260, Arkot 9704, DP393 and DP210 measured in the control temperature (30 °C) and in the elevated high temperature (40 °C) on the day of the heat stress treatment at first flower. Error bars represent ±5% of the mean. Shared capital letters are not significantly different (*P* = 0.05).

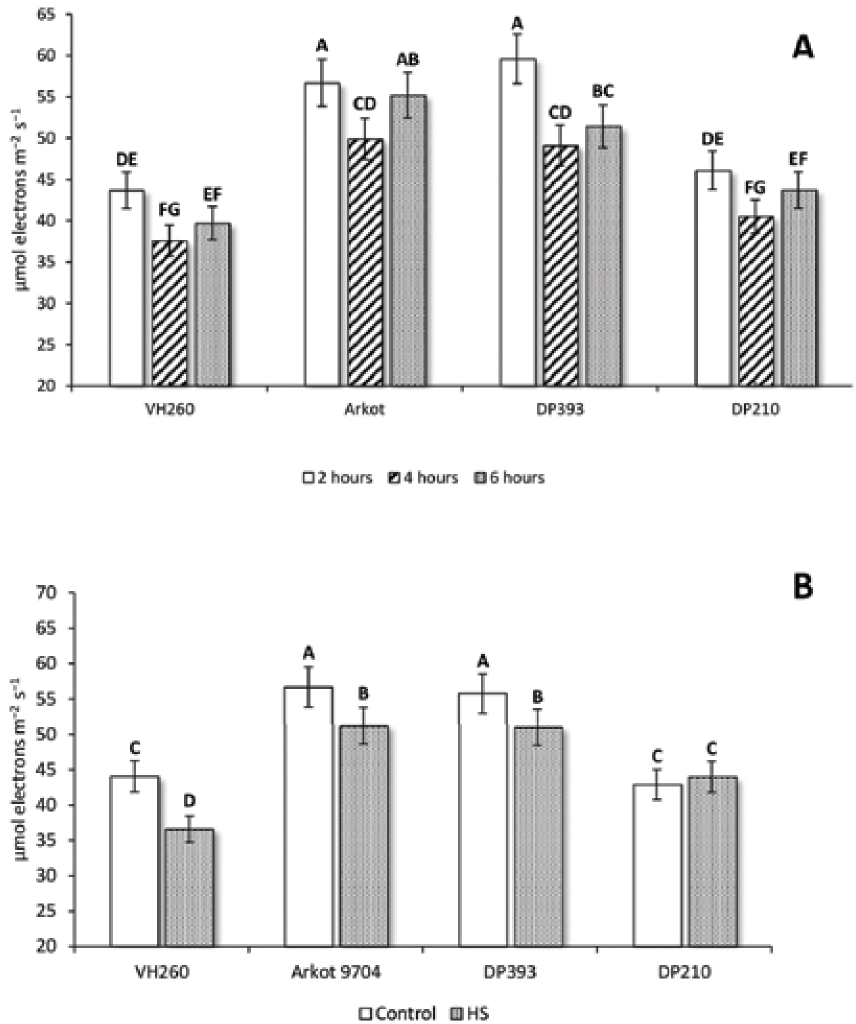

Fig. 3. A) Electron transport rate of four genotypes: VH260, Arkot 9704, DP393 and DP210 measured at 2, 4 and 6 hours after heat stress (HS) as an indication of the effect of heat stress on fluorescence. B) Electron transport rate of four genotypes: VH260, Arkot 9704, DP393 and DP210 measured in the control temperature (30 °C) and in the elevated high temperature (40 °C) on the day of the heat stress treatment at first flower. Error bars represent ±5% of the mean. Shared capital letters are not significantly different (*P* = 0.05).

Improved Two-Dimensional Electrophoresis Through Better Tissue Preservation

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

RESEARCH PROBLEM

One of the more utilized aspects of proteome analysis is the art of two-dimensional (2D) electrophoresis. This useful tool provides a fast and relatively simple method of determining differences in protein regulation of a tissue. This tool is not without its particular drawbacks, however, as the results of the analysis depends greatly on the manner in which the tissue was handled during the preservation process. Cotton in particular has proven to be enigmatic in its ability to have consistent electrophoresis gels from one tissue sample to another due to increased interfering substances or degradation effects between the two lots. Thus, this research strove to examine the preservation method of tissue as a possible hindrance to successful 2D electrophoresis.

BACKGROUND INFORMATION

The use of 2D electrophoresis has been a significant contribution to the field of proteomics as providing the most efficient method of viewing a protein snapshot of a particular tissue at a specific time. Although electrophoresis separation and analysis of proteins have been around in some form for many decades, it was not until 1975 when 2D electrophoresis was properly developed (O'Farrell, 1975). The first successful application of 2D electrophoresis for cotton was performed by Earl King examining cotton seeds (King, 1980). Cotton possesses highly recalcitrant tissue as indicated in the difficulties in protein extractions from cotton fibers (Yao et al., 2006), seedlings (Xie et al., 2009), and leaf and root tissues (Saha et al., 1997). Thus no one method of protein extraction is suitable for all tissues, and multiple methods have been proposed for recalcitrant tissues such as cotton (Wang et al., 2008). But the effect of preservation has been an understudied component of successful 2D electrophoresis. Primarily, two methods of preservation have been utilized, lyophilization and samples maintained at ultra-low temperatures of -80 °C. These preservation methods are interchanged extensively throughout the literature with both similar and disparate extraction methodologies. Additionally,

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cotton retains substantial quantities of phenolic compounds, polysaccharides, and secondary metabolites complicating proper extraction (Wan and Wilkins, 1994). However, these interfering compounds may afford protection to protein denaturation during the preservation process (Prestrelski et al., 1993).

RESEARCH DESCRIPTION

Twenty white flowers and twenty of the first fully expanded main-stem leaves (*Gossypium hirsutum* L. cv DP0912 B2RF) were randomly collected at the University of Arkansas System Division of Agriculture's Research and Experiment Station in Fayetteville, Ark. in August 2014. Ovaries were dissected from the corolla, and all tissues were submerged into liquid nitrogen (LN_2) until thoroughly frozen and transported back to the laboratory. Tissues were divided into two groups of different preservation treatments, one group was preserved at ultra-low temperatures of -80 °C and the other group preserved via lyophilization. An improved extraction buffer, developed in-house, included protease inhibitors, polyethylene glycol for secondary metabolite capture, greater amounts of Triton-X100 for protein solubilization, and utilized a PIPES-NaOH buffer (pH 7.0). Analyses included protein concentration per the Bradford method and 2D electrophoresis imaging using 100 µg of protein on a 7 cm pH 5-8.IPG strip run in the first dimension for 40,000 volt-hours, placed onto 12% polyacrylamide gel and ran in the second dimension at 20 amps until the bromophenol blue indicator had run to the end of the gel. Gels were stained according to the procedure outlined in Candiano et al. (2004). Gels were scanned and analyzed using ImageJ according to the procedure outlined by Natale et al. (2011). All statistical comparisons of protein concentration were performed using JMP Pro v. 11.2 at the 0.05 alpha level. Differences between the group means were identified using a Student's *t*-test.

RESULTS AND DISCUSSION

Highly significant differences ($P < 0.0001$) were found between protein concentrations of the different preservation treatments for both leaves and ovaries (Table 1). Leaf protein concentrations preserved by lyophilization were 179% greater than those at -80 °C. Likewise, ovary protein concentrations preserved by lyophilization were 79% greater in their supernatant extracts than those stored in the ultra-low temperature preservation method (Table 1).

Examination of the electrophoresis gels indicated a higher resolution of spots were present within the samples used for lyophilization rather than tissues maintained in the ultra-low temperature preservation method (Fig. 1). Electrophoresis gels of ovaries preserved with lyophilization possessed a greater number of spots that could be seen when compared to tissues stored in the ultra-low temperature preservation method. The breakdown of cellular membranes and intercellular structures due to freeze-thaw cycle of the samples from the ultra-low temperatures of -80 °C prior to extraction and analysis may have initiated large amounts of ice shear on the protein (Cao et al., 2003), possibly allowing proteins to appear in incorrect places or pass through the gel entirely due to their denatured characteristics. Since spots being analyzed via lyophilization were easily identifiable, it is possible that the inherent interfering substances removed in the extraction process afforded proteins protection from subsequent analytical problems.

PRACTICAL APPLICATION

These findings speculate that lyophilized tissue may provide a better preservation medium when performing 2D electrophoresis. Lyophilization also affords greater possibilities of extractable protein concentrations from the tissue samples. The common method of storage at -80 °C led to significant decreases in both the protein extracted and the quality, leading to possible detrimental effects on downstream analysis.

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Table 1. Soluble protein extraction concentrations in mg/g^{-1} fresh weight of both leaves and ovaries preserved under either -80 °C or lyophilization.

Tissue	Preservation	Soluble Protein mg/g^{-1} FW	
Leaf	Lyophilization	33.98 ± 1.65	A[†]
	-80 ˚C	12.20 ± 1.65	B
Ovary	Lyophilization	12.06 ± 0.55	a
	-80 ˚C	6.73 ± 0.55	b

[†] Confidence intervals for each mean are denoted after the (±). Upper and lowercase letters indicate Student's *t*-test mean differences at $\alpha = 0.05$ level for each tissue.

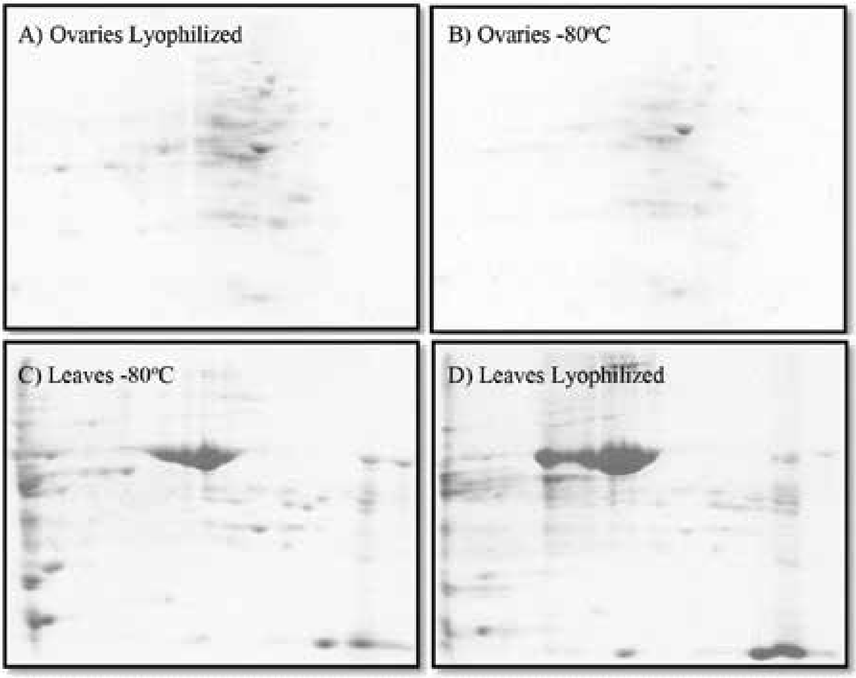

Fig. 1. Comparison of samples that were preserved using either lyophilized or ultra-low deep freezing at -80 °C using a pH gradient of 5 to 8, left to right for each image. Ovaries preserved using (A) lyophilization had better separation and number of spots in relation to ovaries preserved by (B) ultra-low deep freezing. Leaves preserved at (C) -80 °C had fewer spots and lower amounts of clear resolution when compared to the (D) lyophilized leaves.

Evaluating Production Efficiency and Sustainability Using the Fieldprint Calculator

B. Robertson and A. Free[1]

RESEARCH PROBLEM

United States cotton producers are leading the way in responsible cotton production practices. Through the support of research and implementation of technology, U.S. cotton production is on the path to continual improvement. As a result of these efforts since 1980, cotton production has made great progress in increasing efficiency and conserving the resources used to grow cotton as listed below (Field to Market, 2012).

- Land use – 30% reduction
- Soil erosion – 68% reduction
- Irrigation water applied – 75% reduction
- Energy use – 31% reduction
- Greenhouse gas emissions – 22% reduction

BACKGROUND INFORMATION

Field to Market is a diverse alliance working to create opportunities across the agricultural supply chain for continuous improvements in productivity, environmental quality, and human well-being. One tool created by Field to Market to educate U.S. commodity producers to continue their progress and identify areas for improvement on their farm is the Fieldprint Calculator (https://www.fieldtomarket.org/fieldprint-calculator/). Through this tool, they can enter data on their specific production practices for any field on their farm and see how they rank according to national and state averages. As the producer reviews his or her results they can see what aspects of their operation had the biggest impact on a number of outcome-based metrics: land use; soil conservation; soil health (reflected by soil carbon status); irrigation water use efficiency; energy use; greenhouse gas emissions; and water quality.

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[1] Cotton extension agronomist, cotton research verification/sustainability program coordinator, repectively, Newport Extension Center, Newport.

RESEARCH DESCRIPTION

A coordinated sustainability education and research program has a strong opportunity for rapid adoption in Arkansas when paired with the Verification Program. Essentially all the data necessary to enter producer fields into sustainability tools such as the Field to Market Fieldprint Calculator is collected in the Verification Program. While entering a field into the Fieldprint Calculator does not make a field sustainable, it does help give a producer and others in the decision-making process a different way to look at an operation and to see opportunity for improvement. Our challenge will be to demonstrate a direct link to profitability and protecting the environment.

RESULTS AND DISCUSSION

Spider graphs similar to those in Fig. 1 are included in the output from the calculator. The national average for each metric is normalized to be half way from the center to the outside edge of the graph giving it the symmetrical shape. The state average is the other non-symmetrical line on the graph. The shaded area represents the footprint of the field from which the data was collected. The environmental footprint is improved as the shaded area becomes smaller. The spider graphs in Fig. 1 are examples from one field documenting the improvement in their environmental footprint by modifying cultural practices, reducing tillage, and using cover crops.

PRACTICAL APPLICATION

Most consumers likely want to help the farmer and do what's best for the environment. The problem today is that most consumers have difficulty separating fact from fiction given all the information now available on the Internet and provided by the media. No single practice will work in every field, no one recipe will work on every farm, but there are many ways to farm more sustainably. It is critically important that producers, business leaders, consumers, legislators and young people better understand the scientific basis for sustainable crop production and that this basis be better grounded by hands-on field research and experience. We must educate producers and other audiences on the benefits of taking a more holistic approach to farming, supported by realistic applied research on how integrated pest management, soil conservation, water quality, cover crops, crop/landscape diversity, nutrient management and marketing interact to make production systems more sustainable and profitable over the long term.

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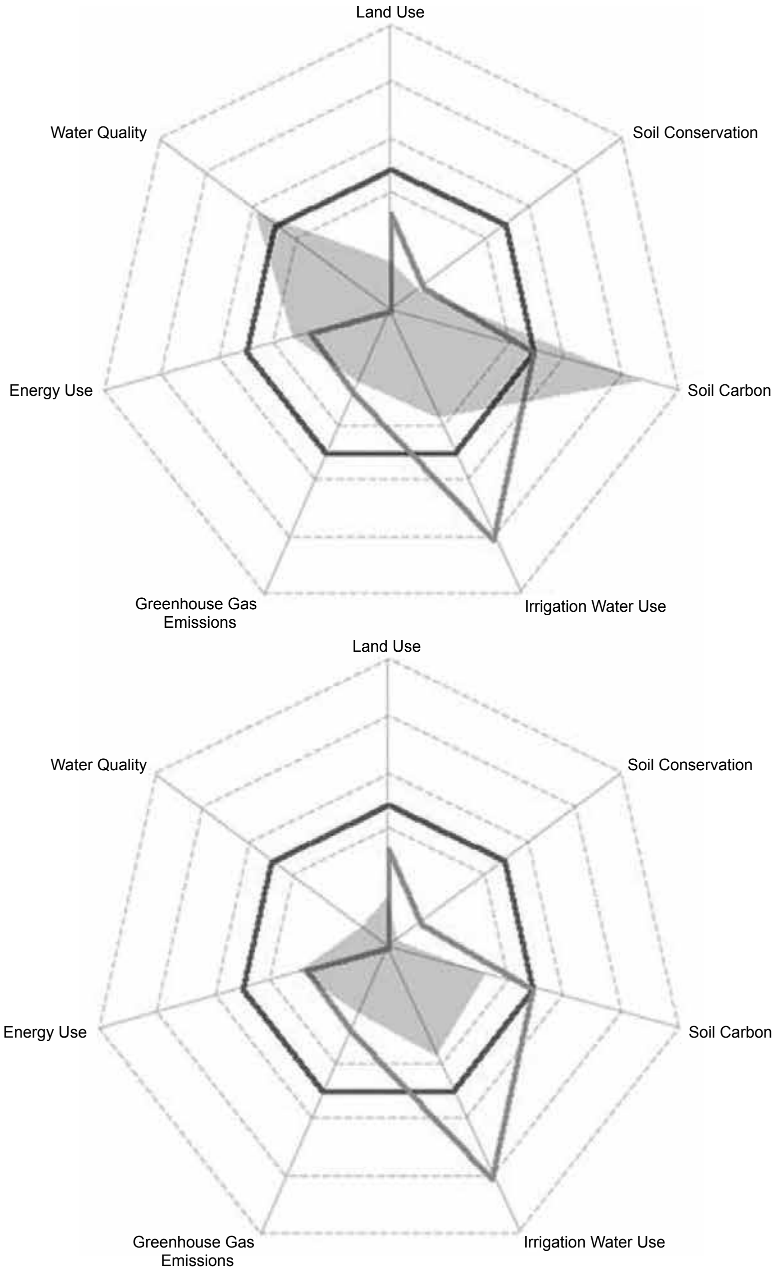

Fig. 1. Spider graphs from the Field to Market Fieldprint calculator. The national average for each metric is normalized to be half way from the center to the outside edge of the graph giving it the symmetrical shape. The state average is the other non-symmetrical line on the graph. The shaded area represents the footprint of the field from which the data was collected. The environmental footprint is improved as the shaded area becomes smaller.

Preservation and Extraction Method Effects on Enzymatic Activity

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

RESEARCH PROBLEM

In agricultural research, seldom is it possible to perform a biochemical analysis on a specimen immediately following its collection. Oftentimes, the quantity of samples collected outweigh the capabilities to minimize unwanted degradation effects. This is especially true when the distance from field to laboratory may be quite far. Further complicating the issue is that a well thought out preservation technique may be usurped by an inefficient extraction protocol. To analyze these effects an investigation was performed to compare the preservation practices of collected tissues from the field with both an older and an in-house developed extraction protocol with the intent of maximal enzyme function.

BACKGROUND INFORMATION

Many researchers use the term "fresh" to describe a tissue sample, although the transport from plant to analysis may be hours or days (Hendrix, 1990; Zhao et al., 2010). Thus the researcher must examine the accepted methods of tissue preservation both for the tissue analyzed and for the analysis needed. A cursory search of recent literature suggests the two most popular methods of preservation are ultra-low deep freezers where temperatures are maintained at or below -80 °C, or by utilizing lyophilization where frozen tissue has near all moisture removed from the sample. Also apparent from the plethora of methodologies in the literature was that proper extraction of the target enzyme determines success. Protocols shared general commonalities between them. All possessed a buffer of some type such as a phosphate buffer (Yoshimura, 2000; Hiner et al., 2000), a Good's buffer like HEPES (Gupta et al., 1993; Matamoros et al., 2010) or PIPES (Snider et al., 2009), or a sodium-acetate buffer (Mika and Lüthje, 2003). Other components include an inhibitor of protease enzymes such as EDTA for metallo-proteinases (Almeselmani et al., 2006; Verma et al., 2013) or a serine inhibitor such as PMSF (Crafts-Brandner and Salvucci, 2000; Jebara et al., 2005) to minimize protein cleavage of target enzymes via proteases. Another commonality includes a pH

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adjustment that was optimal for the particular enzymes being studied. Some formulae include additional compounds, such as PVP (Matamoros et al., 2010) or polyethylene glycol (Carmo-Silva and Salvucci, 2011) for binding of secondary metabolites.

RESEARCH DESCRIPTION

A total of 40 white flowers and 40 fourth main-stem leaves of field cotton (*Gossypium hirsutum* L. cv DP0912B2RF) were randomly collected at the University of Arkansas System Division of Agriculture's Agricultural Research and Experiment Station, Fayetteville, Ark. in August 2014. Flowers were dissected from the corolla and only the ovary was used for analysis. All tissues were submerged into liquid nitrogen and placed into an insulated cooler under blocks of dry ice for transport back to the laboratory. Time between collection and freezing was no more than ten minutes for any tissue sample. Collections were divided by tissue type into two groups of twenty, one group kept at -80 °C and the other group lyophilized. The preservation treatments were then divided further into two groups of ten, ten leaves and ten ovaries, for enzyme extraction protocol comparisons. The protocol being tested was an established enzyme extraction from Anderson et al. (1992), referred forthwith as the older methodology or older extraction method, and a modified extraction buffer and technique developed in-house, referred forthwith as the new extraction method or other methodology. The new extraction buffer included protease inhibitors, polyethylene glycol for secondary metabolite capture, greater amounts of Triton-X100 for protein solubilization, and utilized a PIPES-NaOH buffer (pH 7.0). Analyses included measurements of glutathione reductase and peroxidase enzyme activities. All statistical comparisons were performed using JMP Pro 11.2 as a nested hierarchy of preservation type to extraction methodology at the 0.05 alpha level. Differences between the group means were identified using a Student's *t*-test.

RESULTS AND DISCUSSION

Highly significant differences between preservation and extraction methodologies were found for ovary ($P < 0.0001$) glutathione reductase activities (Fig. 1). Greatest activity was maintained among the lyophilized and newer extraction treatment combinations, with substantial declines in activity using the -80 °C preservation. However, the newer extraction method did preserve activity at greater levels at -80 °C compared to the older methodology. Highly significant activities ($P < 0.0001$) of peroxidase in ovaries were identified in the lyophilized newer extraction combination followed by lyophilized older extraction, the -80 °C preserved samples with the newer extraction, and finally the -80 °C preservation with the older extraction combination (Fig. 2).

Leaves possessed similar highly significant differences ($P < 0.0001$) among glutathione reductase activities dependent upon the extraction and preservation combination (Fig. 1). The highest levels of activities were found in the lyophilized newer extraction method combination, followed by the -80 °C preserved newer extraction method which itself was statistically similar to the lyophilized older extraction method combination. Lyophilized preserved leaves with the older extraction methodology were statistically similar to the -80 °C preserved older extraction methods which had the lowest activity of any treatment combination. Peroxidase activities were greatest among lyophilized leaf samples using the newer extraction protocol (Fig. 2). Activities were statistically similar for the -80 °C preserved leaves using the newer extraction and the lyophilized older extraction combinations. Leaf peroxidase activity was lowest when using the -80 °C preservation and older extraction combination.

PRACTICAL APPLICATION

Results from this study lend pause to methods utilized by researchers to both store and extract their tissue samples prior to analysis. The common method of storage at -80 °C led to the greatest decreases in activities; whereas, lyophilization provided greater activity levels. This can be explained partially by the thawing effect of tissues back and forth from cold storage to extraction allowing samples to warm slightly and protease activity to resume. A lack of water in the freeze-dried samples prevent any enzymatic reaction to take place, regardless of temperature. The newer extraction method also increased the likelihood of improved activities. Insufficient or incompatible proteinase inhibitors in the older methodology may allow proteinases to cleave enzymes during the course of the extraction. It is mindful of the researcher to ensure collected samples are as similar to uncollected samples as possible. These results bring significant value to lyophilization as a superior preservation method, and the newer extraction protocol as a superior extraction medium for downstream enzymatic analyses.

ACKNOWLEDGMENTS

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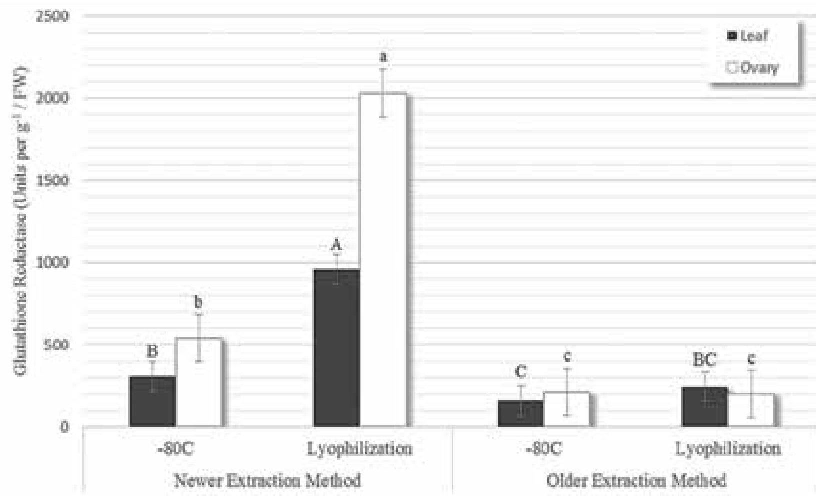

Fig. 1. Glutathione reductase activities for each preservation and extraction combination in activity units per gram of fresh weight. Upper and lowercase letters used to distinguish differences of the means at the 0.05 α-level using Student's *t*-test for each tissue type. Error bars are the 95% confidence interval for each treatment combination.

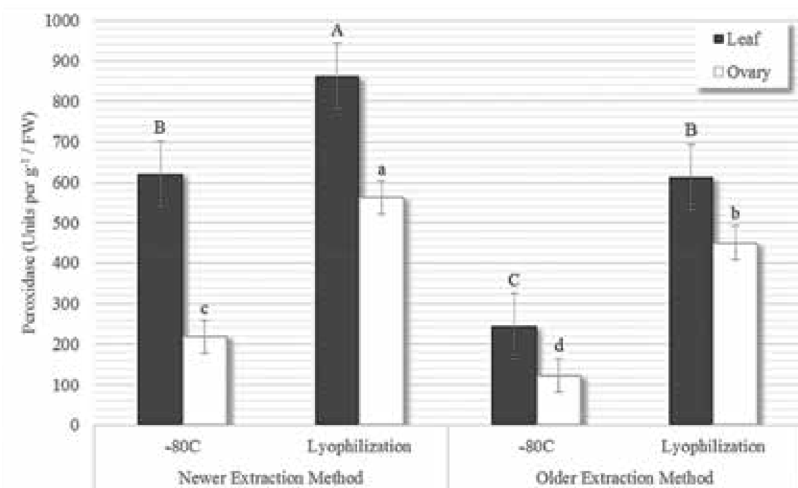

Fig. 2. Peroxidase activities for each preservation and extraction combination in activity units per gram of fresh weight. Upper and lowercase letters used to distinguish differences of the means at the 0.05 α-level using Student's *t*-test for each tissue type. Error bars are the 95% confidence interval for each treatment combination.

