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Summaries of Arkansas Cotton Research 2012

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University of Arkansas, Fayetteville

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Edited by Derrick M. Oosterhuis

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2012

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2012

PREFACE

Arkansas cotton producers harvested approximately 585,000 acres in 2012, down 75,000 acres from 2011. Producers averaged 1083 lbs/acre, the second highest yield recorded since 2007, producing close to 1.3 million bales. Increased commodity prices of corn and soybean with decreased prices for cotton were the main reason for the decline in acres. However, Arkansas maintained the ranking of third in the nation for cotton production behind Texas and Georgia while grossing a total of over $745 million in total value of production with an average lint price of approximately $0.73/lb.

This was the earliest planted cotton crop on record for Arkansas. The bulk of the 2012 crop was planted prior to May 1, with some planted in March, which is unheard of for Arkansas producers. Environmental conditions in 2012 made a big shift from a record flood in 2011, to an extreme drought in 2012, with most of Arkansas affected by extreme drought conditions (Fig. 1). Glyphosate-resistant Palmer amaranth (pigweed) continues to be the number one weed problem but growers have adopted University of Arkansas Cooperative Extension Service recommendations and overall, did a better job controlling it by overlapping residual herbicides and utilizing multiple tolerant technology systems such as Liberty Link. At least 25% of our cotton acres were planted with varieties that were tolerant to Liberty in 2012 (approximately 12% Liberty Link and 13% Widestrike).

Early season thrips pressure seemed to be worse than many could remember and in some cases three applications for thrips were necessary to carry cotton to the 4th leaf stage. Plant bug pressure seemed less this year than the last several, mostly because the cotton was planted early and matured early. Plant bugs, however, were terrible on later planted cotton. Some benefit is still being seen in south Arkansas with spraying Widestrike technology and in some cases Bollgard II cotton for bollworm pressure.

Hurricane Isaac dropped heavy rain and high winds in late August, causing some yield loss and plant lodging in Central and South Arkansas. Yield loss was approximately 15% in these areas due to this storm.

Tom Barber and Derrick Oosterhuis

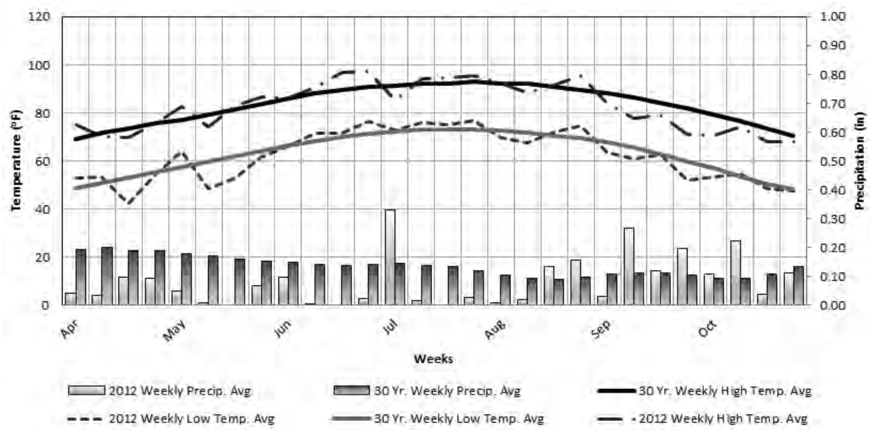

Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2012 compared with the long term 30 year averages in Eastern Arkansas.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research 2012* 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 2012

	2011	2012
New Funds	$321,000	$264,000
Previous Undesignated Funds	$72,347	$67,202
Total	$393,347	$331,202

Researcher	Short Title	2011	2012
Oosterhuis	Cotton Research In Progress	$5,000	$5,000
Burgos	Resistant Pigweeds - Genetics	$11,455	
Kirkpatrick	Soils & Nematode Thresholds	$22,659	
Windham	AR: Site-Specific Seeding Rate	$28,500	
Lorenz	Profitable TPB Management: AR I	$5,513	
Akin	Profitable TPB Management: AR II	$5,513	
Studebaker	Profitable TPB Management: AR III	$5,512	
Bourland