Fieldprint Calculator: Arkansas Study

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

RESEARCH PROBLEM

The desire to stay in business drives producers to continuously focus on adjustments that can be made to improve both efficiency and profitability. Cotton producers utilize many different production practices to improve efficiency and profitability. No single practice will benefit all. With the increasing demand to become more efficient, producers need assistance in determining how changes to their current method of production affects profitability and sustainability.

BACKGROUND INFORMATION

The Fieldprint Calculator is a relatively new tool created by the Field to Market Alliance (https://www.fieldtomarket.org/fieldprint-calculator/). Field to Market is a diverse alliance working to create opportunities across the agricultural supply chain for continuous improvements in productivity, environmental quality and human well-being (http://www.fieldtomarket.org). The Fieldprint Calculator was designed in an effort to help educate producers how adjustments in management could affect environmental factors.

Utilization of the calculator assists producers by making estimates over seven sustainability factors: 1) Land Use: yield, lb. cotton/acre A; 2) Soil Conservation: soil erosion, ton soil loss/lb. cotton produced; 3) Soil Carbon: Soil Conditioning Index, an estimate of change of soil carbon over time; 4) Irrigation Water Use: efficiency calculated by lbs. of cotton produced beyond the dryland yield/inch of irrigation water applied; 5) Water Quality: Water Quality Index, rating of edge of field water quality; 6) Energy Use: actual and embedded energy expressed in gallons of diesel equivalent/lb. cotton produced; and 7) Greenhouse Gas Emissions: emissions expressed in carbon dioxide equivalents per pound of cotton produced.

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[2] Professor, Extension Water Quality, Department of Crop, Soil, and Environmental Sciences, Little Rock.
[3] Assistant Professor, Rice Research and Extension Center, Department of Biological and Agricultural Engineering, Stuttgart.
[4] Assistant Professor, Northeast Research and Extension Center, Keiser.

Fieldprint summaries compare field to county, state and national averages. Calculated summaries give producers insight and the ability to identify areas for improved management on their farm.

RESEARCH DESCRIPTION

The University of Arkansas Cotton Research Verification Program was conducted in eight counties from 2010-2013. Selected fields for the program varied from potentially high yielding fields to low yielding fields. Extension specialists, extension agents, and verification coordinators made University of Arkansas Cooperative Extension Service based recommendations to producers during weekly farm visits. Throughout the study, all producers' inputs were recorded providing information needed to calculate both fixed and variable costs. Data collected from the Cotton Research Verification Program provided approximately 90% of the information needed for Fieldprint data entry. The additional information was provided by interviews with producers. Field information was entered into the Fieldprint Calculator and summaries were evaluated for each field. Calculator summaries allow producers to determine if production methods need management adjustments. In this study, yield and irrigation water use efficiency data from the calculator are compared to another measure of efficiency, total variable cost efficiency, which consists of pounds of cotton produced per dollar total variable cost spent.

RESULTS AND DISCUSSION

Historically within the Cotton Research Verification Program, the most profitable producer is the one who produces the highest yield. The fields in this study are ranked by yield in Table 1, with highest yielding county receiving a ranking of 1, and the lowest yielding receiving the ranking of 20. Counties are coded in an effort to keep them anonymous. Ranking for irrigation water use efficiency and yield per dollar total variable cost are displayed in a similar fashion. In this comparison we see a general trend for those fields with the highest yield to also be the fields in which irrigation water use efficiency and yield per dollar total variable cost were the greatest. As producers become more knowledgeable of factors affecting irrigation water use efficiency, it is expected that we can more closely link irrigation water use efficiency to yield and profitability. It is interesting to note that approximately 80% of the producers improved irrigation water use efficiency the second year of the two-year program.

PRACTICAL APPLICATION

From this four-year study we conclude that as producers improve yield, they often improve irrigation water use efficiency leading to an increase in pounds of cotton produced per dollar spent. The Fieldprint Calculator provides producers a new tool to evaluate efficiency in an effort to improve profitability and become more sustainable as a result. These management tools allow producers to document sustainability factors and evaluate management adjustments to improve sustainability.

Table 1. Ranking of yield, irrigation water use efficiency, and total variable cost efficiency

County & Year	Yield (r)[a]	Irrigation Water Use Efficiency (r)	Total Variable Cost Efficiency (r)
10-13	1	1	2
8-13	2	3	1
4-12	3	7	5
1-11	4	11	4
9-12	5	10	6
4-11	6	16	14
2-10	7	15	10
3-10	8	12	3
3-11	9	8	12
10-12	10	5	11
1-10	11	17	13
9-13	12	4	7
8-12	13	6	8
7-13	14	2	15
7-12	15	19	18
2-11	16	18	19
5-11	17	13	9
5-12	18	14	16
6-12	19	9	17
6-11	20	20	20

[a] 1 is the highest or most efficient and 20 is the lowest or least efficient.

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 establishing cotton stands 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 is important to cotton growers examining ways to reduce planting costs. 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). Seedling pathogens can act individually or in combination to cause a range of symptoms on seed, roots and hypocotyls (stems below seed leaf) which affects germination, emergence, and early-season growth and development of the crop. These pathogens survive for long periods in the soil and cause disease on susceptible crops 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 to an extent that planting is 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 addition of information on seedling disease potential would be beneficial for site-specific planting.

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[2] Professor, Plant Pathology, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

The objectives of this study are 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 are then used to find relationships between the spatial aggregation of seedling pathogens and disease and soil environmental or physical factors in order to predict seedling diseases on cotton. To accomplish these objectives, three fields at the Judd Hill Foundation Cooperative Research Station in Poinsett County, a grower's field in Mississippi County farmed by David Wildy, and another grower's field in Ashley County farmed by Bruce Bond were chosen.

In each of the three field locations at Judd Hill, 15.24-m (50 ft) long four row plots were established across the cotton fields 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 was recorded 1 and 5 days after planting along with soil electrical conductivity (texture). Seedlings were recovered from each sampling point to assess root and hypocotyl discoloration, frequency of isolation of *Fusarium* spp., *Pythium* spp., and *R. solani* on non-selective media, and frequency of isolation and mean colonization of *T. basicola* on TB-CEN selective media (Specht and Griffin, 1985). In addition, soil samples from each plot were assayed for populations of *R. solani* (Paulitz and Schroeder, 2005) and *T. basicola*. Stand counts, skip indices, and plant height were recorded 21 days after planting. Yield for each row was collected at harvest. To assess the role of seedling diseases and stand variability in grower's fields, 20 points from the 100 points in each of the two grower's fields were selected based on variability of stand and soil physical or environmental characteristics to undergo controlled environmental experiments using the seed treatments listed previously. Spatial data exploration was performed using *Moran's I* (Unwin and O'Sullivan, 2003) to determine distributions of observations within fields. Regression analysis 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 disease on cotton.

RESULTS AND DISCUSSION

From preliminary analyses using one of the field locations at Judd Hill, the fungicide responses in 2014 showed treatment 1, a combination fungicide seed treatment, significantly improved stands over the control by 22% (Table 1). Soil temperature was shown to be significantly aggregated 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) 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 (Table 3). The stand difference between treated and non-treated rows was less in the sites with higher temperature. For this trial, soil water was also shown to have a clustered spatial distribution ($P < 0.001$; Table 2.). Over the entire field, plots with higher soil water had a positive correlation with stand counts among the non-treated rows and no significant correlation with the broad spectrum seed treatment rows. This suggests that soil water content has an impact on seedling disease. In 2014, only 1.9 cm (0.75 inch) of rainfall occurred the first 5 days after planting.

Soil environment, temperature, and rainfall are important factors in stand establishment in cotton and in seedling disease 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. This study suggests that seedling disease does vary across a field as indicated by the stands and the use of various fungicide seed treatments. 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 stands across the field examined. Understanding factors that influence stand establishment and seedling disease should allow growers to minimize losses from seedling diseases on cotton.

PRACTICAL APPLICATION

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.

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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	
Vortex + Spera + Allegiance + Evergol Prime + Evergol Energy	0.08 + 1.8 + 1.5 + 0.32 + 2.0	105.6§	A
Metalaxyl	1.5	92.6	B
PCNB	14.5	90.3	BC
None		87.4	C

† Test was planted at the Judd Hill Research Station on 6 May 2014.
‡ 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 temperature 1 day after planting	Soil temperature 5 days after planting	Soil water 1 day after planting	Soil water 5 days after planting
	20.2 – 21.4 ° C	21.7 – 22.6 ° C	9.4 – 16.2%	12.0 – 20.1%
Moran's I‡	0.730	0.490	0.500	0.700
Distribution	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

† Test was planted at the Judd Hill Plantation on 6 May 2014 at 3 seed/0.305m (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.[†]

	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 Research Station on 6 May 2014.
[‡] *P* - value for spatial lag regression model.
[§] *P* - value for ordinary least squares regression.

Effects of Water-Deficit Stress on Nutrient Concentrations of Cotton Pistils Under Field Conditions

D.A. Loka[1], D.M. Oosterhuis[2], B.L. McMichael[3] and C. Pilon[1]

RESEARCH PROBLEM

Water-deficit stress is a major abiotic factor affecting more than a third of cultivated lands around the world. Extended research has been conducted on the effects of water-deficit stress on the physiology and metabolism of the cotton plant; however, little attention has been given to its reproductive units. This study was aimed at quantifying the effect of water-deficit stress on nutrient concentrations under field conditions.

BACKGROUND INFORMATION

Uptake of mineral nutrients is generally known to decrease under conditions of limited water supply due to substantially lower rates of transpiration as well as impairments in ion transport and membrane permeability (Levitt, 1980). Previous research has indicated that macronutrients such as potassium (K) and calcium (Ca) play significant roles in flowering and fruiting due to their involvement in plant/water relations and the stabilization of membranes and cell wall structures, respectively (Marschner, 1995). Joham (1955) reported that lower than suggested rates of K fertilization resulted in significant decreases in fruiting sites and number of bolls. Similar to K, Joham (1955) observed that deficiencies in Ca during cotton's flowering period had as a consequence a disruption in the flowering process and a severe decrease in the flowering index. Boron (B) is a micronutrient that significantly affects plant development since it is involved in carbohydrate translocation (Joham, 1986). According to Rothwell et al. (1967) a mild deficiency in B resulted in decreased square retention and increased shedding of young bolls, while Donald (1964) observed that a severe B deficiency produced deformed or dead apical buds that completely restrained further growth of the main stem.

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RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) cultivar ST5288B2F seeds were sown at a density of ten plants per meter in a Captina silt loam (Typic Fragidult) soil at the University of Arkansas System Division of Agriculture's Agricultural Experiment Station in Fayetteville, Ark. and in a sandy loam (Typic Amarillo) soil at Texas Tech University Farm in Lubbock, Texas. Plots were 4 m × 7 m with 1-m borders between each plot. To maintain well-watered conditions until stress was imposed, plants in Fayetteville were furrow-irrigated to soil saturation every six days in the absence of saturating rainfall; while in Lubbock, subsurface drip irrigation was provided daily. Fertilizer application, weed control, and insecticide applications were performed according to extension center recommendations and practices. Irrigation was withheld in the water-stress plot when plants reached the flowering stage. First sympodial branch fruiting position white flowers and their subtending leaves were sampled at 1200 h at the end of the second week after irrigation was withheld and analyzed for mineral nutrient content from both locations. Measurements of soil moisture content were taken also at the end of the second week from both sites.

RESULTS AND DISCUSSION

Water-deficit stress resulted in significant decreases in soil moisture content in Fayetteville; whereas no significant differences were observed in soil moisture content between control and water-stressed plots (Table 1). However, we speculate that this was a sampling mistake since the vapor pressure deficit in Lubbock, was consistently higher compared to Fayetteville (data not shown).

The nutrient analysis showed that both macronutrients and micronutrients were affected by water-deficit stress. Specifically, a significant reduction in pistil K and Ca concentrations was observed under conditions of water-deficit stress while no changes were observed in the other macronutrients. (Table 2) Additionally, pistil B content was significantly decreased under conditions of water stress compared to the control. (Table 3)

PRACTICAL APPLICATION

The results of our study indicated that pistil nutrient content was significantly affected by limited water supply. All four of the mineral nutrients that were affected have been shown to have important roles in flowering, fruiting index and boll load indicating that better fertilization could potentially help maintain yield under conditions of water stress. However, further research is needed in order to provide fertilization recommendations for better yields under conditions of water-deficit stress.

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Table 1. Effect of water-deficit stress on soil moisture content in Fayetteville, Ark. and Lubbock, Texas.

Soil Moisture Content (%)			
Fayetteville		Lubbock	
Control	Water Stress	Control	Water stress
0.89	0.94	0.97	0.98
b†	a	a	a

†Different letters indicate statistical significance at α = 0.05.

Table 2. Effect of water-deficit stress on mineral macronutrient content of cotton pistils.

	P		K		Ca		Mg		S	
Treatments	....%...									
Control	0.563	a†	1.54	a	1.185	a	0.369	a	0.3121	a
Water Stress	0.528	a	1.36	b	1.096	b	0.359	a	0.31	a

†Different letters indicate statistical significance at α = 0.05.

Table 3. Effect of water-deficit stress on mineral micronutrient content of cotton pistils.

	Na		Fe		Mn		Zn		Cu		B	
Treatments	....mg/kg...											
Control	124.87	a†	21.8	a	23.5	a	33.6	a	5.2	a	20.3	a
Water Stress	117.65	a	18.8	a	23.1	a	32.8	a	5.4	a	18.3	b

†Different letters indicate statistical significance at α = 0.05.

Effect of Application of Polyamines, Salicylic Acid and Abscisic Acid on Cotton Pistil Polyamine Content Under Conditions of Water-Deficit Stress in the Field

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

RESEARCH PROBLEM

Drought is considered to be the main environmental factor compromising plant growth and resulting in significant yield reductions. Polyamines are endogenous plant growth promoters that are involved in a variety of physiological and metabolic functions and are particularly important in the flowering process. Previous research has indicated that application of polyamines under conditions of heat stress has positive effects on pistil polyamine concentrations and number of ovules; however, limited information exists on the effects of plant growth regulator application on the polyamine concentrations under conditions of water-deficit stress. Similarly, salicylic acid and abscisic acid have been shown to favorably affect plant physiology under adverse environmental conditions, but no information exist on their application on cotton under limited water conditions. The objective of this study was to determine the effect of polyamine, salicylic acid and abscisic acid application on the pistil polyamine concentrations under water stress.

BACKGROUND INFORMATION

Cotton (*Gossypium hirsutum* L.) growth and yield are greatly compromised under conditions of water-deficit stress. Although debate still exists on the most drought-sensitive developmental stage of the plant, it is generally accepted that limited supply of water during flowering results in significant yield reductions. Polyamines, the diamine putrescine (PUT) and its derivatives triamine spermidine (SPD) and tetramine spermine (SPM) are significant plant growth regulators due to their participation in a multitude of plant metabolism functions (Oosterhuis and Loka, 2012 and references therein). In addition to their implication in the flowering and reproductive process, polyamines have been observed to function as protective agents under conditions of environmental stress. In experiments with cotton, Bibi et al. (2010) reported that application of PUT on cotton flower buds

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one day before anthesis increased seed fertilization in heat-stressed plants compared to the control; however no information exists on the effects of polyamines under conditions of water stress.

Salicylic acid (SA) is another endogenous plant growth regulator that has been observed to enhance flower induction and flowering index in a number of species (Singh and Kaur, 1980; Kharana and Cleland, 1992). In addition to its implication in flowering SA has been reported to protect plants under conditions of abiotic stress (Rivas-San Vicente and Plasencia, 2011). Heitholt et al. (2001) in experiments with foliar application of SA on cotton, approximately two to three weeks before flowering, observed no significant effects on flower number and cotton yield but no information exists on SA application under conditions of water-deficit stress.

Abscisic acid (ABA) is a plant hormone, mostly associated with plant responses to stress and especially with water stress since it acts as the signaling molecule in the plant's response (Davies and Zhang, 1991). Nevertheless, a number of reports indicates that ABA can enhance dry matter accumulation in sink organs indicating a correlation between ABA levels and seed growth rates (Schussler et al., 1984, 1991). In addition, Yang et al. (2000), in experiments with wheat, observed that under conditions of mild water stress during grain filling, carbon remobilization from the vegetative tissues to the grains was increased, thus accelerating the grain filling rate.

RESEARCH DESCRIPTION

Cotton cultivar ST5288B2F seeds were sown at a density of ten plants per meter in a Captina silt loam (Typic Fragidult) soil at the University of Arkansas System Division of Agriculture's Agricultural Experiment Station in Fayetteville, Ark. Plots were 4 m × 7 m with 1-m borders between each plot. To maintain well-watered conditions until stress was imposed, plants were furrow irrigated to soil saturation every six days in the absence of saturating rainfall. Fertilizer application, weed control, and insecticide applications were performed according to extension center recommendations and practices. Irrigation was withheld when plants reached the flowering stage. First sympodial branch fruiting position candles were tagged and sprayed with 10 millimolar (mM) PUT, SPD, SPM and 1 mM SA and ABA solutions at the end of the first week after irrigation was withheld. Double deionized water was used as the control. The white flowers were sampled at 1200 h the following day and were analyzed for polyamine content according to Bibi et al. (2010). Measurements of stomatal conductance were taken also at the end of the first week of stress to indicate the extent of the stress.

RESULTS AND DISCUSSION

Our results indicated that none of the plant growth regulators applied had a significant effect on pistil PUT concentration under conditions of water stress (Table 1), since the control contained significantly higher levels of PUT compared to the rest of the treatments (Fig. 1). A similar pattern was observed in water-stressed pistil SPD concentrations (Fig. 2) where control and SPM application significantly increased pistil SPD levels, while the lowest SPD content was reported after application of PUT. Lastly, the SPM concentrations of water-stressed pistils significantly decreased after application of all plant growth regulators compared to the control (Fig. 3). We speculate that the lack of positive results was due to the non-effective dosage of plant growth regulators applied and we suggest that further research should be conducted in order to provide better effective application rates.

PRACTICAL APPLICATION

Despite the potential for exogenous applications of polyamine, salicylic acid, and abscisic acid application on cotton flowers under water stress, we had no significant effect on pistil polyamine concentrations. We speculate that the lack of positive results was due to the non-effective dosage of plant growth regulators applied and we suggest that further research should be conducted in order to provide better effective application rates, so as to realize the potential of these plant growth regulators to maintain physiological functions of cotton flowers under stress.

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Table 1. Effect of water-deficit stress on leaf stomatal conductance at the end of the stress period.

Stomatal Conductance ($mmol/m^2s$)	
Control	Water Stress
717.5 a[†]	428.5 b

[†] Different letters indicate statistical significance at α = 0.05.

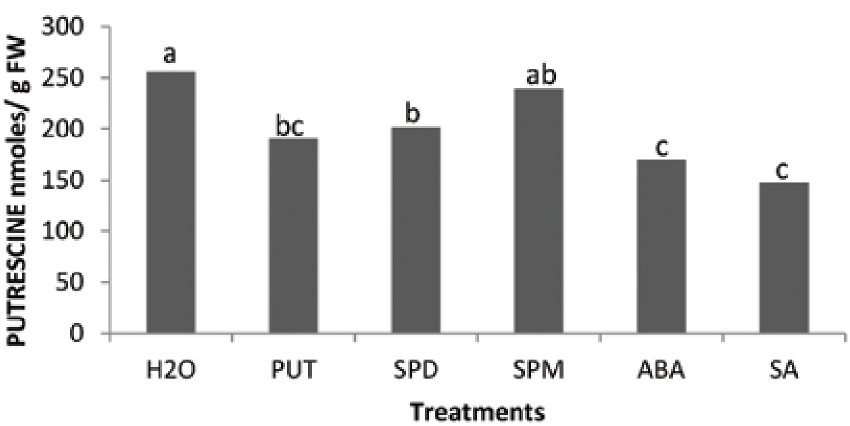

Fig. 1. Effect of sprayings on pistil putrescine content. Different letters indicate statistical significance at α = 0.05.

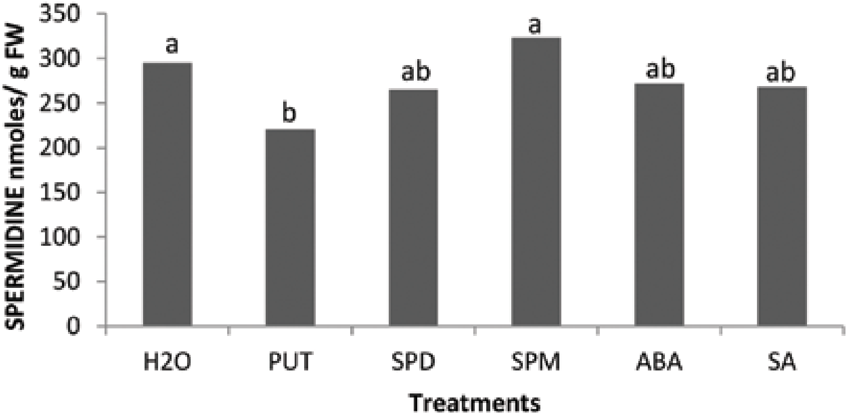

Fig. 2. Effect of sprayings on pistil spermidine content. Different letters indicate statistical significance at α = 0.05.

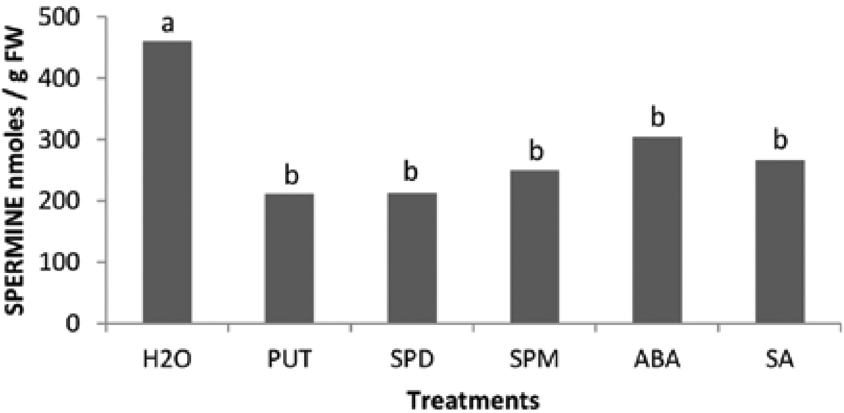

Fig. 3. Effect of sprayings on pistil spermine content. Different letters indicate statistical significance at α = 0.05.

Effect of Fruit Removal on Diurnal Water Relations of Cotton

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

RESEARCH PROBLEM

Osmotic adjustment is a mechanism by which crop plants maintain turgor when subjected to water deficits (Hsiao et al., 1976; Turner and Jones, 1980) and it has been shown in cotton leaves and roots in response to water stress (Oosterhuis and Wullschelger, 1987). Previous research has indicated that plant osmotic potential varies during the day and that there is a relationship between osmotic cycling and source-sink balance in cotton. The objective of this study was to observe the changes in leaf water and osmotic potential after the removal of all fruits from the plant.

BACKGROUND INFORMATION

Diurnal variation of leaf osmotic potential has been observed by many researchers in a variety of crops (Hsiao et al., 1976; Acevedo et al., 1979; Takami et al., 1982). Osmotic potential, the decrease of water potential due to the presence of solutes, is dependent upon the accumulation of organic solutes (Ho, 1976). Ackerson (1980) reported that concentrations of leaf soluble carbohydrates fluctuate during the day which led to suggestions that they contribute to the diurnal leaf osmotic potential cycling. Radin et al. (1985) in field experiments observed the osmotic potential to have a marked diurnal cycle when the plants were lightly loaded with fruits, which almost disappeared as the number of fruits increased indicating that the presence of fruits affected leaf osmotic potential.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) cultivar ST5288 B2F seeds were sown at a density of ten plants per meter in a Captina silt loam (Typic Fragidult) soil at the University of Arkansas System Division of Agriculture's Agricultural Experiment Station in Fayetteville, Ark. Plots were 4 m × 7 m with 1-m borders between each plot. To maintain well-watered conditions, plants were furrow irrigated to soil sat-

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uration every six days in the absence of saturating rainfall. Fertilizer application, weed control, and insecticide applications were performed according to extension center recommendations and practices. Twelve plants were chosen randomly. Six of the plants had all their bolls, squares and flowers removed while the rest remained as they were. All reproductive units were removed from the plants at noon and measurements of leaf water and osmotic potential were taken, using thermocouple psychrometers according to Oosterhuis and Wullschleger (1987) the following day at 600 h, 1200 h and 1800 h from the subtending leaf of the first position of the 9th, 10th and 11th fruiting node.

RESULTS AND DISCUSSION

The results showed that leaf water potential remained unaffected at all times during the first, second and seventh day after fruit removal (Figs. 1-3). A similar pattern was observed for the leaf osmotic potential with the exception of the first day at 18:00 h where leaf osmotic potential of plants with all their fruits removed was significantly more negative compared to the control (Fig. 1). During the second day after fruit removal, leaf osmotic potential of control plants was almost identical to that of plants that had all their fruits removed (Fig. 2). This, however, changed during the seventh day of the experiment when leaf osmotic potential of control plants was less negative at 600 h, almost identical at 1200 h and more negative at 1800 h compared to the leaf osmotic potential of the plants that had all their fruits removed (Fig. 3). The differences, even though not statistically significant, provide an indication that leaf osmotic potential is affected by fruit load; however, more research is required in order to accurately identify the relationship between leaf osmotic changes and source-sink balance in cotton.

PRACTICAL APPLICATION

The decrease in osmotic potential in leaves of water stressed cotton plants has been associated with the maintenance of turgor during periods of water stress. Our study provides an indication that leaf osmotic potential is affected by fruit load.

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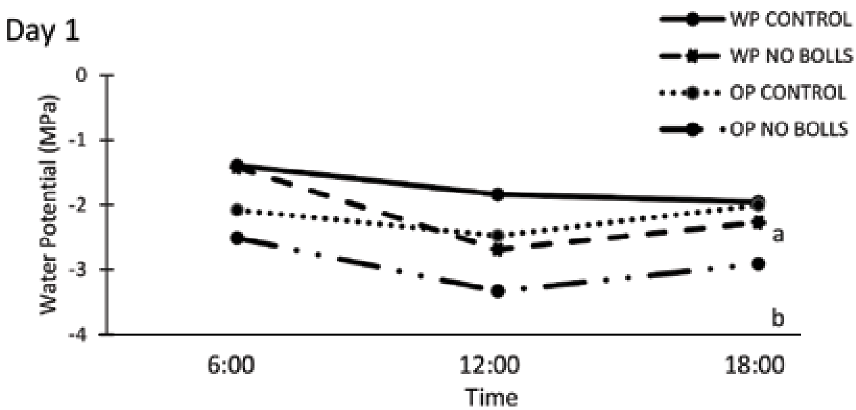

Fig. 1. Effects of fruit removal on leaf water and osmotic potential the first day after boll removal. Different letters indicate significant differences at level a = 0.05. (WP Control, water potential of plants where fruits were not removed; WP NO BOLLS, water potential of plants where fruits were removed; OP CONTROL, osmotic potential of plants where fruits were not removed; OP NO BOLLS, osmotic potential of plants where fruits were removed).

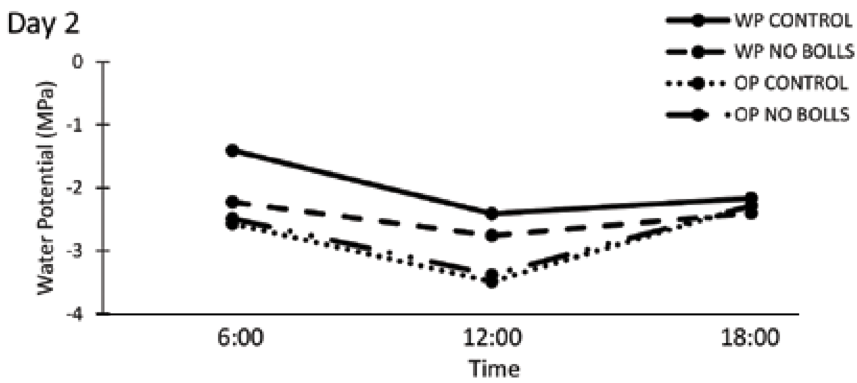

Fig. 2. Effects of fruit removal on leaf water and osmotic potential the second day after fruit removal. (WP Control, water potential of plants where fruits were not removed; WP NO BOLLS, water potential of plants where fruits were removed; OP CONTROL, osmotic potential of plants where fruits were not removed; OP NO BOLLS, osmotic potential of plants where fruits were removed).

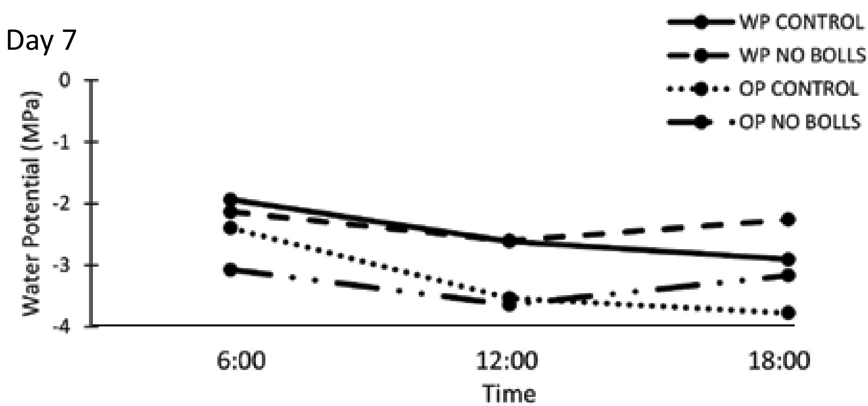

Fig. 3. Effects of fruit removal on leaf water and osmotic potential the seventh day after fruit removal. (WP Control, water potential of plants where fruits were not removed; WP NO BOLLS, water potential of plants where fruits were removed; OP CONTROL, osmotic potential of plants where fruits were not removed; OP NO BOLLS, osmotic potential of plants where fruits were removed).

Effects of Irrigation Timing and Seeding Rate on the Maturity and Yield of Cotton Grown in a Northeast Arkansas Field

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

RESEARCH PROBLEM

Mid-South cotton producers are searching for ways to improve production efficiency and reduce input costs without sacrificing yield or quality. Adjusting seeding densities may allow producers to reduce production costs while maintaining yield. Better timing of both the initial and final irrigation will help producers conserve precious groundwater, reduce production costs as well as improve yields. Where growing seasons may be time-limited such as in Northeast Arkansas, selection of early-maturing cotton cultivars is vital to achieving profitable production. Cultivar selection and crop earliness also are critical for cost savings for crop protection from insect pests. The purpose of this research project is to develop and refine guidelines for each of these factors to improve profitability of cotton production. These guidelines also should be useful as producers expand their use of site-specific management of fields with variable soils and landscapes.

BACKGROUND INFORMATION

Previous research in Arizona and Arkansas has shown yield advantages associated with early initiation of the first irrigation (Steger et al., 1998; Barber and Francis, 2011). These findings correspond with work done in Northeast Arkansas that showed earlier irrigation start times to allow avoidance of preflower water-deficit stress increased both yields and earliness compared to irrigation initiation after flowering (Teague and Shumway, 2013). Additional Arkansas research results have shown that timing the final irrigation based on date of physiological cutout determined using measures of nodes above white flower (NAWF) can help reduce unnecessary late season irrigations and improve maturity management (Vories and Glover, 2000; Reba et al., 2014).

Results from previous research have suggested that reduced seeding rates have a minimal impact on cotton lint yield (Bednarz et al., 2005; Pettigrew and Johnson, 2005; Siebert et al., 2006; Wrather et al., 2008). In those experiments, re-

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searchers hand-thinned plantings to achieve the desired plant stand density. From a practical standpoint, questions remain regarding impact of reducing seeding rates using production planters. Reduced stand densities and plant biomass has been shown to be less attractive to immigrating adults of *Lygus* spp. (Heteroptera: Miridae) (Leigh et al., 1974; Willers et al., 1999). Given the prospect that cotton producers will soon have variable-rate planter controllers available that will allow planting of multiple seed types (e.g. cultivars, seed treatments, etc.) at different rates within the same planter pass, expanded research is needed to evaluate variable seeding rates on production efficiency.

RESEARCH DESCRIPTION

An on-farm study was conducted in 2014 in Northeast Arkansas to evaluate the effects of irrigation initiation timing, cultivar, and seeding rate on cotton maturity and yield. The experiment was designed as a 3 × 3 × 2 factorial arranged in a split plot arrangement with 4 replications. The 3 irrigation treatments were considered main plots, and 3 seeding rates and 2 cultivar treatments were considered subplots. Irrigation treatments were 1) early start (initiation timing was 10 days prior to first flower), 2) late start (initiation at first flower) and 3) rain-fed (no irrigation). Seeding rates were 1.5, 3.0 and 4.5 seed per foot of row. Cultivars were Phytogen 375 WRF (relatively susceptible to plant bugs) and Stoneville 5288 (relatively resistant). Soils in the field are classified as Dundee silt loam (Typic Endoqualfs). A John Deere 1700 4-row vacuum planter equipped with a hydrolytic variable rate driver was used for planting. Plots were 8 rows wide, 100 ft long with 10-ft alleys separating plots within the field. Weekly stand counts beginning at 8 days after planting (DAP) were made using line-transect sampling with counts of plants per 3 ft in two transects across 8 rows in the center portions of each plot. Sampling included weekly plant monitoring using COTMAN Crop Management System (Oosterhuis and Bourland, 2008) and pest monitoring with drop cloths performed weekly from early squaring through NAWF = 5. Cultural practices followed the cooperating farmer's standard and were consistent across all plots with the exception of irrigation timing. Plots were harvested on 26 October using a 4-row research picker. Data were analyzed using PROC GLM (SAS Institute, Inc., Cary, N.C.) with mean separation using Fisher's protected least significant difference at $P \leq 0.05$.

RESULTS AND DISCUSSION

Rainfall levels were above average for 2014 (Table 1), confounding irrigation timing treatment effects. Plant stand count results, presented as a percentage of the target seeding rate planted (Fig. 1), showed that Phytogen 375 had a significantly higher percentage of emerged plants at 8 DAP than did Stoneville 5288; however Stoneville 5288 had a higher percentage of emerged plants in the remaining sample dates. No significant interaction between seeding rate and cultivar were observed. Pace of plant nodal development, apparent in COTMAN growth curves (Fig. 2), was affected by seeding rate and irrigation. Mean squaring nodes at approximately first flower were greater in the lowest seeding rate plots than for either the 3.0 or 4.5 seed/ft seeding rates. This likely was the result of less interplant competition associated with the lower plant population density. Significant irrigation effects were also observed with delayed maturity (days to cutout) noted with irrigated compared to rain-fed treatments. *Lygus lineolaris* abundance and damage was observed among cultivars and seeding rates most notably during the week of first flowers (63 DAP) when numbers surpassed the action threshold in the high-density planting of Phytogen; this was about 3 weeks before bug numbers associated with other treatments reached similar levels. We interpret these data to indicate increased oviposition preference and higher nymphal survival (data not shown). For yield, there were no differences observed among seeding rate ($P = 0.57$), irrigation timing ($P = 0.64$) or cultivar ($P = 0.51$; Fig 3).

PRACTICAL APPLICATION

No yield reductions were associated with lower seeding rates in this 2014 field study in Northeast Arkansas. These findings suggest there are cost saving opportunities that could improve profitability of cotton production in the region. Providing seeding rate guidelines for variable rate planting should be one eventual result of this research.

ACKNOWLEDGMENTS

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Table 1. Irrigation and precipitation timing information for irrigation × cultivar × seeding rate study; Manila Airport, 2014.

Date	Early Start Irrigation	Late Start Irrigation	Precipitation (inches)
25-Jun	Irrigation		
29-Jun			1.2
1-Jul			0.9
9-Jul			0.3
11-Jul	Irrigation	Irrigation	
14-Jul			1.7
21-Jul	Irrigation	Irrigation	
23-Jul			1.5
28-Jul	Irrigation	Irrigation	
7-Aug	Irrigation	Irrigation	
8-Aug			1.6
17-Aug			3.5

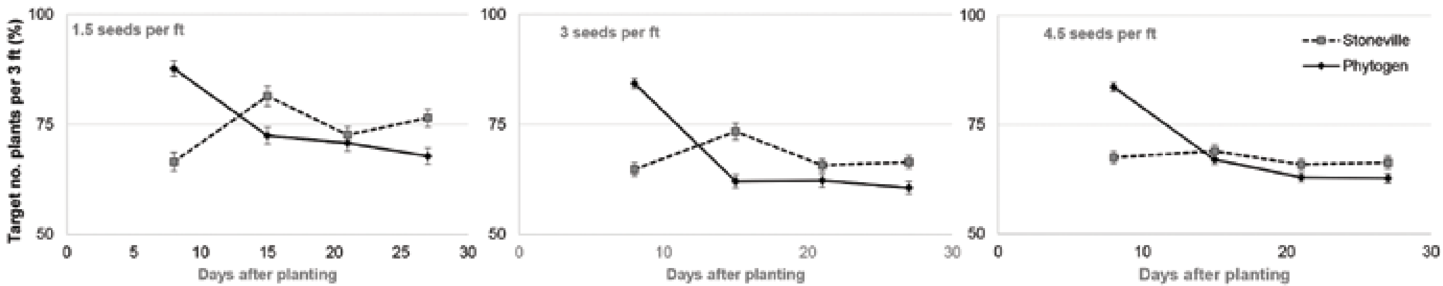


Fig. 1. Stand counts for cultivars and seeding rates (1.5, 3.0 and 4.5 seeds/ft) expressed as a percentage of the target seeding rate. No significant interactions between seeding rate and cultivar were observed by 14 days after planting; Manila Airport, 2014.

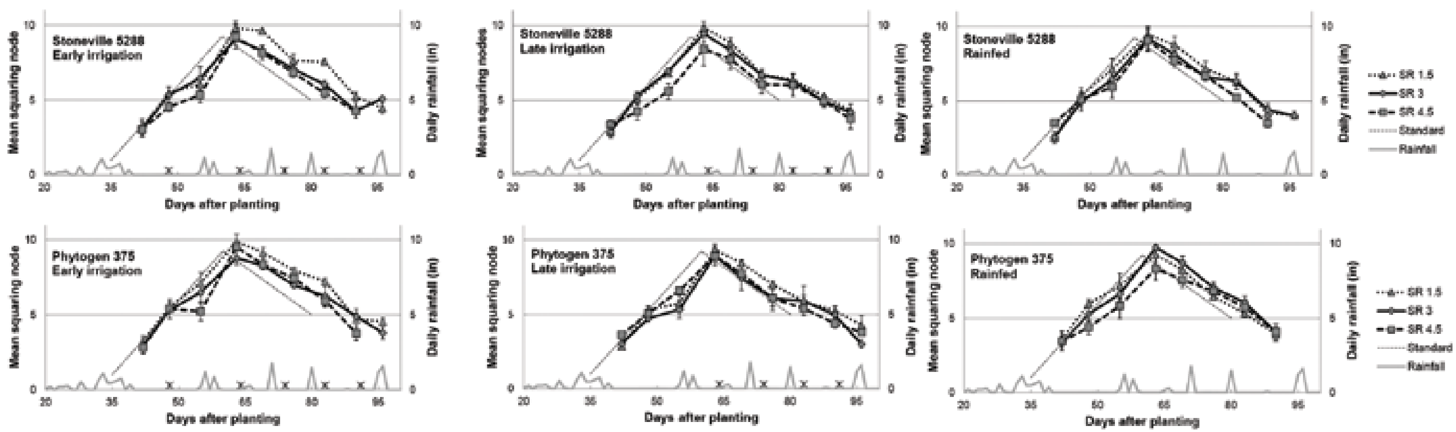
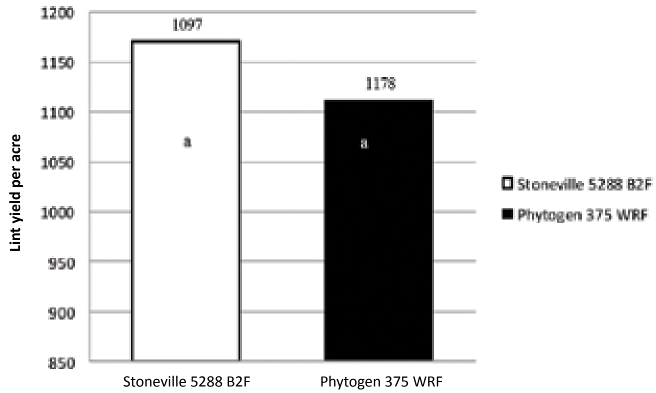
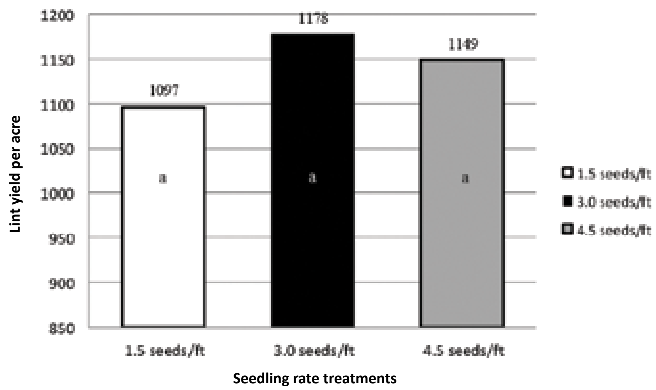


Fig. 2. COTMAN growth curves along with rainfall and irrigation timing for the 2014 irrigation × cultivar × seeding rate trial, Manila Airport.





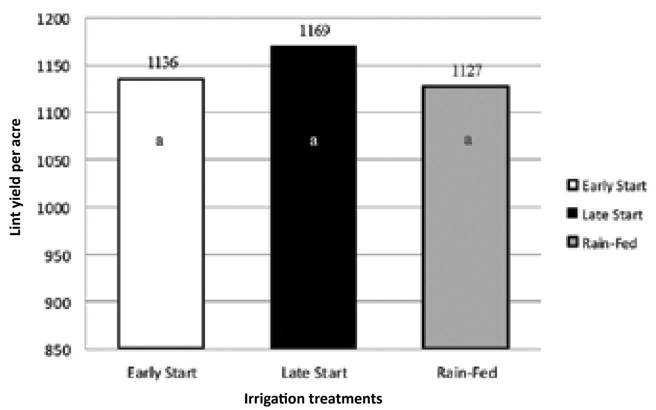


Fig. 3. Lint yield/acre for irrigation timing main plot effects (top), and for subplot treatments for cultivar (center) and seeding rate (bottom). No significant interactions between irrigation timing and either seeding rate or cultivar were observed. Columns with the same letters are not significantly different at *P* = 0.05; Manila Airport, 2014.

Water-Deficit Stress Reduces Concentrations of Photosynthetic Pigments in Cotton Plants

C. Pilon, D.M. Oosterhuis, and E.A. de Paiva Oliveira[1]

RESEARCH PROBLEM

Cotton plants are considered sensitive to drought stress; however, this sensitivity fluctuates with different genotypes and plant growth stage. The effects of water-deficit stress during the early reproductive stage on physiological processes of cotton plants have gained more attention lately. Drought events during the flowering stage are known to reduce photosynthetic pigments in cotton plants. However, the alterations in the concentration of these pigments in modern cotton cultivars under water-deficit stress during the squaring stage are not well elucidated. Therefore, studies on changes in concentration of photosynthetic pigments are needed for a better understanding on the effects of drought during the squaring stage on modern cotton cultivars.

BACKGROUND INFORMATION

Water shortage has increased the concern for attaining high crop yields through improved plant tolerance to periods of drought stress. The effects of water-deficit stress in crops vary with severity and duration of the stress, plant growth stage and genotype, as well as the interaction between stress and other factors (Kramer, 1983).

Studies on photosynthetic response of plants under water-deficit stress have been reported to be a useful indicator for tolerance due to its sensitivity to water scarcity conditions. Photosynthetic pigments can be degraded by water-deficit stress; however, plant sensitivity is variable among the modern cultivars. The photosynthetic pigments are essential in plants as they contribute to the process of absorbing light energy for conversion into adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide phosphate (NADPH) during the light reaction of the photosynthesis process. Chlorophyll *a*, chlorophyll *b* and carotenoids are examples of common photosynthetic pigments found in plants. Chlorophyll *a* is the predominant pigment in plants harvesting light energy for photosynthesis, fol-

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lowed by chlorophyll *b,* which assists in increasing the absorption band of light to be utilized in photosynthesis (Taiz and Zeiger, 2010). When light energy is at high intensity, plants can absorb more light than used in photosynthesis resulting in overexcitation of chlorophylls. This leads to formation of chlorophyll triplet and singlet oxygen that can reduce efficiency of the photosynthetic process. Carotenoids function by preventing the formation of singlet oxygen due to their capacity to collect the triplet excitation energy of chlorophylls (Malkin and Niyogi, 2000).

Although all stages of development of modern cotton cultivars are sensitive to drought stress, the reproductive phase of flowering is generally accepted as the most sensitive stage (Loka et al., 2011). In addition, there is evidence that the early stages of square development when meiosis is taking place is also a sensitive stage (Lewis et al., 2000). However, there is very little information on the effects of water-deficit stress during the early squaring stage on the photosynthetic process of cotton plants. Therefore, the objective of this study was to evaluate the alterations in concentrations of photosynthetic pigments of cotton plants under water-deficit stress during early squaring.

RESEARCH DESCRIPTION

A field experiment was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Ark. in 2013. Treatments consisted of three cotton (*Gossypium hirsutum* L.) cultivars, DP 0912 B2RF, PHY 499 WRF, and ST 5288B2F, and two water regimes, well-watered control and water stress imposed at appearance of floral buds (pinhead square stage). The experimental design was a randomized complete block design in strip split plot, with water regimes as the main plot and cultivars as subplot. Seeds were sown on 8 May in a 0.96-m inter-row spacing at a density of approximately 11 seeds/m^{-1}. The soil was mapped as a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs). The whole field was irrigated with a furrow system according to University of Arkansas Cooperative Extension Service recommendations until the pinhead square stage. When plants reached the pinhead square stage, water was withheld from the water-stress treatment for 14 days. Samples for determinations of chlorophylls *a* and *b*, and carotenoids were performed at 7 and 14 days after irrigation was withheld on the fully expanded main-stem leaf on the fourth node below the apical meristem from the two middle rows of each plot. For pigments concentrations, 2 leaf discs were collected from 5 leaves in each plot and placed in vials filled with 1.5 mL dimethylformamide and incubated at ambient temperature (25 °C) for 48 h for pigments extraction. After the incubation period, the samples were read in a spectrophotometer at wavelengths of 480, 646.8, and 663.8 nm for carotenoids, chlorophyll *a* and chlorophyll *b* concentrations, respectively, according to calculations described by Inskeep and Bloom (1985). Cottonseed yield was determined by mechanically harvesting the two middle rows of each plot, and values were expressed as kg ha^{-1}. Data were subjected to analysis of variance, and means were separated using Student's t test ($\alpha = 0.05$). Comparison analyses were performed using JMP Pro 11 (SAS Institute, Inc. Cary, N.C.).

RESULTS AND DISCUSSION

The concentrations of the pigments chlorophyll *a*, chlorophyll *b*, and carotenoids were affected by cultivar and water regime (Table 1). The cultivars PHY499 and ST5288 had higher concentrations of chlorophylls *a* and *b* than DP0912 at the end of the first and second weeks of the stress. Additionally, water-stressed plants showed 14% and 10% lower chlorophyll *a* concentrations compared with the control at the end of the first and second weeks of the stress, respectively; while the reduction in chlorophyll *b* concentrations of the water-stressed plants was approximately 9% and 7% at the end of the first and second weeks of the stress, respectively. Carotenoids concentration was higher in ST5288 compared with the other cultivars at the end of the first week of the stress (Table 1). At the end of the second week of the stress, ST5288 and PHY499 showed higher carotenoids concentration than DP0912. The water-stressed conditions decreased carotenoid concentrations in the cotton plants compared with the control at both the end of the first and second weeks of the stress (Table 1). These results indicate that ST5288 has lower photosynthetic pigment sensitivity to water-deficit stress during the squaring stage than the other cultivars.

Cottonseed yield was affected only by cultivar (Table 1). The cultivars DP0912 and ST5288 showed higher cottonseed yield than PHY499. However, there was no significant difference in the cottonseed yield between water-stressed and control plants.

In conclusion, the modern cotton cultivars studied varied in concentrations of photosynthetic pigments, and water-deficit stress at the squaring stage reduced chlorophylls and carotenoids concentrations in all cultivars. However, this decrease in the photosynthetic pigments did not affect cottonseed yield indicating that water-deficit stress during the squaring stage might affect photosynthetic process, but the impairment was not severe enough to reduce yield.

PRACTICAL APPLICATION

Variation in photosynthetic pigments in modern cotton cultivars has not been clarified under water-deficit stress during the squaring stage. The reduction in the photosynthetic pigments might impair the photosynthesis process due to lower light harvesting efficiency by the leaves, therefore resulting in reduced plant growth and productivity. The characterization of the effects of water-deficit stress during the early reproductive stage of cotton on physiological processes is important as we speculate that the modern cotton cultivars are also sensitive at the squaring stage as well as the flowering stage.

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Table 1. Effect of cultivar and water-deficit stress on Chlorophyll *a* (µg cm^{-2}), Chlorophyll *b* (µg cm^{-2}), and Carotenoids (µg cm^{-2}) in cotton plants after one and two weeks of water-deficit stress, and Cottonseed Yield (kg ha^{-1}) at the end of growing season in Marianna, Ark., 2013.

Treatment	Chlorophyll *a* Week 1	Chlorophyll *a* Week 2	Chlorophyll *b* Week 1	Chlorophyll *b* Week 2	Carotenoids Week 1	Carotenoids Week 2	Cottonseed yield
Cultivar							
DP0912	8.82 b†	8.04 b	2.16 b	2.05 b	2.64 b	2.63 b	4386 a
PHY499	9.20 a	8.71 a	2.40 a	2.29 a	2.61 b	2.73 a	4118 b
ST5288	9.37 a	8.58 a	2.41 a	2.35 a	2.77 a	2.71 a	4457 a
Water Regime							
Control	9.80 a	8.92 a	2.43 a	2.32 a	2.85 a	2.86 a	4340
Water Stress	8.46 b	7.98 b	2.22 b	2.15 b	2.50 b	2.52 b	4300
ANOVA							
Cultivar (C)	0.0049	0.0003	0.0002	0.0003	0.0030	0.0128	0.0069
Water regime (WR)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	NS
Interactive C x WR	NS‡	NS	NS	NS	NS	NS	NS

† Values in column, within each factor (Cultivar and Water regime), followed by the same letter are not significantly different at $P \leq 0.05$ according to Student's *t* test.

‡ NS, not significant at the 0.05 probability level.

Agronomic and Water Quality Impacts of Incorporating Polyacrylamide in Furrow Irrigation Water in Arkansas Cotton —2014

M.L. Reba[1], A.L. Lewis,[2] and T.G. Teague[3]

RESEARCH PROBLEM

Arkansas ranks third after California and Nebraska in irrigated acres among the states in the USA (USDA NASS, 2013). Improved management is needed to increase irrigation efficiency, particularly in the 45% of Arkansas's irrigated acres that use furrow irrigation. Prudent irrigation management not only preserves resources and reduces production costs, but also impacts water quality by reducing the amount of runoff and associated nutrients and agrochemicals entering waterways from agricultural fields.

BACKGROUND INFORMATION

In low rainfall production areas in the western U.S., applications of polyacrylamide (PAM) have been shown to increase infiltration rate and reduce irrigation advance times in furrow-irrigated systems (Barta et al., 2004). Additional benefits have included improved aggregate stability, soil stabilization and improved runoff water quality (Lentz and Sojka, 1994). Polyacrylamide application is an approved practice in the USDA-NRCS Environmental Quality Incentives Program in Arkansas. Some limitations on practical use of PAM include challenges with formulation (e.g. high viscosity complicates spray applications) and the need for multiple applications (Green and Stott, 2001). Results from field studies in Northeast Arkansas have shown reduction of sediment following PAM application in furrow-irrigated systems (Shumway, 2009). The objective of this project was to improve our understanding of the impact of PAM on agronomic production and irrigation efficiency as well as run-off water quality.

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RESEARCH DESCRIPTION

This study took place at the Judd Hill Foundation Research Farm near Trumann, Ark. Soils in the field are 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 (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 (*Gossypium hirsutum* L.) cultivar Delta Pine 0912 RFB2 was seeded on 7 May 2014. 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 80 ft (24.4 m) long and 10 rows wide. The furrow length was approximately 530 ft (161.54 m) long.

Irrigation was applied on 5 separate dates: 10 July, 16/17 July, 29 July, 5 August, 18/19 August, and 25 August (64, 70, 83, 90, 103 and 110 days after planting (DAP)). The field was irrigated using 15 in (38.1cm) polyethylene irrigation tubing or polypipe, with groundwater from the Mississippi River Valley Alluvial Aquifer (MRVAA) from a well with an output of 850 GPM (0.05 m^3/s). Pipe Planner was used on the field to help with the irrigation advance uniformity in the furrows. On 15 July, just prior to the 16/17 July irrigation, furrows (row middles) in all treatment plots were prepared for irrigation using a V-shaped furrow-forming plow ca. 2 to 3 inches (5 to 8 cm) deep. There were no further tillage operations. Polyacrylamide applications were made 17 July and 19 August. Liquid Flobond (SNF Holding Company, Riceboro, Ga.) L33 (30% active product, 30% anionic charge) at concentrations of 2 ppm was injected with a small pump into the access port of the Y-valve connected to the polytubing.

Data collection included plant and insect pest monitoring, soil moisture and water quality sampling, as well as yield and fiber quality assessments. Weekly plant monitoring using the COTMAN crop monitoring system (Oosterhuis and Bourland, 2008) was used to document differences in crop development among irrigation treatments from squaring until physiological cutout. End-of-season plant mapping was performed using the COTMAP procedure (Bourland and Watson, 1990). The field was defoliated on 30 September and harvested 1 November with a two-row research cotton picker. For fiber quality evaluations, fifty boll samples for 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 with mean separation using Fisher's protected least significant difference test. To monitor soil moisture, twelve Decagon EC5 sensors (Decagon Devices, Inc., Pullman, Wash.) were deployed in each treatment plot in one replication. Each treatment had three replicates of four sensors. The four sensors were placed at 15 cm and 30 cm in the shoulder of the row and in the row directly below the plant at 1, 2, and 3 meter(s) from the plot edge down the furrow (Fig. 1a). Grab samples for water quality analysis were collected for three irrigation events. Two collection events were over the course of two days (16/17 July; 18/19 August); PAM was applied on day two. No PAM was applied on 25 August. Water samples were collected every two hours for six hours; 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-NO_3-E), Orthophosphate (APHA 2005 method 4500-P E), and Total P & N (4500-P J). A weather station, located within 1 km of the field study collected precipitation, air temperature, humidity, radiation and soil temperature data for the season (weather.astate.edu).

RESULTS AND DISCUSSION

There were multiple in-season precipitation events early in the season, after which monthly precipitation values were below the 30-year normal precipitation levels in August and September (PRISM Climate Group, 2015). Soil moisture measures taken from the IRR treatment show a clear response to irrigation events (Fig. 1); soil moisture data from the IRR+PAM treatment in 2014 were not usable. Water quality analysis showed few differences between water quality sampling from the IRR and IRR+PAM treatments in the parameters measured. Total phosphorus showed statistically different values ($P < 0.1$) between the two irrigation treatments for the samples collected.

Days to physiological cutout ranged from 83 DAP for Rainfed compared to 89 and 91 DAP for IRR and IRR+PAM, respectively. Earlier cutout for Rainfed plants was apparent in COTMAN growth curves (Fig. 2a). Mean lint yield was significantly higher in irrigated compared to Rainfed cotton; however, addition of PAM in irrigation water significantly reduced yield ($P = 0.001$; Fig. 2b). The reasons for the reduction in yield with PAM are unknown, but results from plant monitoring and end-of-season mapping suggest reduced first position boll retention with addition of PAM (Fig. 2; Table 1). Retention was not related to insect infestations (data not shown). Results from HVI analysis indicated no differences in fiber quality associated with PAM; however uniformity and fiber length were significantly reduced in Rainfed compared to the irrigated treatments (data not shown).

Findings from the impact that PAM had on cotton production from this study are preliminary. The research will continue in the next production season. It is encouraging that total P was reduced with the PAM application but other water quality parameters were not statistically different. Environmental benefits associated with PAM application have included reduced pesticide and fertilizer runoff (Green and Stott, 2001).

PRACTICAL APPLICATION

Research on understanding the impact and potential benefit from PAM applications in high rainfall production regions for soil conditioning will help inform crop managers on potential direct and indirect benefits and costs in Mid-South cotton production.

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 with special thanks to UA Program Technicians, Erin Kelly and Alan Beach; and Farm Foreman, Mark Poag.

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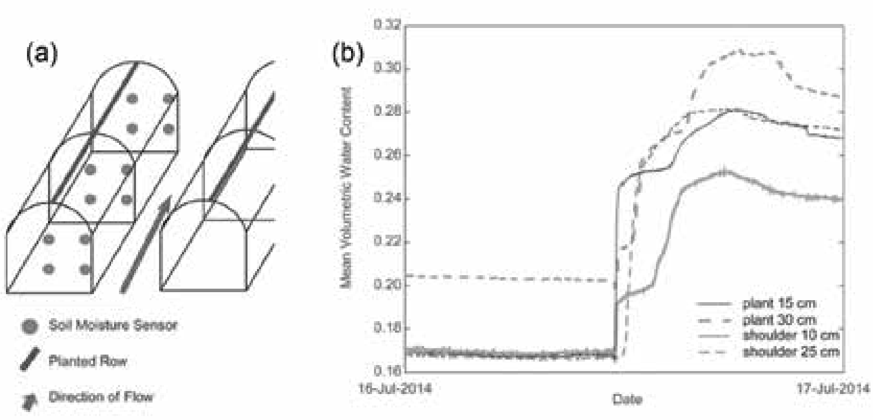

Fig. 1. Soil moisture sensor deployment diagram (a) showing the furrow and planted row; volumetric water content (b) from the irrigation treatment showing mean volumetric water content of shallow and deep sensors placed below the plant and below the shoulder of the bed on 16 July 2014.

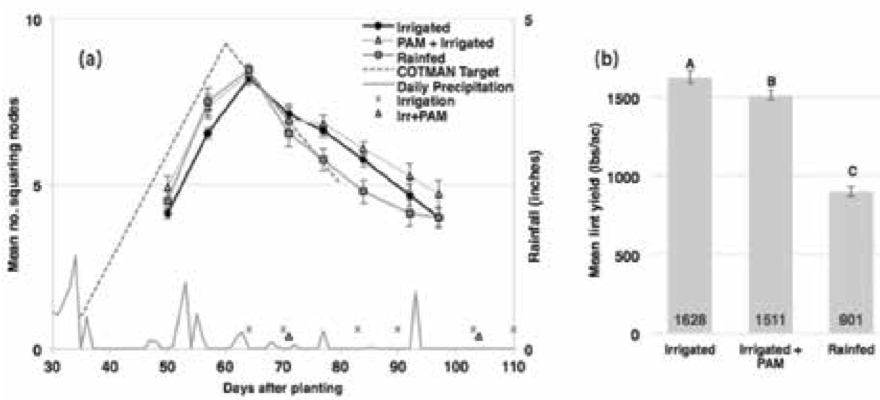

Fig. 2. COTMAN growth curves (a) for the three treatments with the standard target development curve (dotted line) and timing of, precipitation and irrigation events. (b) Mean lint yield (±SEM) for three treatments, Judd Hill, Ark., 2014.

Table 1. Results from final, end-of-season plant mapping using COTMAP, Judd Hill, Ark. 2014.

Category	IRR	IRR+PAM[a]	Rainfed	*Pr>F*	*LSD*
	....	Mean per plant	....		
1st Sympodial Node	7.4	6.9	7.0	*0.12*	
No. of Monopodia	1.4	1.4	1.6	*0.67*	
Highest Sympodia with 2 nodes	11.1	11.8	9.6	*0.01*	*0.10*
Plant Height (inches)	31.6	31.7	31.1	*0.96*	
No. of Effective Sympodia	8.3	8.3	7.0	*0.16*	
No. of Sympodia	14.5	15.1	13.0	*0.004*	*0.81*
Total Bolls/Plant	8.7	10.0	8.3	*0.07*	
% Total Bolls in 1st Position	63.9	51.9	61.1	*0.07*	
% Total Bolls in 2nd Position	23.4	24.2	22.1	*0.49*	
% Total Bolls in Outer Position	3.9	12.3	6.6	*0.06*	
% Total Bolls on Monopodia	8.8	11.6	10.2	*0.72*	
% Boll Retention - 1st Position	38.4	34.4	39.5	*0.16*	
% Boll Retention - 2nd Position	18.6	20.5	19.4	*0.42*	
% Early Boll Retention	52.3	50.0	50.0	*0.45*	
Total Nodes/Plant	20.9	20.9	19.0	*0.01*	*0.95*
Internode Length (inches)	1.5	1.5	1.7	*0.46*	

[a] IRR = irrigation, PAM = polyacrylamide.

Value of Cover Crops on Weed Control in Cotton

M.G. Palhano, J.K. Norsworthy, Z.D. Lancaster, S.M. Martin, and C.J. Meyer[1]

RESEARCH PROBLEM

Weed control in reduced tillage systems prior to glyphosate-resistant cotton was a challenge in cotton production (Koskinen and McWhorter, 1986). Today, weed control is again challenging in the absence of tillage because of the widespread occurrence of glyphosate-resistant weeds in cotton, which had led to more expensive herbicide programs for proper weed control (Sosnoskie and Culpepper, 2014). To manage this problem sustainably, a more diverse weed management program is required.

BACKGROUND INFORMATION

Cover crops have primarily been used in agricultural systems due to the benefits related to soil, carbon sequestration, water management, and pest control (Ducamp et al., 2012). Cover crop residues can persist over the surface of the soil and alter weed emergence patterns by impacting the microenvironment surrounding weed seed, such as light availability, soil moisture, and temperature early in the season (Creamer et al., 1996). Cover crops have shown limited weed control benefit when used alone in the absence of herbicides. However, when combined with herbicides, cover crops can offer adequate weed control and potentially increase cotton yield (Reddy et al., 2003).

RESEARCH DESCRIPTION

Two separate field experiments were conducted at the University of Arkansas System Divison of Agriculture's Arkansas Agricultural Experiment Station in Fayetteville, Ark. in 2014 to (1) evaluate the value of various cover crops in suppressing weed emergence; and (2) determine the effect of cereal rye seeding rate, cover crop planting method, and herbicide program on weed control in cotton. Cover crops were sown at the recommended seeding rate in the early fall of 2013 and chemically terminated 21 days before cotton planting in the spring of 2014. At cotton planting, aboveground cover crop biomass was collected from 2 random

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0.5 m^2 quadrants 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}. Experiment 1 was a split-plot design with 14 cover crops serving as the main plot factor and the use and nonuse of a residual herbicide program serving as sub-plots. The non-residual herbicide program was designed to assess weed emergence in each cover crop throughout the growing season. Experiment 2 was a split-plot design with the main plot being cereal rye seeding rates of 58, 115, and 172 kg ha^{-1} in the absence or presence of a herbicide program. Subplots consisted of drilled and broadcasted planting methods. Palmer amaranth emergence was evaluated throughout the growing season, visual weed control rated, and seedcotton yield data collected for both experiments. All data were subjected to analysis of variance using JMP 11 Pro (SAS Institute, Inc., Cary, N.C.).

RESULTS AND DISCUSSION

Experiment 1.

All cover crops initially diminished Palmer amaranth emergence. However, cereal rye had the greatest suppression, with 90% less emergence compared to no cover crop plots (Fig. 1) Brassica and legume cover crops had only a minor impact on Palmer amaranth emergence. Physical suppression of the weeds from the cereal residues is most likely the greatest contributor to reducing weed emergence, since they produce greater biomass and persist longer above the ground than legume and brassica residues due to the higher carbon and nitrogen ratio (Fig. 2). Unfortunately, similar to weed suppression, as biomass production increased there was greater difficulty in establishing a stand of cotton. Due to this fact, yields were affected by the presence of cover crop residues at cotton planting.

Experiment 2.

No significant differences were observed between planting methods in any parameter evaluated. Cereal rye biomass production increased as seeding rate increased (data not shown). Cereal rye by itself was more effective on Palmer amaranth suppression than barnyardgrass (Figs. 3 and 4). When herbicides were not applied, cereal rye at 58 kg/ha provided the least weed control. Cereal rye at 115 and 172 kg/ha provided comparable levels of weed control. All plots treated with a standard herbicide program had weed control greater than 98% for all species, regardless of the seeding rate (Figs. 3 and 4). Yields from plots with the standard herbicide program were significantly higher than from plots without herbicide, independent of seeding rates (Fig. 5). Yield improvement was observed due to use of cereal cover crop in the system compared to no cover crop.

PRACTICAL APPLICATION

Based on the results of these studies, it can be concluded that cereal cover crops provided better weed suppression than legume and brassica cover crops, since they produce greater biomass and more persistent residues. Broadcast planting appears to produce the same cover crop biomass production, weed control and increased cotton yield as the drilled planting method. Cover crop by itself demonstrated limited effect on weed control. Hence, it is essential to integrate herbicide programs with cover crops in order to obtain adequate weed control and higher yields. On experiment 1, a deleterious yield effect was observed on the cover crop plots. It is possible that this was a result of the moist conditions that occurred at the time of planting. Proper equipment and conditions during planting should alleviate this problem. In contrast, yield improvement was observed due to use of cereal cover crop in the system compared to no cover crop on experiment 2.

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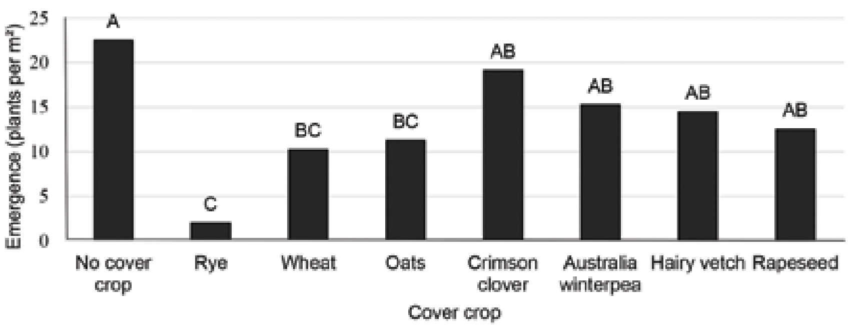

Fig. 1. Influence of cover crop selection on total Palmer amaranth emergence over the entire cotton growing season in the absence of residual herbicides. Means followed by the same letter are not significantly different.

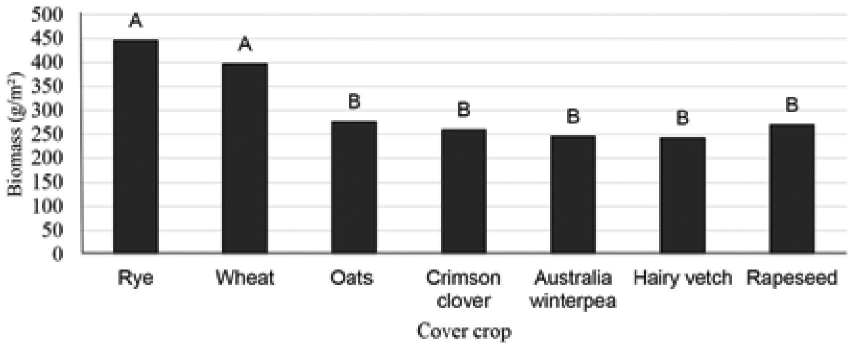

Fig. 2. Cover crop biomass prior cotton planting. Means followed by the same letter are not significantly different.

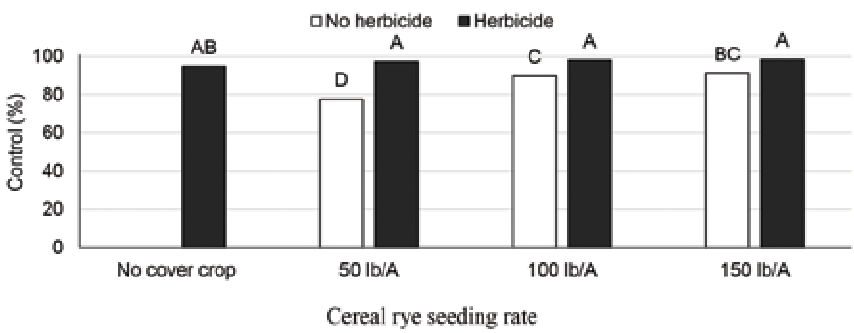

Fig. 3. Palmer amaranth control in absence and presence of herbicides as influenced by cereal rye seeding rate at 8 weeks after cotton planting. Means followed by the same letter are not significantly different.

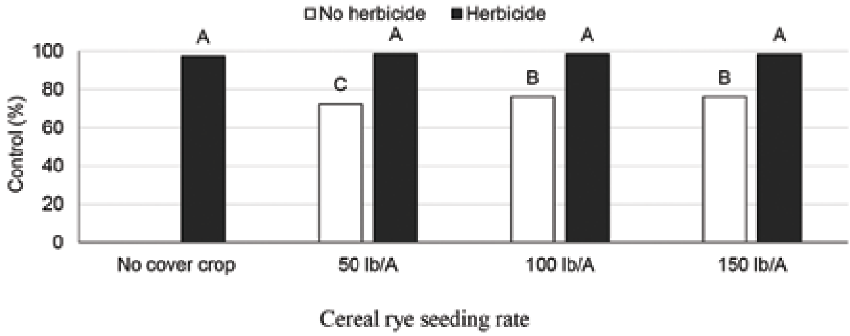

Fig. 4. Barnyardgrass control in absence and presence of herbicides as influenced by cereal rye seeding rate at 8 weeks after cotton planting. Means followed by the same letter are not significantly different.

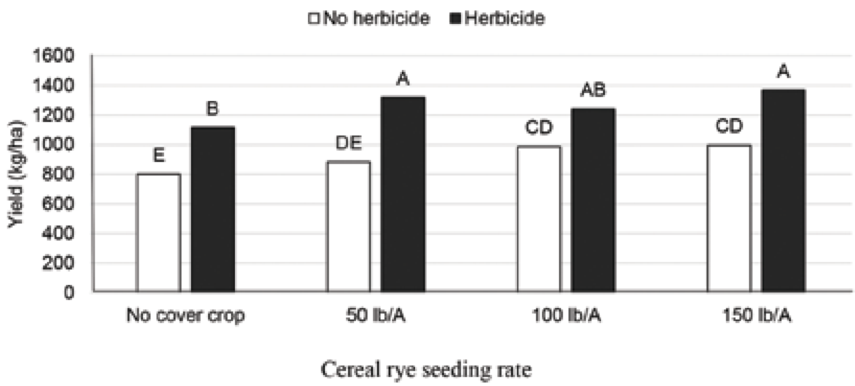

Fig. 5. Influence of cover crop alone and integrated with an herbicide program on seed cotton yield. Means followed by the same letter are not significantly different.

Control of Glyphosate-Resistant Johnsongrass in Mid-South Cotton Production Systems

C.J. Meyer[1], J.K. Norsworthy[2], D.O. Stephenson IV[3], R.R. Hale[1], and M.T. Bararpour[4]

RESEARCH PROBLEM

Johnsongrass (*Sorghum halepense* L.) is a problematic weed in Arkansas and Louisiana cotton production. Since 2007, johnsongrass has evolved resistance to glyphosate in multiple locations throughout Arkansas and Louisiana. As resistant populations become more prevalent across the Mid-South, alternative weed control programs must be implemented.

BACKGROUND INFORMATION

Johnsongrass interference can cause severe yield losses in cotton and inhibit harvest (Bridges and Chandler, 1987; Keeley and Thullen, 1989). Historically, johnsongrass has proved to be more difficult to successfully control in agricultural systems than many other weeds because of its ability to reproduce through underground stems or rhizomes (McWhorter, 1989). Cotton producers rely heavily on glyphosate (EPSPS-inhibitor) for control of johnsongrass in their production systems. Glyphosate readily translocates to all parts of the plant, reducing the likelihood of regrowth from reproductive structures such as rhizomes. However, other herbicides are labeled for use in cotton including photosystem II (PSII), acetolactate synthase (ALS), acetyl-CoA carboxylase (ACCase), and glutamine synthetase inhibitors that may be effective in controlling johnsongrass that has evolved resistance to glyphosate.

RESEARCH DESCRIPTION

Three research trials were conducted in 2012, 2013, and 2014 at the University of Arkansas System Division of Agriculture's Agricultural Experiment Station in Fayetteville, Ark., and the Louisiana State University Agricultural Center

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Dean Lee Research and Extension Center in Alexandria, La. to evaluate herbicide programs and strategies for management of glyphosate-resistant johnsongrass. All experiments were set up as a randomized complete block design utilizing various combinations of pre-plant (DPP), preemergence (PRE), early-postemergence (EPOST, 2-4 leaf cotton), mid-postemergence (MPOST, 6-8 leaf cotton) and layby (LAYBY) application timings. The objectives of each trial were: Trial 1, evaluate total herbicide programs for season-long control of glyphosate-resistant johnsongrass; Trial 2, evaluate the effectiveness of pyrithiobac and trifloxysulfuron tank-mixed with clethodim POST on johnsongrass control; and Trial 3, evaluate the efficacy single and sequential applications of glufosinate with and without clethodim POST for johnsongrass control. All herbicides were applied at recommended rates. Weed control ratings were collected at various times throughout the growing season; number of culms and panicles m^{-2} were recorded for each plot at the end of the season, and seed cotton yields were collected. Due to the high variability between site years for some treatments and low variability for others, all data did not meet the equal variance assumptions for analysis of variance. Therefore, simple treatment means are discussed and data are presented as box-and-whisker plots.

RESULTS AND DISCUSSION

Fluometuron or fluometuron + pyrithiobac applied PRE followed by (fb) EPOST, MPOST, LAYBY tank-mixtures containing multiple modes of action increased control for johnsongrass. For example, a PRE application of fluometuron + pyrithiobac fb glufosinate EPOST, fb glufosinate + trifloxysulfuron MPOST, fb diuron + MSMA LAYBY provided the highest level of control across locations and years. The inclusion of fomesafen 14 DPP had no measurable effect on early-season johnsongrass control. Assessments collected 14 days after EPOST showed that including fluometuron PRE increased johnsongrass control over total POST programs (Fig. 1). Although herbicide treatment did not have a measurable effect on seed cotton yield (data not shown), failing to control minor infestations in a production field can rapidly proliferate through vegetative reproduction and seed dispersal, resulting in severe yield losses as observed by Bridges and Chandler (1987). This hypothesis is also supported by the increased culms m^{-2} and panicles m^{-2} observed at the end of the season in weaker herbicide programs (Figs. 2 and 3). Culms and panicles m^{-2} for fluometuron PRE fb glufosinate fb glufosinate were greater than other treatments containing additional ALS herbicides PRE or POST.

Results from Trial 2 demonstrated that when only ALS and ACCase-inhibiting herbicides are used to control johnsongrass, including clethodim at both application timings is critical for obtaining acceptable control. Pyrithiobac fb trifloxysulfuron only provided 67% control, and including clethodim in either the first or the second application improved control to 79% and 86%, respectively (Fig. 4). However, it appears both ALS-inhibiting herbicides antagonize the activity of clethodim, likely by reducing the photosynthetic rate of the plant thereby decreasing sensitivity of ACCase to clethodim (Burke and Wilcut, 2003). The highest levels of control were achieved with clethodim fb clethodim (95%). Based on these data, pyrithiobac applied in the first application (93%) had less of an antagonistic effect on two applications of clethodim than when trifloxysulfuron was tank-mixed in the second application (86%). Counts of the number of culms m^{-2} and panicles m^{-2} also support that two applications of clethodim was the most effective treatment (Figs. 5 and 6). At the end of the season, clethodim fb clethodim reduced the number of panicles m^{-2} by 97% and number of culms by 96% compared to the nontreated check.

In Trial 3, sequential applications of glufosinate + clethodim provided the greatest control (95%) of johnsongrass whether the johnsongrass was 15 cm or 46 cm at the time of application (Fig. 7). The second best treatment was glufosinate fb glufosinate, which provided 88% and 91% control when the first application was made to 15 and 46 cm johnsongrass, respectively. Also, single applications of glufosinate or glufosinate + clethodim were not sufficient to control johnsongrass with both treatments providing <82% control. Analysis of the culm and panicle data collected at the end of the season had similar results. A sequential application of glufosinate + clethodim reduced the number of panicles by 97% and culms by 96% compared to the nontreated check for both application timings (Figs. 8 and 9). Results of the culm and panicle data for sequential applications of glufosinate was similar to the aforementioned treatments when the first application was made to large johnsongrass; however, when the first application of glufosinate was made to 15 cm johnsongrass, panicles m^{-2} were only reduced by 86% and culms by 85%. This indicates that a POST program of glufosinate fb glufosinate will not be effective at managing glyphosate-resistant johnsongrass because neither is it practical for a grower to wait for johnsongrass to exceed 15 cm in height to apply the first herbicide application, nor is it a sound herbicide-resistance prevention strategy. The recommended program from this experiment would be to apply glufosinate + clethodim fb glufosinate + clethodim.

Comparing the data for the single applications, it appears if only one POST herbicide application is used to control glyphosate-resistant johnsongrass, the application should be made to larger plants. However, this would go against best management practices for managing herbicide resistance (Norsworthy et al., 2012) and still does not result in effective control. Furthermore, cotton yield losses have resulted from as little as three weeks of competition between johnsongrass and the crop (Bridges and Chandler, 1987). Therefore, sequential POST applications utilizing multiple effective modes of action applied to small (<15 cm) johnsongrass is the recommended POST herbicide program for adequate control. Surprisingly, when results from Trial 3 are compared to those from Trial 2, glufosinate does not appear to effect the activity of clethodim. Therefore, glufosinate is a better tank-mix partner with clethodim than the ALS herbicides to improve control on johnsongrass and increase the weed control spectrum of the application.

PRACTICAL APPLICATION

A rigorous herbicide program involving multiple effective modes of action PRE, EPOST, and MPOST provided the highest and most consistent control across locations and years. Simplifying the herbicide program by removing any herbicide or eliminating an application timing reduced control, increased vegetative and sexual reproduction of johnsongrass, and reduced yield under severe infestations. To manage severe infestations or escapes, a two pass POST program consisting of multiple effective modes of action (glufosinate + clethodim fb glufosinate + clethodim, clethodim fb trifloxysulfuron + clethodim, etc.) was effective at controlling small (15 cm) johnsongrass. To help prevent evolution of herbicide resistance, antagonistic interactions such as tank-mixing ALS and ACCase-inhibitors should be avoided if possible. In the absence of clethodim, fluometuron PRE fb glufosinate + pyrithiobac fb glufosinate + trifloxysulfuron is the best program for managing glyphosate-resistant johnsongrass. In summary, effective herbicide programs are available to growers to control glyphosate-resistant johnsongrass but the use of a total herbicide program approach is critical for successful management.

ACKNOWLEDGMENTS

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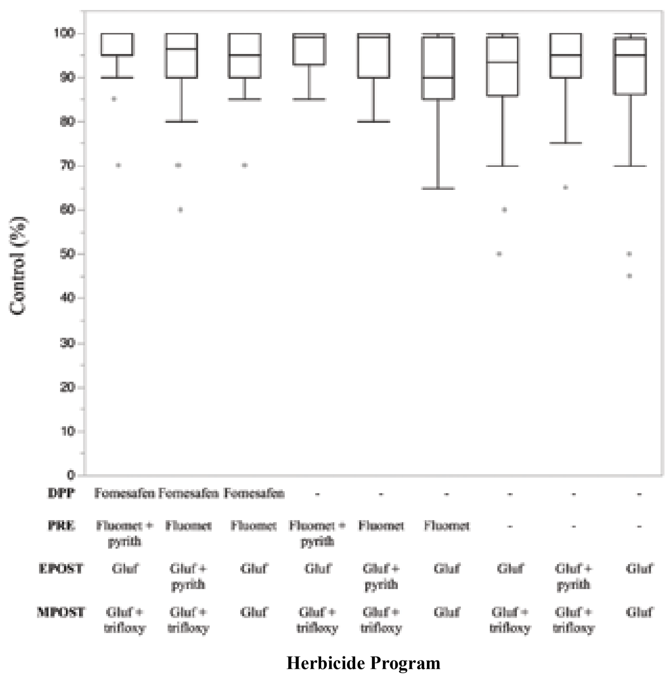

Fig. 1. Percent control of johnsongrass two weeks after the mid-postemergence (MPOST) application for each herbicide programs in Trial 1 consisting of fomesafen, fluometuron (fluom), pyrithiobac (pyrith), glufosinate (gluf) and trifloxysulfuron (trifloxy). All herbicide programs also included a LAYBY application of diuron + MSMA applied after this rating assessment.

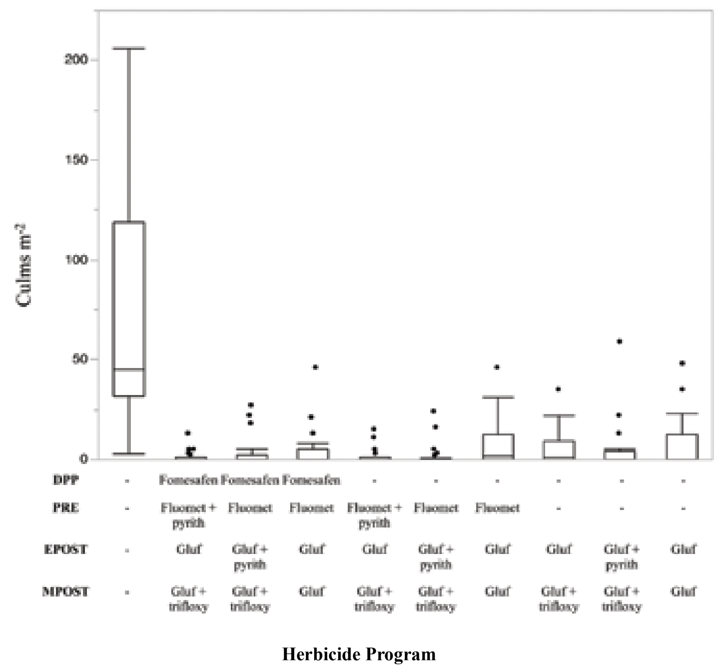

Fig. 2. Number of johnsongrass culms m^{-2} determined at the end of the season for each herbicide program in Trial 1 consisting of fomesafen, fluometuron (fluom), pyrithiobac (pyrith), glufosinate (gluf) and trifloxysulfuron (trifloxy). All herbicide programs also included a LAYBY application of diuron + MSMA

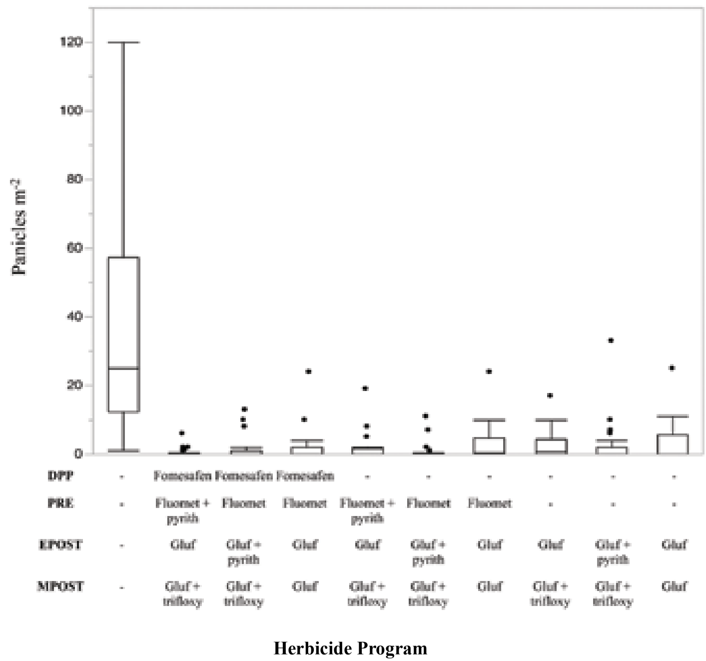

Fig. 3. Number of johnsongrass panicles m^{-2} determined at the end of the season for each herbicide program in Trial 1 consisting of fomesafen, fluometuron (fluom), pyrithiobac (pyrith), glufosinate (gluf) and trifloxysulfuron (trifloxy). All herbicide programs also included a LAYBY applicationof diuron + MSMA

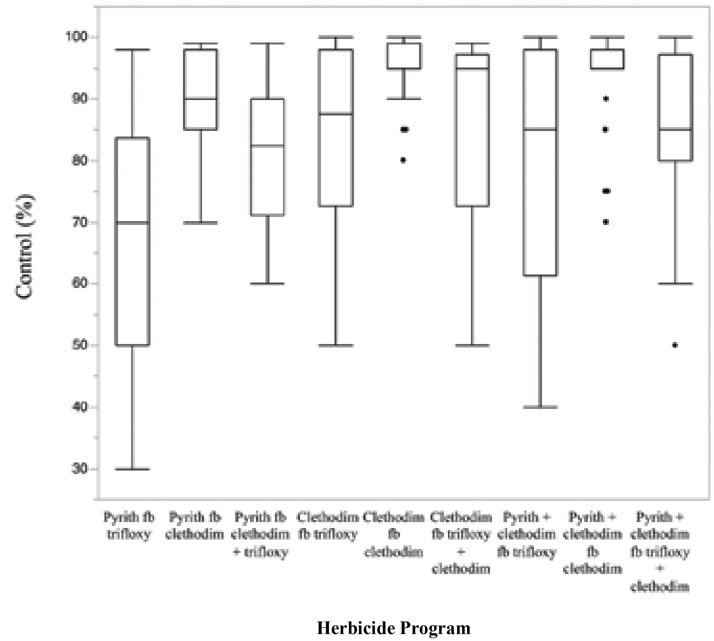

Fig. 4. Percent control of johnsongrass two weeks after the follow-up application for each herbicide program in Trial 2 consisting of pyrithiobac (pyrith), trifloxysulfuron (trifloxy), and glufosinate (gluf). Each treatment consisted of one application followed by (fb) a second application.

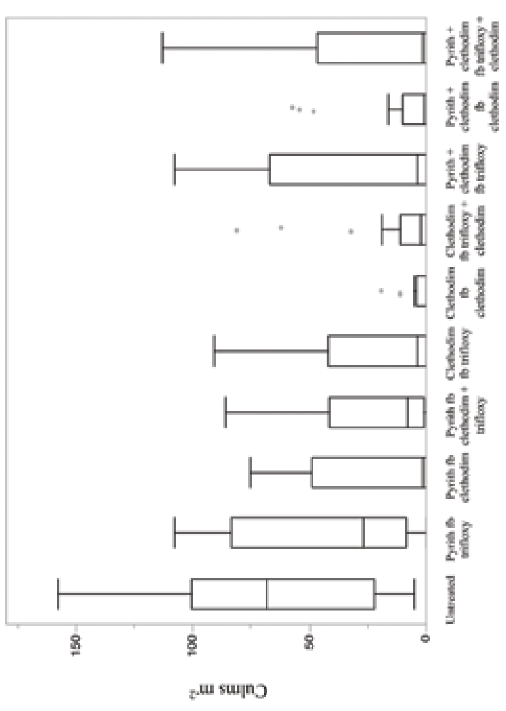

Fig. 5. Number of johnsongrass culms m^{-2} determined at the end of the season for each herbicide program in Trial 2 consisting of pyrithiobac (pyrith), trifloxysulfuron (trifloxy), and glufosinate (gluf). Each treatment consisted of one application followed by (fb) a second application.

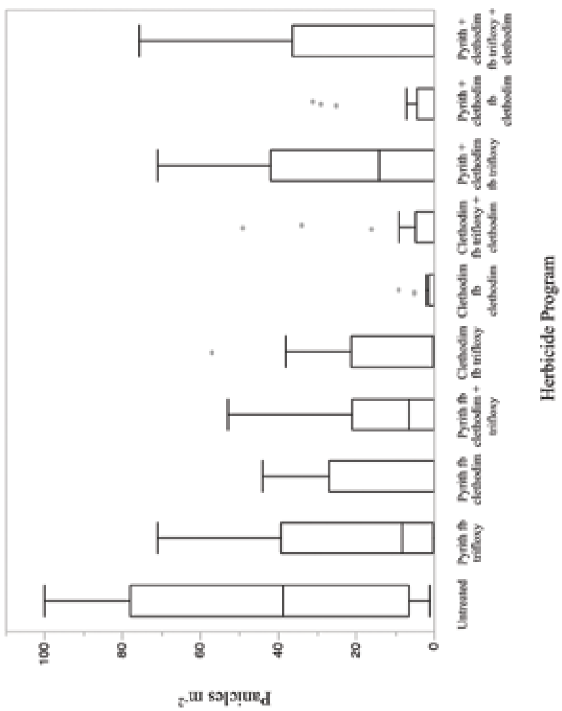

Fig. 6. Number of johnsongrass panicles m^{-2} determined at the end of the season for each herbicide program in Trial 2 consisting of pyrithiobac (pyrith), trifloxysulfuron (trifloxy), and glufosinate (gluf). Each treatment consisted of one application followed by (fb) a second application.

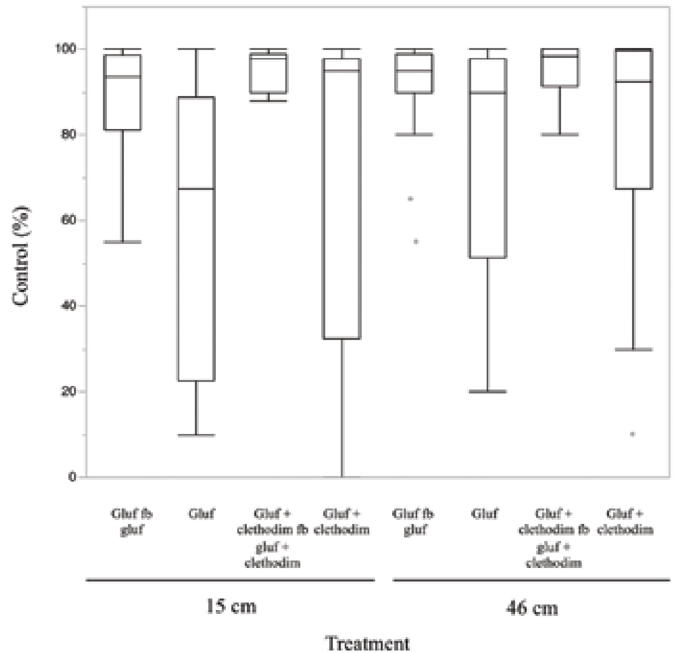

Fig. 7. Percent control of johnsongrass two weeks after the follow-up application for each herbicide program in Trial 3 consisting of either a single or sequential application of glufosinate (gluf) and clethodim. The first application either occurred on 15 cm or 46 cm johnsongrass. Sequential treatments are referred to as the first application followed by (fb) the second application.

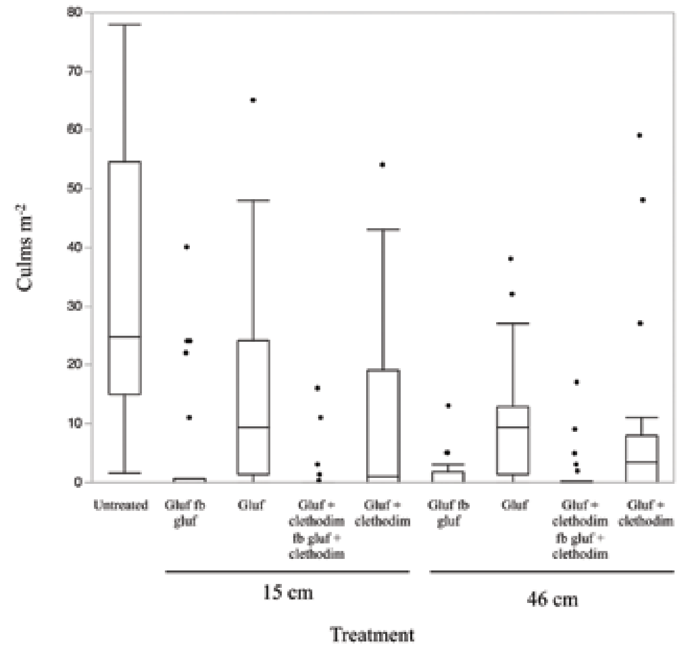

Fig. 8. Number of johnsongrass culms m^{-2} determined at the end of the season for each herbicide program in Trial 3 consisting of either a single or sequential application of glufosinate (gluf) and clethodim. The first application either occurred on 15 cm or 46 cm johnsongrass. Sequential treatments are referred to as the first application followed by (fb) the second application.

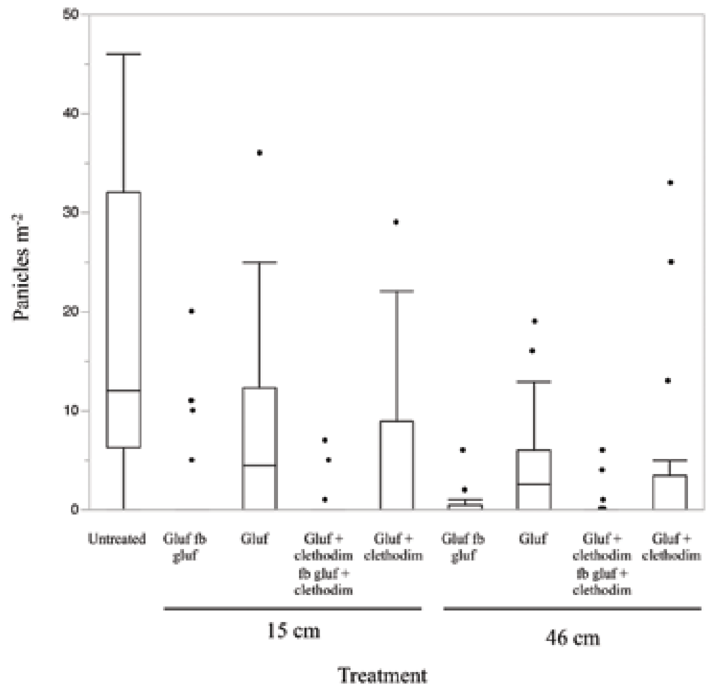

Fig. 9. Number of johnsongrass panicles m^{-2} determined at the end of the season for each herbicide program in Trial 3 consisting of either a single or sequential application of glufosinate (gluf) and clethodim. The first application either occurred on 15 cm or 46 cm johnsongrass. Sequential treatments are referred to as the first application followed by (fb) the second application

Enlist-Duo™ Weed Control Systems in Arkansas Cotton

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

RESEARCH PROBLEM

First confirmed in 2006, glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) remains a major concern for cotton (*Gossypium hirsutum*) growers in Arkansas. Herbicide systems that contain multiple modes of action and are applied timely are essential in controlling this invasive weed. The Enlist Duo technology provides an opportunity and the flexibility to use multiple modes of action over-the-top of cotton for control of many weeds including Palmer amaranth. The objective was to evaluate Enlist Duo and Enlist Duo systems for crop response and weed control.

BACKGROUND INFORMATION

Glyphosate-resistant Palmer amaranth has forced cotton weed control programs to evolve into full-season systems. Currently there is no single herbicide that will control glyphosate-resistant Palmer amaranth after it reaches 3-4 inches in height (Scott et al., 2015). More information was needed on crop tolerance and weed control provided by Enlist Duo and systems which include this new technology.

RESEARCH DESCRIPTION

Field trials were conducted in 2013 and 2014 at the Southeast Research and Extension Center in Rohwer, Ark. The trials were established in a Hebert silt loam soil. The design was randomized complete block with four replications. Treatments were applied at three timings: preemergence, 2-4" weeds, and 14-21 days after the 2-4" weed application. Herbicides used included Enlist Duo, 2,4-D choline, Cotoran, Roundup WeatherMax, Liberty, Dual Magnum, and Warrant. 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 GPA. Means were separated using Fisher's protected least significant difference test. (P = 0.05). Weed control and cotton injury was record-

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ed 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 not caused by Enlist Duo or any Enlist Duo system in 2013 or 2014. In 2013 seven days after application B (DAB), Cotoran followed by (fb) Round-up and Cotoran fb Liberty provided 75% and 76% control of Palmer amaranth. Cotoran alone provided 25% control of Palmer amaranth. All other treatments provided 99% control. Cotoran fb Liberty and Cotoran alone provided 89% and 33% control of Southwestern cup grass (*Eriochloa gracilis*), while all other treatments provided 97% or greater control. In 2013, seven DAC all treatments provided 95% or greater control of Palmer amaranth and 91% or greater control of Southwestern cupgrass except Cotoran alone, which provided no control. In 2014, nine DAB Cotoran fb Enlist Duo and Cotoran fb Liberty plus 2,4-D choline plus Dual Magnum provided 83% and 92% control of Palmer amaranth respectively, while both provided 94% control of barnyardgrass (*Echinochloa crus-galli*). All other treatments provided less than 78% control of either weed species. In 2014 twelve DAC Cotoran fb Liberty plus 2,4-D choline plus Dual Magnum fb Enlist Duo and Cotoran fb Liberty plus 2,4-D choline fb Enlist Duo provided 95% and 91% control of Palmer amaranth respectively. Cotoran fb Liberty plus 2,4-D choline plus Dual Magnum fb Enlist Duo and Cotoran fb Enlist Duo fb Enlist Duo both provided 98% control of barnyardgrass. In 2014, the addition of residual herbicides at the 2-4" weed application timing improved overall weed control. In both 2013 and 2014, systems that contained multiple modes of action in the 2-4 inch weed application provided better weed control.

PRACTICAL APPLICATION

Enlist Duo and Enlist Duo systems can provide good broad-spectrum weed control without causing any injury to the cotton crop. The addition of this technology to our growers herbicide options will provide an additional mode of action and may increase overall success in controlling glyphosate-resistant broadleaf weeds. The information from this trial will be used to make Palmer amaranth control recommendations throughout the state.

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Evaluation of Herbicide Programs in Glytol® LibertyLink® Cotton

M.R. Miller[1], J.K. Norsworthy[2], C. Starkey[3], and C.J. Meyer[1]

RESEARCH PROBLEM

In recent years, mid-southern cotton growers have been forced to base their weed management decisions around controlling glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*), which was listed as the most problematic weed in cotton in a recent survey (Riar et al., 2013). As this and other herbicide-resistant weeds continue to spread across the Cotton Belt, new technologies and recommendations are needed to achieve effective control.

BACKGROUND INFORMATION

In 1997, Roundup Ready® cotton cultivars were introduced to the marketplace and were rapidly adopted by growers (Norsworthy et al., 2012). However, misuse and over-reliance on total postemergence (POST) programs centered on the use of glyphosate ultimately resulted in the evolution of glyphosate-resistant weed species such as Palmer amaranth (Young, 2006). The new stacked trait technology available in Glytol® LibertyLink® cotton provides growers with an effective alternative for difficult-to-control and herbicide-resistant weed species by allowing over-the-top applications of glufosinate and glyphosate. Since the rapid development of glyphosate-resistant weed species, researchers have promoted the use of alternative herbicide-resistant traits and overlaying multiple residual herbicides, finding it necessary in order to achieve season-long weed control (Jha and Norsworthy, 2009; Neve et al., 2011; Norsworthy et al., 2012).

RESEARCH DESCRIPTION

A field experiment was conducted in 2014 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

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various herbicide programs utilizing Roundup® (glyphosate) and Liberty® (glufosinate) in Glytol® Libertylink® cotton for the management of glyphosate-resistant Palmer amaranth and other difficult-to-manage weeds in cotton. The experimental design was a randomized complete block design with 11 herbicide programs plus a nontreated check. A multi-application approach was evaluated by utilizing preemergence (PRE) followed by POST herbicide applications which was compared to less diverse programs comprised of only postemergence applications. Preemergence treatments consisted of Direx® (diuron), Cotoran® (fluometuron) and Direx + Cotoran (diuron + fluometuron). Postemergence treatments consisted of Roundup and Liberty applied alone or in combination with current herbicide standards. 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; second application, at the 2- to 3-leaf growth stage of cotton; third application, at the 5- to 6-growth leaf stage; and the fourth application was directed at layby. Visual ratings of broadleaf signalgrass (*Urochloa platyphylla*) and Palmer amaranth control were taken 2 to 3 weeks after each application timing. Cotton injury was rated throughout the season and yield was collected at the time of harvest. All data were subjected to analysis of variance using JMP Pro 11 and orthogonal contrast were used for program comparison.

RESULTS AND DISCUSSION

Throughout the experiment, all programs provided ≥95% control of broadleaf signalgrass and no program caused ≥5% cotton injury (data not shown). Therefore, only glyphosate-resistant Palmer amaranth management and seedcotton yield were analyzed. Contrast analysis 14 days after the second application timing indicated a significant difference between total POST herbicide programs and programs that utilized a PRE followed by a POST herbicide for the control of Palmer amaranth (Table 1). All herbicide programs that began with a PRE herbicide provided 80% to 90% control of Palmer amaranth whereas a single post application of Liberty only provided 54% control 14 days after the second application timing. A similar trend was observed after the third application timing where total POST herbicide programs that were comprised of sequential applications of Liberty only achieved 46% control of Palmer amaranth while all other herbicide programs provided 80% to 85% control.

Towards the completion of the growing season, Palmer amaranth control was significantly impacted by the use a PRE herbicide 21 days following the layby application. Further contrast analysis indicated a significant difference between programs that contained a residual herbicide in the POST application and programs that did not. As observed in this study, effective Palmer amaranth control relies heavily upon the use of residual herbicides, which are necessary in order to achieve season-long control (Norsworthy et al., 2012). At harvest, the highest seedcotton yield was observed with the most diverse herbicide programs, which was expected due to the poor competiveness of cotton and the rapid growth rate of Palmer amaranth.

PRACTICAL APPLICATION

This research demonstrated the importance of residual herbicides in order to achieve effective season-long weed control which is further explained by Palmer amaranth's rapid growth rate and ability to emerge over an extended time period (Jha and Norsworthy, 2009). The herbicide programs evaluated in this research indicated that diverse weed control programs in Glytol® LibertyLink® cotton that begin with PRE residual herbicides have the potential to provide season-long control of glyphosate-resistant Palmer amaranth and other difficult-to-manage weeds in cotton. In order to reduce the risk of herbicide-resistance, multiple effective modes of action must be used. Furthermore, proper stewardship must be practiced to achieve the best protection of the Glytol® LibertyLink® 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 herbicide programs on glyphosate-resistant palmer amaranth control and seedcotton yield.

			Palmer amaranth control			Yield
			14 days	14 days	21 days	
Treatment	**Timing**	**Rate**	**after EPOST**	**after MPOST**	**after LAYBY**	**Seedcotton**
		fl oz/acre	------------------- %	-------------------		--- **lbs/A** ---
Nontreated						311 D
Liberty	EPOST[†]	29	54 b[‡]	47 a	52 c	1,438 c
Liberty	MPOST	29				
Liberty	LAYBY	29				
Direx	PRE	32	81 a	80 a	72 b	2,247 b
Liberty	EPOST	29				
Liberty	MPOST	29				
Liberty	LAYBY	29				
Direx	PRE	32	85 a	83 a	94 a	2,945 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty	MPOST	29				
Liberty	LAYBY	29				
Direx	PRE	32	85 a	84 a	98 a	3,305 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty	LAYBY	29				
Direx	PRE	32	85 a	84 a	93 a	2.948 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty + MSMA	LAYBY	29 + 32				
Cotoran	PRE	32	87 a	80 a	91 a	2,926 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty + MSMA	LAYBY	29 + 32				
Cotoran	PRE	32	86 a	79 a	92 a	3,263 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty + Dual Mangum		29 + 40 + 24				
+ Reflex	LAYBY					
Cotoran	PRE	32	86 a	80 a	91 a	2,965 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty + Dual Mangum		29 + 40 + 2				
+ Valor	LAYBY					
Cotoran	PRE	32	90 a	83 a	95 a	2,915 a
Liberty + Roundup +		29 + 22 + 40				
Dual Magnum	EPOST					
Liberty + Dual Magnum	MPOST	29 + 40				
MSMA + Valor	LAYBY	32 + 2				
Cotoran	PRE	32	92 a	83 a	96 a	2,982 a
Liberty + Roundup +		29 + 22 + 40				
Dual Magnum	EPOST					
Liberty + Roundup +		29 + 22 + 40				
Dual Magnum	MPOST					
MSMA + Valor	LAYBY	32 + 2				
Direx + Cotoran	PRE	32 + 32	88 a	85 a	90 a	3,042 a
Liberty + Dual Magnum	EPOST	29 + 40				
Liberty + Dual Magnum	MPOST	29 + 40				
Liberty + MSMA + Valor	LAYBY	29 + 32 + 2				
Contrasts[§]						
Total POST vs. PRE fb. POST			***	---	***	---
Direx PRE vs. Cotoran PRE			NS	---	NS	---
No Residual POST vs. Residual POST			---	---	***	---

[†] EPOST = early postemergence, MPOST = mid postemergence, LAYBY = post directed layby application, PRE = Preemergence.

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

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

Differential Response to Glufosinate in Palmer Amaranth Populations from Arkansas

R.A. Salas[1], N.R. Burgos[1], S. Singh[1], R.C. Scott[2], and R.L. Nichols[3]

RESEARCH PROBLEM

The widespread occurrence of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) has prompted a shift in weed management strategies. Glufosinate in LibertyLink® crops is an alternative tool for controlling glyphosate-resistant weeds. However, intensive use of glufosinate (or any herbicide) imposes strong selection pressure on weed populations. It would be informative to characterize the response of Palmer amaranth populations to glufosinate to identify high-risk populations or localities.

BACKGROUND INFORMATION

Palmer amaranth is one of the most common, troublesome, and economically damaging weeds in the U.S. The competitive ability of Palmer amaranth is attributed to its fast growth rate, high fecundity, good light interception, and high water use efficiency (Jha et al., 2008; Keeley et al., 1987). At densities of 5 plants/9-m row, Palmer amaranth can reduce cotton lint yield by 54% (Morgan et al., 2001). The problem of Palmer amaranth escalated with the evolution of glyphosate-resistant populations. With LibertyLink® crops, growers can use glufosinate as an additional tool in managing glyphosate-resistant Palmer amaranth.

RESEARCH DESCRIPTION

Whole-plant bioassays were conducted in the greenhouse to screen tolerance to glufosinate in 59 Palmer amaranth and 2 tall waterhemp populations from Arkansas collected between 2008 and 2013. The experimental design was a randomized complete block with two replications. Each replication consisted of one tray with 50 seedlings. Seeds were planted in cellular trays at one plant/cell. Three- to four-inch seedlings were treated with 0.49 lb ai/acre glufosinate in the spray chamber

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at 20 gallons per acre volume. Injury and mortality were recorded 21 days after treatment. The overall effects of herbicide were visually assessed relative to the nontreated control, using a scale of 0 (no visible injury) to 100 (complete dessication). Data were analyzed using JMP Pro 11 (SAS Institute, Inc., Cary, N.C.). Hierarchal clustering was done using injury and mortality data.

RESULTS AND DISCUSSION

All of the populations were controlled ≥95% with 0.49 lb ai/acre glufosinate except for 4 populations which had 88-94% mortality. Most of the survivors showed 31-80% injury but a few individuals from 2 populations showed lesser injury (≤30%). Twenty-four populations had survivors with ≤60% injury which are likely to grow healthy up to the reproductive stage (Table 1). The populations differentiated into 3 clusters based on mortality and levels of injury of the survivors (Fig. 1 and Table 2). The first cluster consisted of 35 sensitive populations. The second cluster, composed of 22 populations, showed 96% to 99% control with few survivors. Cluster 3 was composed of 3 recalcitrant populations, having the lowest control (88-94%) and most variable response to glufosinate (30-95% injury). These populations are harder to control with glufosinate than the other populations. Some individuals in these populations, or other similar populations, can escape glufosinate treatment when application conditions or plant growth stage is suboptimal (Everman, 2008). Previous study by Botha (2012) indicated that some Palmer amaranth populations from Arkansas had greater tolerance to glufosinate than sensitive populations. Although glufosinate controlled most Palmer amaranth populations, some populations had escapes that if left uncontrolled will produce seeds and accelerate selection for tolerant plants leading to evolution of resistant populations.

PRACTICAL APPLICATION

Some Palmer amaranth populations from Arkansas show high risk of escapes from glufosinate application and if left uncontrolled will lead to selection of tolerant plants and evolution of resistant populations. This calls for monitoring of survivors and implementing integrated management strategies to delay the evolution of a resistant population and conserve the utility of glufosinate.

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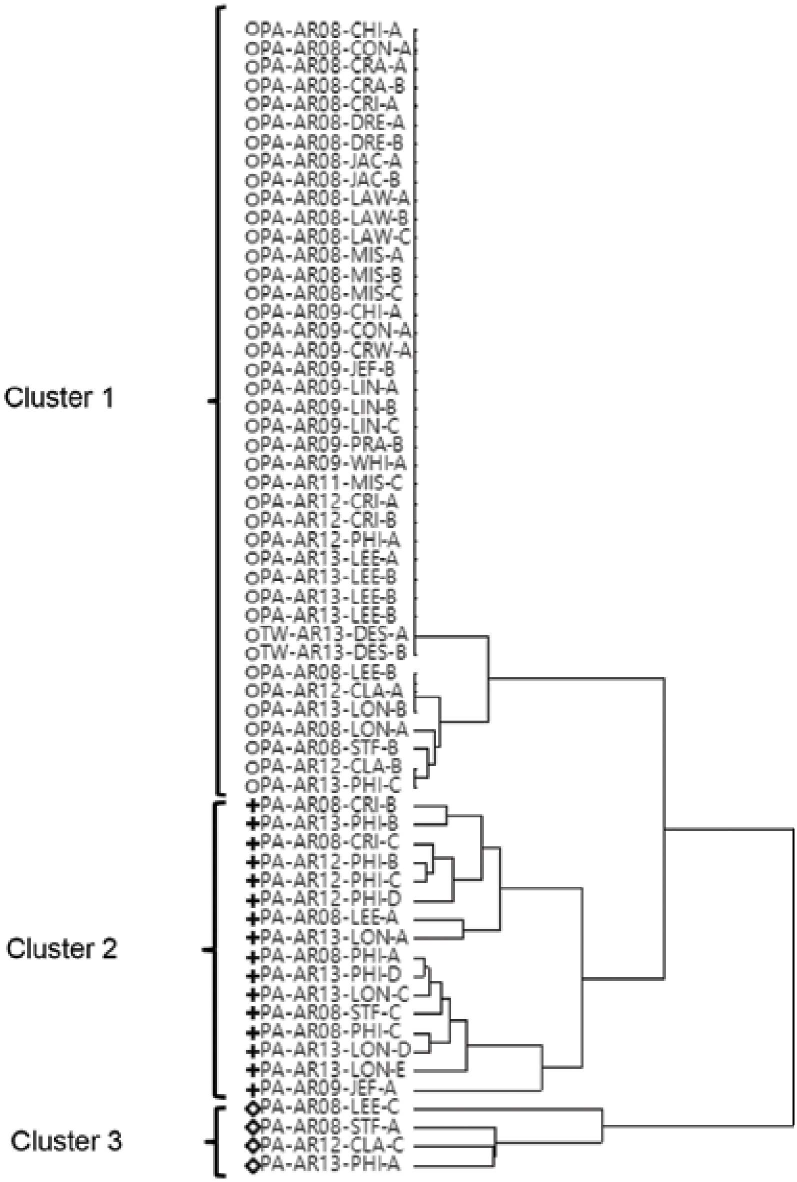

Fig. 1. Hierarchal cluster analysis of *Amaranthus* populations tested with 0.49 lb ai/acre glufosinate.

Table 1. Palmer amaranth populations with survivors showing <60% injury from 0.49 lb/acre glufosinate application.

Population	Year of collection	Mortality (%)	Frequency of survivors[a]	
			11-30% injury	31-60% injury
PA-AR08-CRI-B	2008	97	0	4
PA-AR08-CRI-C	2008	98	0	2
PA-AR08-LEE-B	2008	99	0	1
PA-AR08-LEE-C	2008	93	3	9
PA-AR08-LON-A	2008	99	0	2
PA-AR08-PHI-A	2008	99	0	2
PA-AR08-PHI-C	2008	98	0	4
PA-AR08-STF-A	2008	88	0	4
PA-AR08-STF-C	2008	96	0	2
PA-AR09-JEF-A	2009	97	2	4
PA-AR12-CLA-A	2012	99	0	1
PA-AR12-CLA-B	2012	99	0	1
PA-AR12-CLA-C	2012	94	0	7
PA-AR12-PHI-B	2012	99	0	2
PA-AR12-PHI-C	2012	99	0	1
PA-AR13-LON-A	2013	96	0	3
PA-AR13-LON-B	2013	99	0	1
PA-AR13-LON-C	2013	98	0	3
PA-AR13-LON-D	2013	97	0	4
PA-AR13-LON-E	2013	97	0	6
PA-AR13-PHI-A	2013	91	0	6
PA-AR13-PHI-B	2013	97	0	4
PA-AR13-PHI-C	2013	99	0	1
PA-AR13-PHI-D	2013	98	0	2

[a] Number of individuals in the population.

Table 2. Differential response to 0.49 lb ai/acre glufosinate in *Amaranthus* populations from Arkansas.

Cluster	No. of populations	Mortality (%)			Mean frequency of survivors[a]			
		Mean	Min	Max	11-30% injury	31-60% injury	61-80% injury	81-99% injury
1	35	100	99	100	0	0	0	0
2	22	98	96	99	0	2	2	0
3	4	91	88	94	1	7	8	1

[a] Average number of individuals in the populations for each cluster.

Differential Response of Palmer Amaranth to Glyphosate

S. Singh[1], V. Singh[1], R.A. Salas[1], N.R. Burgos[2], R.C. Scott[3] and R.L. Nichols[4]

RESEARCH PROBLEM

The introduction of genetically modified glyphosate-resistant crops in the 1990s significantly increased the use of glyphosate. It was reported that by 2007, 91% glyphosate-resistant cotton was grown in the U.S. (Dill et al., 2008). Overreliance on glyphosate in herbicide-resistant cropping systems, leads to tremendous selection pressure imposed by constant and repetitive usage of this herbicide. The survivors of selected populations can tolerate the recommended rate, leading to the evolution of herbicide-resistant populations.

BACKGROUND INFORMATION

Palmer amaranth (*Amaranthus palmeri*) is one of the most common, troublesome and economically challenging weeds of the southern U.S. (Ward et al., 2013). It is a prolific seed producer capable of producing 500,000 seeds/m^2 (Sellers et al., 2003). It easily outgrows slower-growing crops such as cotton and reduces lint yield up to 92% (Rowland et al., 1999). Also, Palmer amaranth density of 1 to 10 plants/9.1-m row can reduce the cotton canopy volume 35-45% (Morgan et al., 2001). In such situations, glyphosate has been the tool for Palmer amaranth control regardless of resistance to acetolactate synthase (ALS) inhibitors or other herbicides (Bond et al., 2006).

RESEARCH DESCRIPTION

Bioassays were conducted in the greenhouse for resistance profiling of Palmer amaranth populations that were collected between 2011 and 2013. Composite seed of each population (each field considered as one population) was planted in cellular trays (1 plant/cell). A total of 10 to 20 plants were sampled from each field. The experiment was set up as a randomized complete block design with two replications (50 plants per replication). At 3-4 inch height, the plants were

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sprayed with 1× the recommended dose of glyphosate (0.75 lb ae/acre) in a spray chamber using a boom fitted with two flat-fan nozzles delivering 20 gallons per acre at 46 psi. At 21 days after treatment (DAT), each plant was evaluated visually for injury relative to the non-treated control. Injury was recorded on a scale of 0-100% where 0 is no injury and 100% is dead. Data was analyzed using analysis of variance in JMP Pro v.11 (SAS Institute, Inc. Cary, N.C.). Hierarchal clustering was done using injury and mortality data.

RESULTS AND DISCUSSION

All 36 Palmer amaranth populations differed within and among populations based on injury (Table 1). Out of 36 populations 19% were controlled completely with 1 × rate of glyphosate. Based on the levels of injury on the survivor plants, the populations were divided into 4 categories: HR (highly resistant), MR (moderately resistant), SR (slightly resistant), and S (susceptible). Most of the survivors were found as MR and showed 11-70% injury. The populations differentiated into 4 clusters based on mortality and levels of injury on survivors (Fig. 1 and Table 2). The first cluster, consisted of 10 populations with 99% mortality and 84% injury on the survivor. The second cluster, was composed of 9 populations, 30% of the total plants survived with an average injury of 87%. In the third and fourth clusters, the mortality was only 14% and 5% and an average injury of 63% and 35%.

PRACTICAL APPLICATION

This study showed that 36% of the populations are highly resistant, and overall 72% of the populations of Palmer amaranth from Arkansas are resistant to glyphosate which poses a higher risk for selection of resistant populations. It calls for a strategic and effective approach towards the use of available herbicides with different modes of action along with the conventional weed management practices.

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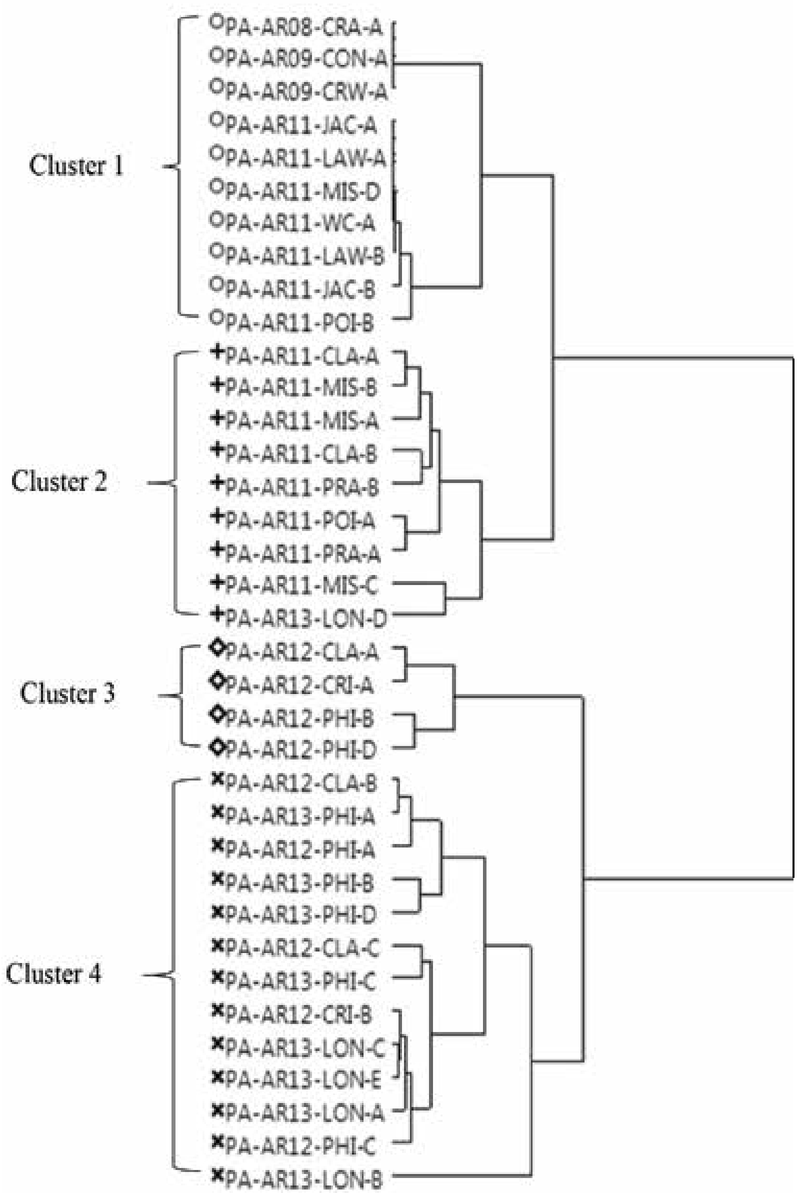

Fig. 1. Hierarchal cluster analysis of Palmer amaranth populations tested with 0.75 lb ae/acre glyphosate.

Table 1. Differential response of Palmer amaranth populations to 0.75 lb ae/acre glyphosate in Arkansas.

Population	Injury (%)				Mean frequency of survivors[a]			
	Mean	Min	Max	Mortality (%)	0-10% (HR)[b]	11-70% (MR)[c]	71-90% (SR)[d]	91-100% (S)[e]
PA-AR08-CRA-A	100	100	100	100	0	0	0	100
PA-AR09-CON-A	100	100	100	100	0	0	0	100
PA-AR09-CRW-A	100	100	100	100	0	0	0	100
PA-AR11-CLA-A	89	5	100	78	6	8	8	78
PA-AR11-CLA-B	86	5	100	70	5	12	14	69
PA-AR11-JAC-A	100	100	100	100	0	0	0	100
PA-AR11-JAC-B	99	50	100	96	0	3	1	96
PA-AR11-LAW-A	100	100	100	100	0	0	0	100
PA-AR11-LAW-B	100	50	100	99	0	1	0	99
PA-AR11-MIS-A	78	10	100	57	8	26	9	57
PA-AR11-MIS-B	86	5	100	71	4	17	8	71
PA-AR11-MIS-C	74	5	100	52	12	21	15	52
PA-AR11-MIS-D	100	100	100	100	0	0	0	100
PA-AR11-POI-A	89	5	100	79	3	13	5	79
PA-AR11-POI-B	98	40	100	93	0	4	3	93
PA-AR11-PRA-A	94	20	100	82	0	14	4	82
PA-AR11-PRA-B	97	10	100	88	1	1	11	87
PA-AR11-WC-A	100	100	100	100	0	0	0	100
PA-AR12-CLA-A	47	10	100	6	4	71	22	3
PA-AR12-CLA-B	36	5	100	1	11	88	0	1
PA-AR12-CLA-C	64	10	100	23	2	75	0	23
PA-AR12-CRI-A	68	10	100	8	1	69	22	8
PA-AR12-CRI-B	27	10	100	5	6	88	1	5
PA-AR12-PHI-A	36	10	100	5	12	79	4	5
PA-AR12-PHI-B	67	15	100	28	0	61	11	28
PA-AR12-PHI-C	62	10	100	14	6	80	1	13
PA-AR12-PHI-D	69	45	100	14	0	74	14	12
PA-AR13-LON-A	26	5	100	1	8	90	1	1
PA-AR13-LON-B	18	0	40	0	34	66	0	0
PA-AR13-LON-C	29	5	60	0	6	94	0	0
PA-AR13-LON-D	87	5	100	58	2	17	23	58
PA-AR13-LON-E	32	5	100	1	5	93	1	1
PA-AR13-PHI-A	30	5	100	4	11	85	1	3
PA-AR13-PHI-B	22	5	60	0	21	79	0	0
PA-AR13-PHI-C	40	5	100	6	2	87	5	6
PA-AR13-PHI-D	29	5	90	0	17	78	5	0

[a] Average number of survivors based on injury%.
[b] HR = Highly resistant.
[c] MR = Moderately resistant.
[d] SR = Slightly resistant.
[e] S = Susceptible.

Table 2. Population cluster analysis of Palmer amaranth populations tested with 0.75 lb ae/acre glyphosate.

Cluster	No. of Populations	Injury %	Mortality %			Mean frequency of survivors[a]				Overall mean of survivors[b]	Resistance level[c]
		Mean	Mean	Max	Min	0-10% Injury	11-70% Injury	71-90% Injury	91-100% Injury		
1	10	100	99	100	93	0	0	1	81	0.3	S
2	9	87	71	88	52	5	14	11	70	10	SR
3	4	63	14	28	6	1	69	17	13	29	MR
4	13	35	5	23	0	11	83	1	4	32	HR

[a] Average number of individuals in the populations for each cluster.
[b] Overall mean of survivors excluding injury range 91-100%.
[c] HR = Highly resistant; MR = Moderately resistant; SR = Slightly resistant; S = Susceptible.

Combinations of Fluridone and Fomesafen for Weed Control in Arkansas Cotton

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

RESEARCH PROBLEM

Current residual herbicides available in cotton such as fluometuron and fomesafen can cause injury to emerging cotton seedlings, resulting in reduced plant stand and poor seedling vigor. Fluridone was evaluated in 1983 as a potential pre-emergence herbicide for cotton and high tolerances were noted (Miller and Carter, 1983). Results from previous research on fluridone activity indicate the potential for fluridone to provide an alternative for Palmer amaranth control (Meier et al., 2014). Options of residual herbicides, combining two modes of action pre-emergence, such as fluridone and fomesafen, create more residual herbicide diversity, and potentially delay further resistance.

BACKGROUND INFORMATION

Arkansas cotton growers rely on residual herbicides to control glyphosate-resistant weeds such as Palmer amaranth (*Amaranthus palmeri*). Options of residual herbicides, combining two modes of action pre-emergence, such as fluridone and fomesafen, create more residual herbicide diversity, and potentially delay further resistance.

RESEARCH DESCRIPTION

This trial was conducted to evaluate the combination of fluridone and fomesafen at different rates, and to compare it against other commonly used residual herbicides in Arkansas.

RESULTS AND DISCUSSION

These trials were conducted in 2014 on 38-inch rows at the University of Arkansas System Divison of Agriculture's Soil Testing and Research Laboratory,

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Marianna, Ark. and Rohwer Research Station, Rohwer, Ark. using cotton (*Gossypium hirsutum* L.) cultivar Stoneville 4946 GLB2. The soil types for this trial were a Commerce silt loam at the Marianna location and a Herbert silt loam at the Rohwer site. Palmer amaranth (*Amaranthus palmeri*), pitted morningglory (*Ipomoea lacunosa*), and barnyardgrass (*Echinochloa crus*-galli) were overseeded at planting to provide a consistent weed population. Residual herbicides were applied at planting at 12 gal/acre. Fluridone and fomesafen were applied alone and in tankmix combinations at rates 0.125, 0.2, and 0.25 lb ai/acre. These applications were compared to fluometuron at 1 lb ai/acre and to an untreated control.

No significant differences among treatments in regard to weed control were noted at the Rohwer, Ark. location 14 days after treatment (DAT; Fig. 1). Obvious differences in weed control were noted at 30 DAT (Fig. 2). Fluridone applied alone at any rate, did not provide equivalent control as industry standards fluometuron or fomesafen at 1.0 lb ai/ace or 0.25 lb ai/acre, respectively. The combination of fluridone and fomesafen at 0.25 lb ai/acre provided the greatest control (80%) of Palmer amaranth and barnyardgrass at 30 days after treatment, but control was not significantly different than fomesafen applied alone at 0.2 lb ai/acre. It was also noted that fluridone at any rate alone did not provide equivalent control of morningglories as fluometuron at 1.0 lb ai/acre. No differences in weed control were observed at Marianna until 20 DAT (Fig. 3) mostly due to increased rainfall at this location. The highest control of Palmer amaranth and barnyardgrass at 20 days after application was achieved with fluometuron 0.75 lb ai/acre plus fomesafen 0.2 lb ai/acre and combinations of fluridone plus fomesafen at 0.2 or 0.25 lb ai/acre. Morningglory control was less for fomesafen 0.125 lb ai/acre than any other treatment. By 40 DAT (Fig. 4), weed control decreased for all treatments, but the combination of fluridone and fomesafen at 0.25 lb ai/acre continued to control Palmer Amaranth and morningglory greater than 80%.

PRACTICAL APPLICATION

Combinations of fluridone and fomesafen at rates of at least 0.2 lb ai/ acre for each, provide an additional option for broad spectrum pre-emergence weed control in cotton. If rainfall occurs often, as was the case in Marianna, residual control for Palmer amaranth could last for 6 weeks. Although cotton injury was not significant, potential for injury with fomesafen applied pre-emergence may exist on specific soil types in Arkansas.

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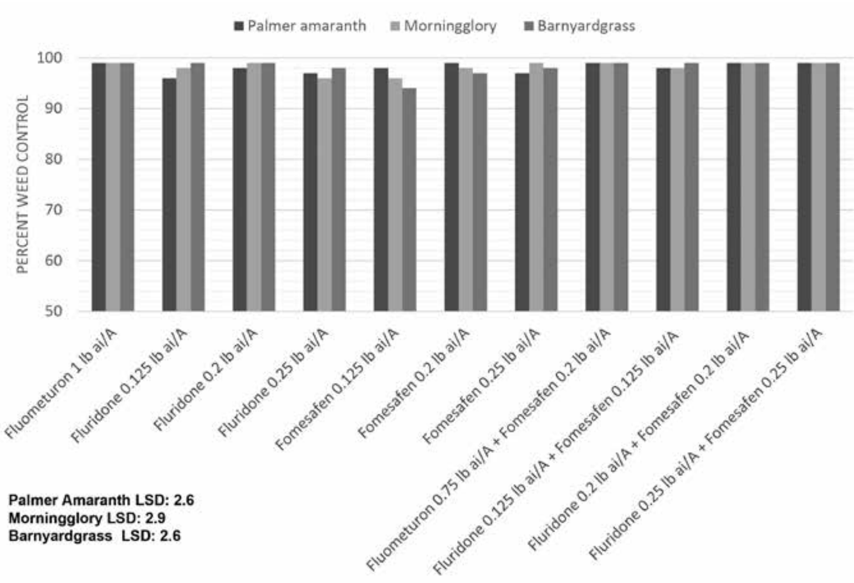

Fig. 1. Percent weed control 14 days after application in Rohwer, Ark.

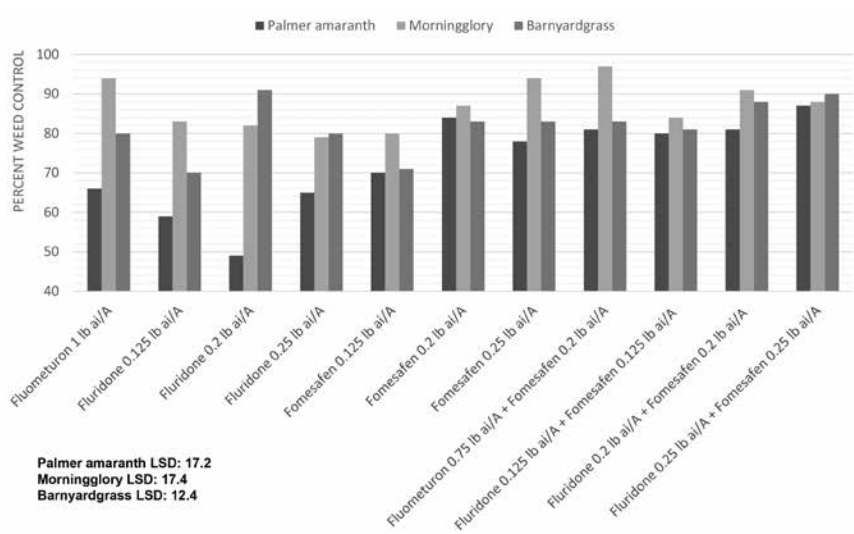

Fig. 2. Percent weed control 30 days after application in Rohwer, Ark.

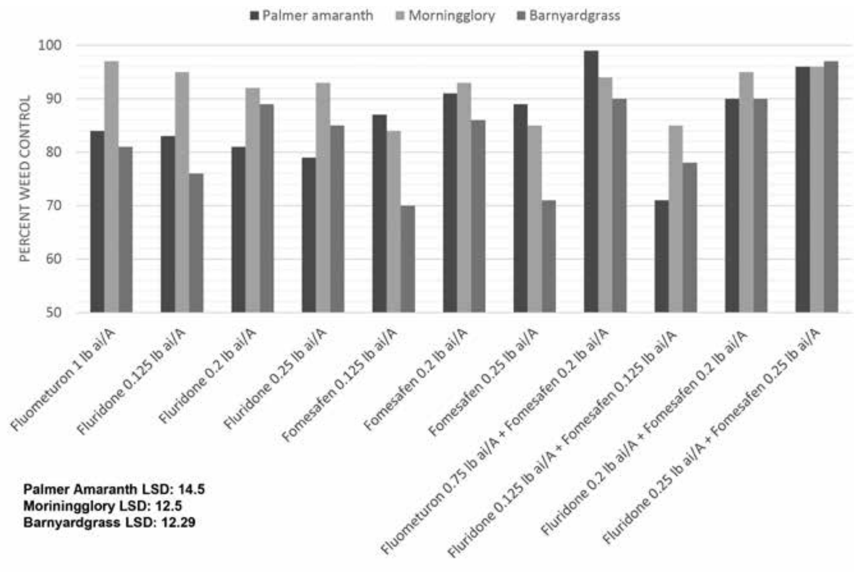

Fig. 3. Percent weed control 14 days after application in Marianna, Ark.

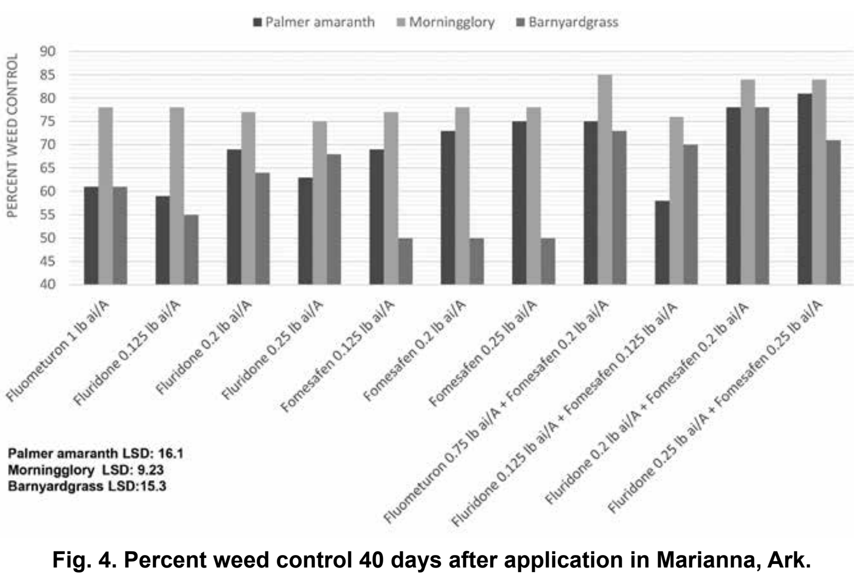

Fig. 4. Percent weed control 40 days after application in Marianna, Ark.

Impact of Foliar Insecticide Application on Conventional and Dual Gene Cotton in Arkansas, 2014

N. Taillon[1], G. Lorenz[1], A. Plummer[1], N. Seiter[2], M. Chaney[1], and B. Thrash[3]

RESEARCH PROBLEM

In 2014 a trial was conducted in Arkansas to evaluate the impact and efficacy of foliar oversprays on conventional and dual-gene, and triple-gene cottons, specifically Bollgard II, WideStrike, WideStrike III and Twinlink, for control of cotton bollworm, *Helicoverpa zea*. The foliar insecticide used was Prevathon (rynaxapyr or chlorantraniliprole).

BACKGROUND INFORMATION

While plant bugs are considered the number one pest in Arkansas cotton, caterpillar pests can be equally or even more devastating to the bottom line for our producers. In 2014, 97% of the cotton acreage in Arkansas was planted with dual-gene *Bacillus thuringiensis* (*Bt*) cultivars and every acre was infested by the bollworm, *Helicoverpa zea* (Williams, et. al., 2014) New technologies such as Twinlink became available in 2013 and Widestrike 3 was available on a limited basis in 2014.

When bollworm populations are high in cotton, dual gene *Bt* cotton may not provide adequate protection to maintain potential yield. In those situations, supplemental foliar applications may be required to provide additional yield protection. Growers treated 65% of total acres for lepidopteran pest, 57% of which was for the bollworm, and lost 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*.

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[3] Program technician, Department of Entomology, Fayetteville.

RESEARCH AND DESCRIPTION

This trial, part of a regional mid-South Entomologists Working Group study, was located in Pine Bluff, Ark. Plot size was 12.5 ft by 40 ft in a randomized complete block split design with 4 replications (Fig. 1) Plots consisted of Conventional, cultivar DP174; Twinlink, cultivar ST 5289GLT; Bollgard II, cultivar DP1311; WideStrike, cultivar PHY499; and WideStrike III, cultivar PHY495. Treatments included an untreated control and foliar applications of Prevathon (20 fl oz/a). Foliar applications were made using a Mudmaster sprayer. The boom was fitted with TX8 hollow cone nozzles at 19 in. nozzle spacing. Spray volume was 10 gal/a, at 40 psi. Foliar applications were applied on 4 August and 26 August. Damage ratings were taken 3 (terminals and squares only), 11, and 17 days after first application; and, 3 and 9 days after second application by sampling 25 terminals, squares, blooms, and bolls per plot. Plots were machine harvested using a John Deere two-row plot picker. Data were processed using Agriculture Research Manager Version 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. 2). WideStrike had more damage compared to Bollgard II and WideStrike III, but was similar to Twinlink. WideStrike III had less damage compared to Twinlink.

In the sprayed portion of the test, cumulative damage was higher in the Conventional cultivar than Twinlink, Bollgard II, and Widestrike III (Fig. 3). No difference in damage was observed between Widestrike and conventional. There was less damage in Bollgard II and Widestrike III.

Foliar applications reduced cumulative damage in all treatments except for Widestrike III (Figs. 2 and 3). No differences in damaged fruit numbers were observed for Widestrike III whether it was sprayed or not; all other treatments had less damage when sprayed. This would indicate that the third gene enhanced bollworm control.

Conventional unsprayed had more total damaged fruit (%) than all other treatments (Fig. 4). However, 2 applications of Prevathon (20 oz/acre) reduced damage for the Conventional cultivar similar to the unsprayed trangenics. Supplemental foliar applications to Twinlink, BG II, WideStrike III reduced damaged compared to the conventional sprayed cultivar, but WideStrike was not different.

Yield data indicated that all transgenics had higher yield compared to the Conventional cultivar, whether sprayed or unsprayed (Fig. 5). Twinlink and Widestrike III had similar yields and were higher than the yield of Bollgard II. However, unlike previous studies (Lorenz, et al., 2013; Orellana, et al., 2014) supplemental applications of Prevathon did not increase yield within each cultivar. The differences that occurred in our study may have been due to agronomic issues with those varieties rather than control of caterpillar pests.

PRACTICAL APPLICATION

These studies suggest that in some years when a conventional variety 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. More studies will be conducted to determine the impact of supplemental foliar applications on second and third generation *Bt* cottons.

ACKNOWLEDGMENTS

Appreciation is expressed to Chuck Hooker. We thank Bayer, Dow, and Monsanto for their support.

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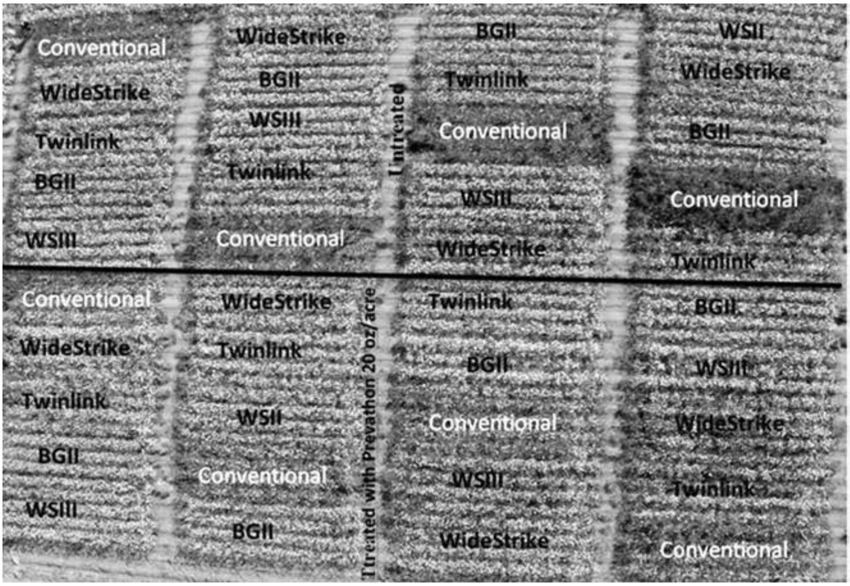

Fig. 1. Overhead view of conventional and transgenic variety sprayed vs. unsprayed, 2014 test with plots labeled to show obvious differences between sprayed and unsprayed environments.

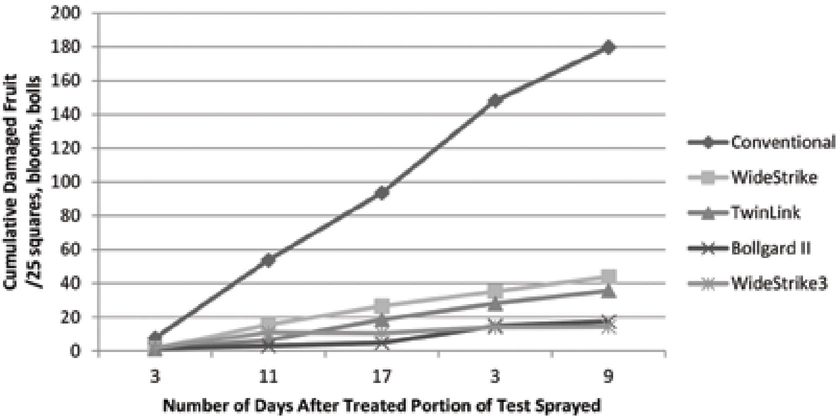

Fig. 2. Cumulative damage of fruit (25 squares, blooms, and bolls when present) on treated plots compared to the conventional treatment.

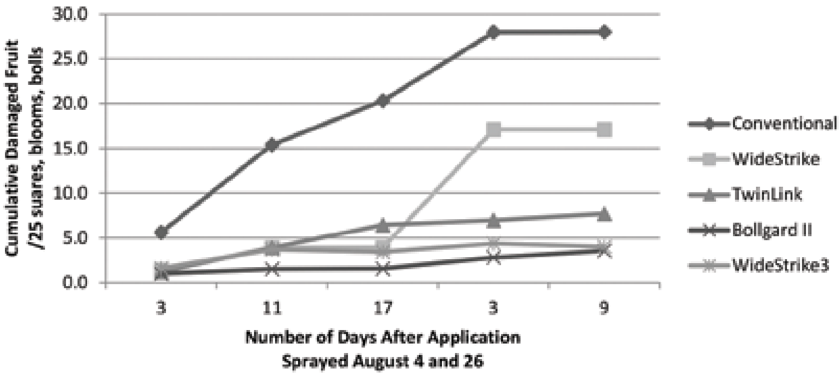

Fig. 3. Cumulative damage of fruit (25 squares, blooms, and bolls) on plots treated with Prevathon 20 oz/acre, 2 and 26 August 2014.

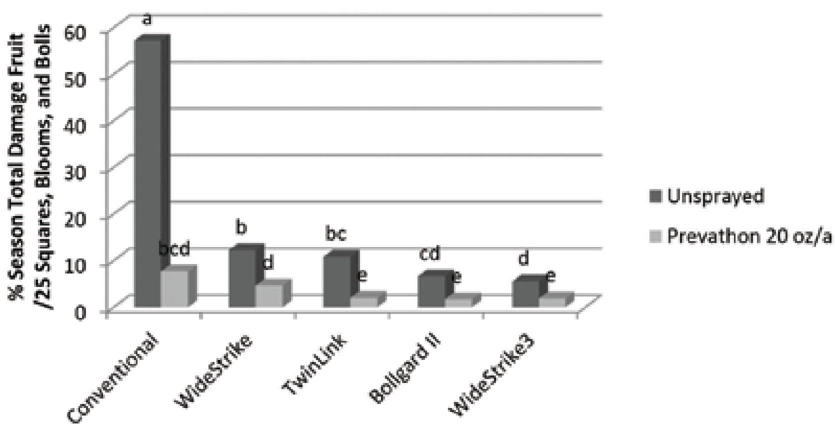

Fig. 4. Season Total damage rating % of 25 squares, blooms, and bolls after two applications, 4 and 26 August 2014.

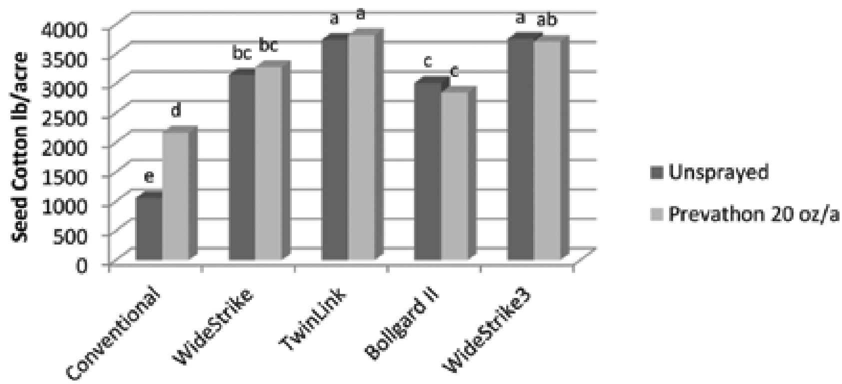

Fig. 5. Seed cotton (lb/acre) as affected by the treatments. Planted 3 June and harvested 31 October 2014.

Zone Management of Tarnished Plant Bug (*Lygus lineolaris*) in Cotton: Site Specific Termination Timing for Insecticidal Control

T.G. Teague[1] *and D.K. Morris*[2]

RESEARCH PROBLEM

The perennial nature of cotton (*Gossypium hirsutum* L.) often complicates crop management decision making particularly in late season. A key determinant for timing crop termination practices is identification of the final cohort of bolls that contribute to harvestable yield. Flowering date for these last effective bolls is considered the date of physiological cutout (Oosterhuis and Bourland, 2008). Extensive research throughout the U.S. Cotton Belt has affirmed that plant monitoring techniques using counts of main-stem nodes above first position white flowers (NAWF) can be used as a gauge of plant maturity and to identify date of cutout (Kerby et al., 2010). A field average of NAWF = 5 signals physiological cutout in mid-South cotton systems (Bourland et al., 1992). As a boll matures, the boll wall eventually becomes sufficiently hardened such that feeding by specific arthropod pests is no longer of economic importance. Managers quantify boll maturity using growing degree days (DD60s), and by 250 DD60s after anthesis feeding by the key insect pest, tarnished plant bug, *Lygus lineolaris,* (Hemiptera Miridae) is unlikely to cause economic damage. Tarnished plant bugs also prefer feeding on floral buds (squares) rather than bolls. The final stage of crop susceptibility recognized for tarnished plant bugs in mid-South cotton is defined as NAWF = 5 plus 250 DD60s (Teague et al., 2002, 2008).

BACKGROUND INFORMATION

Irrigation can impact both crop earliness and yield potential. In Arkansas production fields with center pivot sprinkler irrigation, the entire field is usually planted. This includes the rain-fed "corners" outside the irrigated circle. Rain-fed corners can represent as much as 10% to18% of a production field. Because rain-fed plants typically reach cutout earlier than irrigated plants, those plants also reach the final stage of crop susceptibility to insect pests sooner. Plants in rain-fed

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corners therefore would not require prolonged protection using costly insecticides to control boll feeding pests. We suggest the large, predictable patterns associated with rain-fed corners make center pivot fields ideal candidates for zone management. This report summarizes a three year field study to evaluate a site-specific, zone management approach for using NAWF-based measures of crop maturity for timing insect control termination in irrigated and rain-fed management zones in a center-pivot irrigated field in Northeast Arkansas.

RESEARCH DESCRIPTION

The experiment was carried out on Wildy Family Farms, Manila, Ark. in a 150-acre commercial field irrigated using a 1/4 mile center pivot sprinkler. The latest possible cutout dates for this production area — that date with a 50% or 85% probability of attaining 850 DD60s from cutout — are 11 August and 31 July, respectively (Oosterhuis and Bourland, 2008). The study field had soils classed as a Routon Dundee–Crevasse Complex, ranging from coarse sand to fine sandy loam. Production and timing details are summarized in Table 1. There were three treatments: 1) a conventional blanket insecticide spray (Broad) timed to protect susceptible irrigated cotton from tarnished plant bug at infestation levels that exceeded recommended action thresholds, 2) management zone specific insecticide (Zone) applied exclusively in the irrigated zone where plants had not accumulated > 250 DD60s from physiological cutout but not in rain-fed zones, or 3) no insecticide (Check). There were three replications. Treatment strips were re-randomized in 2013 and 2014. A John Deere 4730 self-propelled high clearance sprayer with 90-ft boom applied dicrotophos + bifenthrin (Bidrin 8EC, 6.4 oz + Brigade 2EC, 6.4oz) in 10 gal/acre spray volume. The operator manually adjusted spray patterns in the zone management strips as it was driven through irrigated and rain-fed cotton. Scouts employed standard COTMAN plant monitoring protocols to gauge plant maturity (Oosterhuis and Bourland, 2008). Tarnished plant bug infestation levels were monitored weekly with drop cloth sampling prior to cutout and then at 4-7 day intervals after the spray. Descriptive statistics and analysis of variance were performed using PROC GLM of SAS.

RESULTS AND DISCUSSION

Spatial and temporal differences in plant maturity among irrigated and rainfed management zones were observed in all three seasons. Mean number f days from planting to physiological cutout for plants in rain-fed compared to irrigated zones for the three seasons were 24, 11 and 6 days earlier in 2012 (drought year), 2013 (cloudy, wet year) 2014, (cool, wet year), respectively (Fig. 1). Tarnished plant bug numbers were maintained below threshold levels through cutout in all years. In early August in all three seasons, the cooperating producer's commercial crop advisor reported infestations had exceeded state recommended action thresholds (~ 3 bugs/drop cloth sample) based on monitoring in irrigated cotton. Last effective bolls in the irrigated zone were still considered at a susceptible stage to economic damage; however, plants in the rain-fed zones were well past recommended insect control endpoint of cutout NAWF5 + 250 DD60s (Table 1). Tarnished plant bug numbers were significantly lower in rain-fed compared to irrigated cotton in both 2012 and 2013, but not the 2014 season (Fig. 2). Following the termination insecticide application, tarnished plant bug numbers were reduced to sub-threshold levels in sprayed cotton, but in the unsprayed control strips, *Lygus* numbers continued to increase. By 14 days after the application, pest levels were greater than 2 to 8 fold the action threshold in irrigated, unsprayed cotton in 2012 and 2013; levels in 2014 were double the action threshold.

Rain-fed cotton produced lower lint yields than irrigated cotton in 2012; however, there was no difference ($P = 0.05$) in yields between irrigated and rain-fed zones in the rainy 2013 or 2014 seasons (see Teague et al., 2014 for details of 2012 and 2013 trials). There were no significant differences in lint yield among insect control treatments in any year (Fig. 1). Late season tarnished plant bug infestations did not damage harvestable bolls. Results from this three year field trial indicate that higher population densities of bugs in late season can be tolerated than the standardized mid-South threshold of 3 bugs/drop cloth sample. It is noteworthy that Cooperative Extension Service thresholds in Arkansas were adjusted after the 2014 season. Recommendations now suggest that after cutout, protective sprays should be applied when population densities exceed mean 6 bugs/drop cloth sample. Termination timing for new infestations remains at cutout + 250 DD60s.

PRACTICAL APPLICATION

Zone management of insect control termination in irrigated and rain-fed management zones is practical for the producer who already has sprayers with GPS guidance and controllers, and who is using NAWF-based endpoints for terminating insect control at cutout + 250 DD60s. In these on-farm studies, we observed 14% cost reduction in insecticide use with zone management. Adoption of zone management will benefit Arkansas's cotton growers by reducing protection costs without sacrificing yield

ACKNOWLEDGMENTS

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Table 1. Cultivars, dates of planting, defoliation and harvest as well as plant maturity measurements and heat unit accumulations at the time of the final insecticide application for 2012, 2013 and 2014 insecticide termination by management zone trial in a commercial field on Wildy Family Farms, Manila, Ark.

Year	Cultivar	Date of Planting	Zone	Date of NAWF = 5	Days from planting to NAWF = 5	Termination Insecticide Application Date	DD60s from Cutout	Date of Defoliation/ Harvest
2012	Americot NG 1511	1 May	Rainfed	5-Jul	62	1-Aug	650	10 Sep/ 2 Oct
			Irrigated	28-Jul	85		113	
2013	Fibermax 1944	9 May	Rainfed	21-Jul	73	15-Aug	439	22 Sep/ 11 Oct
			Irrigated	1-Aug	84		258	
2014	Stoneville 4946	6 May	Rainfed	2-Aug	90	21-Aug	366	29 Sep/ 17 Oct
			Irrigated	8-Aug	96		263	

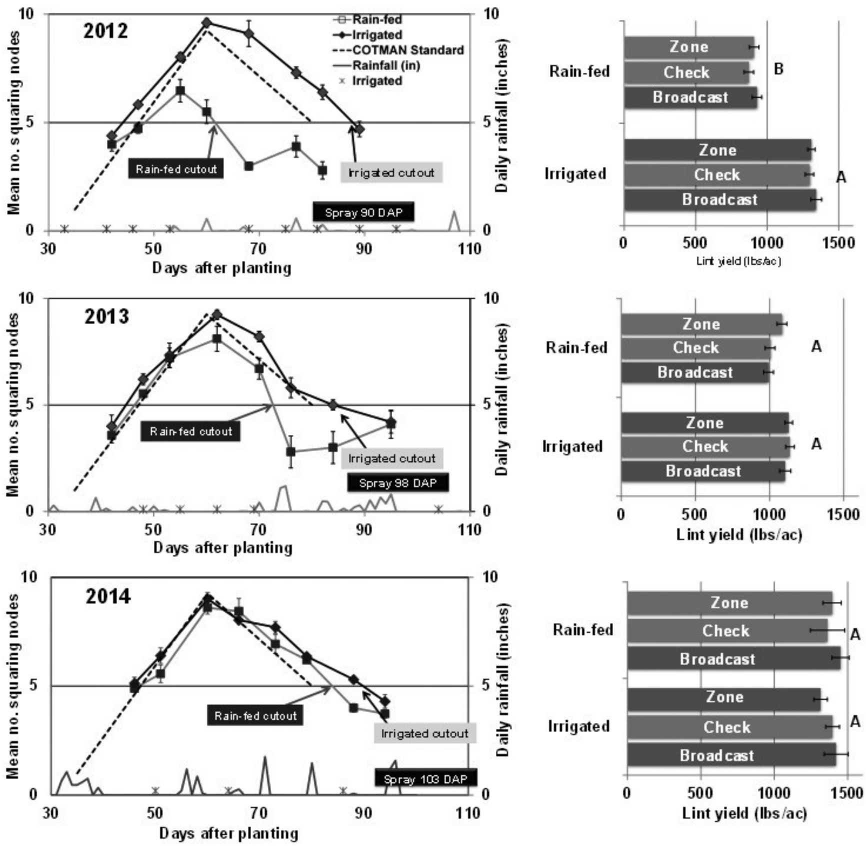

Fig. 1. COTMAN growth curves (left) for plants in irrigated and rain-fed management zones, and mean (±SEM) lint yields for termination treatments (right) in the 2012, 2013, 2014 insecticide termination by management zone trial, Wildy Family Farms, Manila, Ark. Lint yields were similar across insecticide treatments in all years; irrigation increased yield compared to rain-fed cotton only in 2012 (*P* = 0.05). Similar letters adjacent to bars indicate no significant differences.

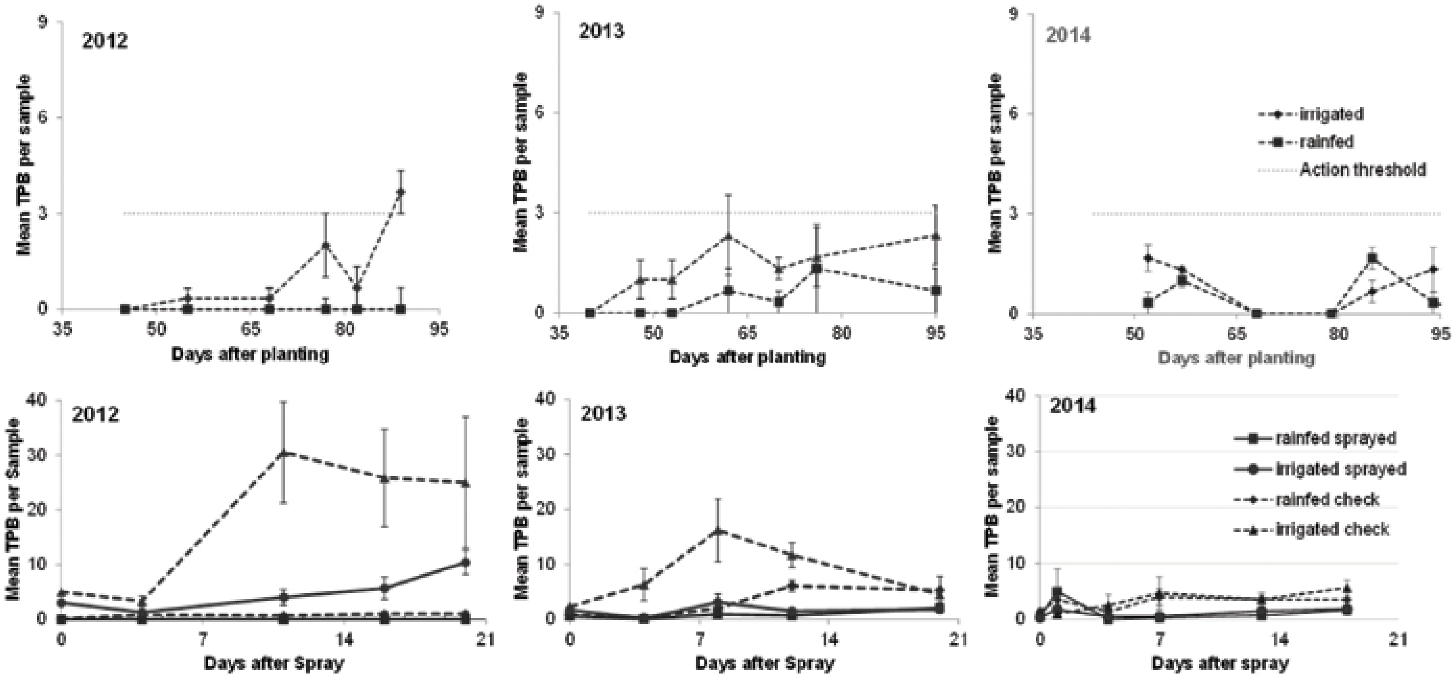

Fig. 2. Mean (±SEM) number of tarnished plant bugs (TPB; *Lygus lineolaris*) per drop cloth sample prior to cutout (above) and after the final termination spray (below) in for the 2012, 2013, and 2014 seasons in the insecticide termination by management zone trial, Wildy Family Farms, Manila, Ark.

Comparison of Selected Insecticides for Control of Tarnished Plant Bug, *Lygus Lineolaris*

H.M. Chaney[1], G.M. Lorenz III[1], N.M. Taillon[1], W.A. Plummer[1], and B.C. Thrash[2]

RESEARCH PROBLEM

Growers depend on foliar insecticides to control tarnished plant bug. It is important that we evaluate insecticides that may have efficacy for control of this pest which will enable growers to make profitable management decisions.

BACKGROUND INFORMATION

Tarnished plant bug is estimated to have caused a yield loss of 3.83% in 2014 (Williams, 2010). Combined with an average cost of $42 per acre to spray, growers lost an average of $78 per acre attributed to tarnished plant bug, which makes it the most important economic cotton pest in Arkansas. In recent years tarnished plant bug numbers have been extremely high and currently labeled insecticides are not providing the level of control needed to reduce plant bug numbers below economic threshold with single product applications in many cases (Colwell et al., 2010). Uses of insecticide premixes and tank-mixes have been shown as an effective way to increase control of tarnished plant bug. (Thrash et al., 2012, 2013)

RESEARCH DESCRIPTION

The trial was located at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station. Plot sizes were 12.5 ft (4 rows) by 50 ft. Foliar applications were made on 16 July and 24 July 2014 using a Mud Master fitted with TXVS-6 hollow cone nozzles; spray volume was 10 gallons per acre at 40 psi. Treatments included an untreated check, Intruder 3.0 oz and 3.5 oz, each rate with and without Dyne-Amic 0.5% v/v; Intruder 3.0 oz plus Transform 1.5 oz; Intruder 3.0 oz plus Acephate 0.75 lb; Transform 1.5 oz; Acephate 0.75 lb; and Bidrin XP 12 oz. Insect numbers were determined by using a 2.5-ft drop cloth and taking 2 samples per plot (10 row ft). The trial was scouted 5 and 7 days after first application and 4, 8, and 12 days after second application. Data were

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processed using Agriculture Research Manager, v. 9 (Gylling Data Management, Inc., Brookings, S.D.), analysis of variance, and Duncan's New Multiple Range Test (P = 0.10) to separate means.

RESULTS AND DISCUSSION

At 5 days after first application, all treatments reduced plant bug numbers compared to the untreated check, while Bidrin XP had fewer plant bugs than all other treatments (Table 1). Bidrin, Transform, and Intruder+Acephate reduced plant bug numbers below the Cooperative Extension Service recommended threshold of 6 per 10 row foot. At 7 days after application, all treatments had reduced plant bug numbers below the untreated control; however, all treatments still exceeded the established threshold and a second application was made.

At 4 days after the second application, all treatments had fewer plant bugs than the untreated control (Table 2). At 8 and 12 days after application, all treatments except the Intruder 3 oz with an adjuvant were below threshold. All treatments increased yield compared to the untreated control (Table 3). Bidrin, Transform, Acephate, and Intruder+Acephate increased yields above all other treatments.

PRACTICAL APPLICATION

Results of this study will assist entomologists in making recommendations to cotton growers and consultants in management of tarnished plant bug.

ACKNOWLEDGMENTS

We thank Cotton Incorporated and the Arkansas Cotton State Support Committee for funding this research, as well as the Lon Mann Cotton Research Station for their help in plot maintenance.

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Table 1. Tarnished plant bugs (per 10 row ft) 5 and 7 days after 1st application, 16 July 2014.

	Plant Bugs (per 10 row feet)			
Treatment Name	5 DAT†		7 DAT	
UTC	46.7	a‡	47.0	a
Intruder 3oz	16.6	b	22.8	b
Intruder 3.5 oz	14.8	bc	20.5	bcd
Intruder 3 oz + Dyne-Amic 0.5%	11.7	bc	15.8	bcd
Intruder 3.5 oz + Dyne-Amic 0.5%	9.6	bcd	12.0	de
Intruder 3 oz + Acephate 0.75lb	4.1	e	6.5	e
Intruder 3 oz + Transform 1.5 oz	10.7	bc	19.0	bcd
Acephate 0.75 lb	8.2	cde	21.5	bc
Transform 1.5 oz	5.3	de	13.8	cde
Bidrin XP 12 oz	1.3	f	13.8	cde

† DAT = Days after treatment; UTC = Untreated control.
‡ Numbers in a column followed by the same letter are not significantly different (*P* = 0.05).

Table 2. Tarnished plant bugs (per 10 row ft) 4, 8, 12, and 18 days after 2nd application, 24 July 2014.

	Plant Bugs (per 10 row feet)					
Treatment Name	4DAT†		8DAT		12DAT	
UTC	29.1	a‡	36.6	a	31.1	a
Intruder 3oz	6.5	b	4.5	bc	5.0	bc
Intruder 3.5 oz	3.9	bc	4.2	bc	4.9	bc
Intruder 3 oz + Dyne-Amic 0.5%	6.1	b	6.2	b	6.4	b
Intruder 3.5 oz + Dyne-Amic 0.5 %	3.7	bc	3.1	bcd	5.6	bc
Intruder 3 oz + Acephate 0.75lb	1.0	e	2.1	cd	2.1	d
Intruder 3 oz + Transform 1.5 oz	3.1	bcd	3.6	bc	5.3	bc
Acephate 0.75 lb	1.4	e	1.5	cd	2.8	cd
Transform 1.5 oz	2.1	cde	0.7	d	3.5	bcd
Bidrin XP 12 oz	1.3	de	2.3	cd	1.8	d

† DAT = Days after treatment; UTC = Untreated control.
‡ Numbers in a column followed by the same letter are not significantly different (*P* = 0.05).

Table 3. Yield data; planted 21 May and harvested 3 November 2014.

Treatment Name	Yield Seed cotton (lb/acre)	
UTC[†]	1023	e[‡]
Intruder 3oz/a	2069	cd
Intruder 3.5 oz/a	2127	bc
Intruder 3 oz/a + Dyne-Amic 0.5% v/v	1849	d
Intruder 3.5 oz/a + Dyne-Amic 0.5 % v/v	1932	cd
Intruder 3 oz/a + Acephate 0.75lb/a	2700	a
Intruder 3 oz/a + Transform 1.5 oz/a	2324	b
Acephate 0.75 lb/a	2723	a
Transform 1.5 oz/a	2574	a
Bidrin XP 12 oz/a	2562	a

[†] UTC = Untreated control.
[‡] Numbers in a column followed by the same letter are not significantly different (*P* = 0.05).

Control of Thrips with Insecticide Seed Treatments in Arkansas

W.A. Plummer[1], G.M. Lorenz III[1], N.M. Taillon[1], H.M. Chaney Jr[1], and B.C. Thrash[2]

RESEARCH PROBLEM

Thrips have become a more difficult pest to control in the last several years. Insecticide seed treatments followed by a foliar application are sometimes needed to achieve control which makes it one of the most expensive pests in Arkansas. Seed treatments have been the standard with growers in Arkansas for thrips control. This reliance has resulted in loss of efficacy and created the need for additional foliar applications to achieve adequate control resulting in higher costs for producers. Recent studies indicated that tolerance/resistance has developed to thiamethoxam (Cruiser/ Avicta) in the mid-South. This trial was part of a mid-South Regional effort and was conducted at the Southeast Research and Extension Center, Rohwer, Ark. to evaluate the efficacy of insecticide seed treatments (IST) for thrips management in cotton.

BACKGROUND INFORMATION

Thrips are early-season cotton pests 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 severity of the thrips infestation (Hopkins, et. al., 2001). Thrips affected 100% of all Arkansas cotton acreage in the 2014 growing season (Williams, et. al., 2015). The cost of control and economic loss caused by thrips was around $3 million in 2014. Efficacy data on new and currently labeled products will help in proper selection of seed treatments for consultants and producers.

RESEARCH DESCRIPTION

Plot size was 12.5 ft by 40 ft in a randomized complete block with 4 replications. Samples were taken when plants reached 1-2 leaf stage and 3-4 leaf stage.

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

Treatments included an untreated control (UTC) with a fungicide (Trilex Advanced 1.6 oz/cwt), Cruiser (0.375 mg ai/seed), Avicta Duo (0.525 mg ai/seed), Aeris Seed Applied System (0.75 mg ai/seed), Gaucho 600 FS (0.375 mg ai/seed), low labeled rate of Orthene (6.4 oz/cwt), high labeled rate of Orthene (20 oz/cwt), Cruiser (0.375 mg ai/seed) + Orthene (6.4 oz/cwt), and Cruiser (0.375 mg ai/seed) + Orthene (20 oz/cwt). All ISTs included the base fungicide of Trilex Advance (1.6 oz/cwt). Thrips numbers were determined by collecting 5 plants per plot and placing in jars with a 70/30 alcohol solution. Plants were washed and filtered in the laboratory at the Lonoke Extension Center, Lonoke, Ark., and thrips were counted using a dissecting scope. Thrips damage ratings were taken at 16 and 22 days after emergence. The standard damage assessment rating was used (1 = no damage, 5 = plant loss). Data were processed using Agriculture Research Manager v. 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

Season total thrips numbers indicated the high rate of Orthene (24 oz/cwt) reduced thrips numbers below all other ISTs (Fig. 1). The addition of Cruiser (0.375 mg ai/seed) with the high rate of Orthene (24 oz/cwt) did not increase control and was no better than the low rate of Orthene (6.4 oz/cwt) alone. Similar results were seen when Cruiser (0.375 mg ai/seed) was added to Orthene (6.4 oz/cwt) where no difference in thrips numbers were observed. Treatments that included Orthene (Orthene 24oz/ cwt, Cruiser 0.375 mg ai/seed + Orthene 24 oz/ cwt, Orthene 6.4 oz/ cwt, Cruiser 0.375 mg ai/seed + Orthene 6.4 oz/ cwt), reduced thrips numbers below all other ISTs (Gaucho 600 FS 0.375 mg ai/seed, Aeris Seed Applied 0.75 mg ai/seed, Avicta Duo 0.525 mg ai/seed, and Cruiser 0.375 mg ai/seed). Treatments without Orthene (Gaucho 600 FS 0.375 mg ai/seed, Aeris Seed Applied 0.75 mg ai/seed, Avicta Duo 0.525 mg ai/seed and Cruiser 0.375 mg ai/seed) did reduce thrips populations below the UTC; however, treatments were not significantly different.

At 16 days, all treatments reduced damage compared to the untreated control except for Cruiser (0.375 mg ai/seed); but by 22 days, all treatments reduced damage compared to the UTC. (Table 1). At 16 and 22 days after emergence, damage ratings correlated closely with yield. When damage ratings were high, yields tended to be low. Avicta Duo (0.525 mg ai/seed), Orthene (6.4 oz) and Cruiser + Orthene (24 oz) had higher yields than all other treatments. Although, Orthene 6.4 oz/cwt and Cruiser 0.375 mg ai/seed + Orthene 24 oz/cwt were not higher than the other treatments in the trial. All ISTs increased yield and averaged just over 340 lb/acre compared to the untreated check.

PRACTICAL APPLICATION

With the development of tolerance to thiamethoxam in the mid-South, studies must be conducted to inform producers of the most cost effective alternatives that are available. Results from this study will assist farmers in choosing the best seed treatment for them.

ACKNOWLEDGMENTS

Appreciation is expressed to the Southeast Research and Extension Center. We also acknowledge Bayer and Syngenta for their support.

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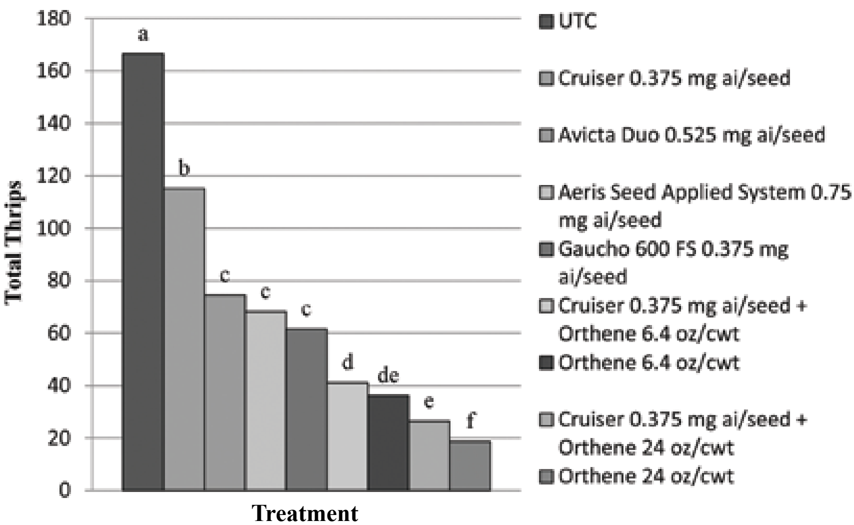

Fig. 1. Control of thrips with insecticide seed treatments season total, 2014. Numbers in columns followed by the same letter are not significantly different (*P* = 0.10).

Table 1. Control of thrips with insecticide seed treatments, 2014.

Treatments	Damage Rating scale 1 (no) – 5 (worst) 16 Days After Emergence	22 Days After Emergence	Yield Seed cotton lbs/acre	Yield lbs over UTC
UTC	4.0 a†	5.0 a	1081.8 d	
Cruiser 0.375 mg ai/seed	3.5 ab	4.0 b	1358.8 bc	277
Avicta Duo 0.525 mg ai/seed	1.8 d	1.7 de	1551.3 a	469.5
Aeris Seed Applied System 0.75 mg ai/seed	1.8 d	2.0 cde	1400.0 bc	318.2
Gaucho 600 FS 0.375 mg ai/seed	2.0 d	1.5 e	1395.5 bc	313.7
Orthene 6.4 oz/cwt	2.3 cd	2.0 cde	1487.8 ab	406
Orthene 24 oz/cwt	3.0 bc	2.5 c	1337.3 c	255.5
Cruiser 0.375 mg ai/seed + Orthene 6.4 oz/cwt	2.5 cd	2.2 cd	1384.3 bc	302.5
Cruiser 0.375 mg ai/seed + Orthene 24 oz/cwt	1.8 d	1.5 e	1468.3 abc	386.5
			Average	341.1

† Numbers in columns followed by the same letter are not significantly different (*P* = 0.10).

Verification of Varietal Resistance to Tarnished Plant Bug in Large Plots

G.E. Studebaker, F.M. Bourland and L. Towles[1]

RESEARCH PROBLEM

Applying recommended insecticides for tarnished plant bug (TPB) when they reach treatment threshold is the most commonly used option to manage this pest in cotton in Arkansas (Studebaker, 2014). However, increasing levels of resistance to insecticides are beginning to make some chemistries less effective. Therefore, it is important to evaluate other options for TPB management, such as host-plant resistance.

BACKGROUND INFORMATION

Tarnished plant bug is one of the most important pests of cotton in Arkansas. From 2003 to 2013 it caused more yield losses than any other pest averaging a loss of over 50,000 bales in Arkansas (Williams, 2013). Ongoing small plot studies have indicated that some commercially grown varieties are less attractive or exhibit some level of resistance to TPB. A large block study was conducted in 2014 to verify the resistance of several varieties that exhibited low damage from TPB in small plot studies in previous years.

RESEARCH DESCRIPTION

Trials were conducted at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser, Ark. Plots were 24 rows by 80 ft long arranged in a split-plot design with 4 replications. Early and late maturing varieties showing low damage in small plots as well as early and late maturing varieties showing high damage in small plots were used to conduct the study (Table 1). Each variety had two TPB treatment regimes: an untreated control and treated when TPB numbers reached 3/5 row-ft. Plots were sampled weekly with a drop cloth. When TPB reached the treatment level of 3 bugs per 5-row feet, treatments were applied with a high clearance sprayer calibrated to

[1] Entomologist, director/professor, and program technician, respectively, Northeast Research and Extension Center, Keiser.

deliver 10 gal/acre-through two hollow cone nozzles per row. Acephate at 0.75 lbs ai/acre was applied when threshold was reached. Plots did not reach treatment level until after bloom. Yields were taken from the center 4 rows of each plot at the end of the season. All data were analyzed using ARM v. 9 software (Gylling Data Management, Inc., Brookings, S.D.). Treatment means were separated at the $P = 0.05$ level.

RESULTS AND DISCUSSION

The two susceptible varieties, UA48 and PHY375WRF, reached treatment threshold more often than the resistant varieties (Fig. 1). Although all varieties tested did suffer yield loss due to TPB, the level of yield loss was much greater in the two susceptible varieties (UA48 and PHY375WRF) than in the two resistant varieties (UA222 and ST5288B2RF; Fig. 1). An outbreak of cotton aphid also occurred within the study area. Cotton aphid populations were extremely high in UA48 and PHY375WRF as a result of multiple applications of acephate for TPB. While there were also aphids in UA222 and ST5288B2RF, populations were much lower comparably.

PRACTICAL APPLICATION

Utilizing resistant varieties to manage TPB in cotton is a viable option for growers in Arkansas. While these varieties are not completely immune to TPB damage, they did require fewer insecticide applications and also suffered less yield loss from this pest than susceptible varieties. By utilizing these varieties, growers should be able to reduce insecticide applications for TPB, avoid secondary pest outbreaks, and delay the development of insecticide resistance in this pest.

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Table 1. Tarnished plant bug (TPB) resistance level and relative maturity of selected varieties.

Variety	TPB Resistance	Maturity
ST5288B2RF	High	Mid to Late
UA222	High	Early
PHY375WRF	Low	Mid to Late
UA48	Low	Early

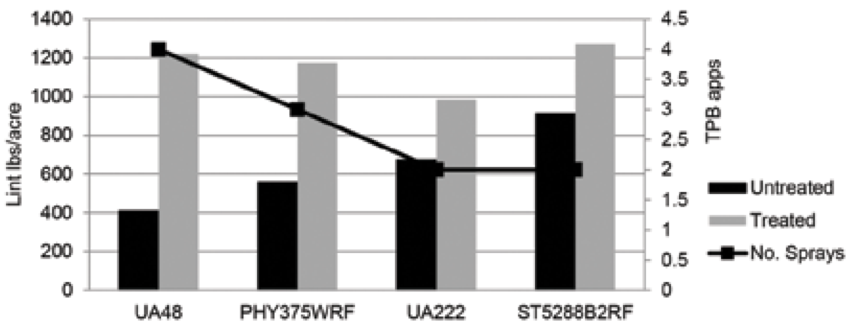

Fig. 1. Lint yield and tarnished plant bug applications: treated vs untreated.

Cotton Research Verification Program: 2014 Progress Report

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

RESEARCH PROBLEM

The Cotton Research Verification Program (CRVP) trains cotton growers and county extension agents in all aspects of cotton production by utilizing the latest technology and research-based recommendations. The program seeks to accomplish multiple goals: to demonstrate to producers that University of Arkansas System Division of Agriculture's Cooperative Extension Service cotton management recommendations developed from small-plot research are applicable to large-scale field applications and provide optimum yields and economic returns; to evaluate the current Cooperative Extension Service cotton management recommendations for completeness and determine where weaknesses in knowledge or information exists and further research is warranted; to train new county extension agents in cotton production and provide experiences that will benefit the agent in his overall county programming with respect to cotton production.

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 261 irrigated fields entered into the program. The CRVP has experienced increased irrigated cotton yields over those of the state irrigated average. While this increase could be attributed to many factors, education certainly played a role. The success of the cotton program spawned verification programs in rice, soybeans, wheat and corn in Arkansas and other states in the mid-South.

[1] Cotton extension agronomist, and cotton research verification/sustainability program coordinator, repectively, Newport Extension Center, Newport.
[2] Assistant professor, Northeast Research and Extension Center, Keiser.

RESEARCH DESCRIPTION

Six fields at two locations comprised the CRVP locations in 2014. Each field was entered into the Field to Market Fieldprint Calculator. Sustainability metrics from the 2014 season will help serve to establish a benchmark for successive years as sustainability efforts will be a major part of the program for 2015.

The fields ranged in size from 11.0 acres to 41 acres. Irrigation methods included furrow, pivot and sub-surface drip. The program was conducted under various tillage systems, irrigation regimes, soil types and environmental conditions. The diversity of the fields in the program reflected cotton production in Arkansas.

The program provided training and guidance in the areas of fertility, variety selection, pathology, weed science, entomology, engineering, and cotton physiology. Field records were maintained and economic analyses were conducted at seasons end to determine net return/A for each field and the program.

RESULTS AND DISCUSSION

The 2014 growing season began with a cooler than normal April which delayed planting across the state. Very little cotton planting occurred in April. The vast majority of the crop in the state was planted the first half of May. A cooler and wetter spring extended into July with July being one of the coolest and wettest on record. Favorable conditions extended through the remainder of the growing season. These conditions helped Arkansas producers set a new yield per acre record of 1193 pounds of lint per acre. Plant bug numbers were moderate this year and insecticide applications were made for these pests. Fields in the verification program were treated an average of 3.2 times for plant bugs. Bollworm pressure was light and averaged 0.67 treatments per field. Glyphosate-resistant pigweed pressure was present throughout the state again this year. Residual herbicides were used to deter pigweed germination and escapes were hand-weeded to reduce the amount of viable pigweed seed in the soil seed bank.

Records of field operations on each field provide the basis for estimating expenses. Production data from the 6 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 presented in Table 2. Price received for cotton of $0.62/lb is the estimated Arkansas annual average for the 2014 production year. Average cotton yield for all verification fields is 1298 lb per acre.

Average operating costs for cotton in Tables 1 and 2 are $492.24 per acre. Table 2 indicates that chemicals are the largest expense category at $148.55/acre. Seeds and associated technology fees are the second largest expense category at $102.99/acre. Fertilizers and nutrients average $75.29/acre.

With average yield of 1298 lb per acre, average operating costs are $0.38/lb in Table 1. Operating costs range from a low of $443.34 in the St. Francis-Norris field to a high of $540.59 in the Desha-Wellcot field. Returns to operating costs average $312.68 per acre. The range is from a low of $150.70 in the St. Francis-Norris field to a high of $452.67 in the St. Francis-Causey field. Average fixed costs are $129.00 which leads to average total costs of $621.23 per acre. The average returns to total specified costs is $183.69 per acre. The low is $60.04 in the St. Francis-Norris field and the high is $335.49 in the St. Francis-Causey field. Total specified costs average $0.48/lb.

PRACTICAL APPLICATION

This program has become a vital tool in the educational efforts of the University of Arkansas. 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.

Table 1. Operating costs, total costs, and returns for Cotton Research Verification Program, 2014.

Field	Operating Costs	Operating Costs per Pound	Returns to Operating Costs	Total Fixed Costs	Total Costs	Returns to Total Costs	Total Costs per Pound
St. Francis-Causey	475.95	0.32	452.67	117.18	593.13	335.49	0.40
St. Francis-Conders	478.13	0.39	274.34	155.29	633.42	119.05	0.52
St. Francis-Norris	443.34	0.46	150.70	90.66	534.00	60.04	0.56
Desha-Homeplace	508.92	0.35	383.88	134.27	643.19	249.61	0.45
Desha-Shop	506.50	0.39	301.98	132.12	638.62	169.86	0.49
Desha-Wellcot	540.59	0.39	312.53	144.46	685.05	168.07	0.50
Average	**492.24**	**0.38**	**312.68**	**129.00**	**621.23**	**183.69**	**0.48**

Table 2. Summary of revenue and expenses per acre for Cotton Research Verification Program, 2014.

	Field						
Receipts	**St. Francis-Causey**	**St. Francis-Conders**	**St. Francis-Norris**	**Desha-Homeplace**	**Desha-Shop**	**Desha-Wellcot**	**Average**
Yield (lb)	1498.00	1214.00	958.00	1440.00	1304.00	1376.00	1298.00
Price ($/lb)	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Total Crop Revenue	928.62	752.47	594.04	892.80	808.48	853.12	804.92
Cottonseed Value	180.48	146.25	115.45	173.52	157.13	165.81	156.44
Operating Expenses							
Seed	98.74	103.84	98.74	98.74	98.74	119.14	102.99
Fertilizers & Nutrients	89.89	88.12	79.53	64.74	64.74	64.74	75.29
Herbicides	68.86	66.89	92.33	60.26	60.26	60.26	68.14
Insecticides	23.43	28.91	33.44	78.76	78.76	78.76	53.67
Other Chemicals	18.52	20.84	18.37	34.23	34.23	34.23	26.73
Custom Applications	6.00	6.00	18.00	0.00	0.00	0.00	5.00
Diesel Fuel	28.07	32.73	18.54	48.71	47.33	53.68	38.18
Repairs & Maintenance	35.60	41.04	28.61	39.72	39.17	43.67	37.97
Irrigation Energy Costs	37.44	28.44	5.37	22.47	22.47	22.47	23.11
Labor, Field Activities	10.72	11.00	5.36	28.09	27.65	29.70	18.75
Other Inputs & Fees, Pre-harvest	58.67	50.33	45.05	33.23	33.17	33.96	42.40
Post-harvest Expenses	180.48	146.25	115.45	173.52	157.13	165.81	156.44
Custom Harvest	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Operating Expenses	**475.95**	**478.13**	**443.34**	**508.92**	**506.50**	**540.59**	**492.24**
Returns to Operating Expenses	**452.67**	**274.34**	**150.70**	**383.88**	**301.98**	**312.53**	**312.68**
Land Rent	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Capital Recovery & Fixed Costs	117.18	155.29	90.66	134.27	132.12	144.46	129.00
Total Specified Expenses[a]	**593.13**	**633.42**	**534.00**	**643.19**	**638.62**	**685.05**	**621.23**
Returns to Specified Expenses	**335.49**	**119.05**	**60.04**	**249.61**	**169.86**	**168.07**	**183.69**
Operating Expenses/lb	0.32	0.39	0.46	0.35	0.39	0.39	0.38
Total Expenses/lb	0.40	0.52	0.56	0.45	0.49	0.50	0.48

[a] 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 2014

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

Burke, James. The response of cotton (*Gossypium hirsutum* L.) to slow release foliar fertilization and the effect of environment on absorption. (M.S., advisor: Oosterhuis)

Clarkson, Derek. Insecticide/herbicide interactions of tankmixes on cotton. (M.S., advisor: Lorenz)

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)

Hill, Zachary. Use of fluridone for control of Palmer amaranth in cotton and on ditch banks. (M.S.; advisor: Norsworthy)

Kathiar, Soolaf. Ecology of insect pests of cotton and their natural enemies. (Ph.D., advisor: Lanza)

Kelly, Erin. Variation in crop and insect pest dynamics across soil EC based management zones in Arkansas cotton (M.S., advisor: Teague)

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

Ma, Jainbing. Influence of soil physical parameters, *Thielaviopsis basicola*, and *Meloidogyne incognita* on cotton root architecture and plant growth. (Ph.D., advisors: Kirkpatrick and Rothrock)

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

Navas, Juan Jaraba. The influence of the soil environment and spatial and temporal relationship on *Meloidogyne incognita* and *Thielaviopsis basicola* and their interaction on cotton. (Ph.D., advisor: Rothrock)

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

Raper, Tyson. Potassium deficiency during reproductive development: effect on reproductive development, remote sensing and amelioration. (Ph.D., advisor: Oosterhuis)

Schrage, Brandon. Cotton Injury due to soil- or foliar-applied herbicides: An assessment based on the influence of genetic, agronomic, and environmental factors. (M.S., advisor: Norsworthy) van der Westhuizen, Mathilda. High temperature tolerance in cotton. (Ph.D., advisor: Oosterhuis)

Von Kanel, Michael B. Fruit injury and developing injury thresholds in transgenic cotton. (M.S., advisor: Lorenz)

Zhang, Jin. Identification of heat stress genes related to heat tolerance in *Gossypium hirsutum* L. (M.S., advisors: Stewart and Srivastava)

APPENDIX II

RESEARCH AND EXTENSION 2014 COTTON PUBLICATIONS

BOOKS AND CHAPTERS

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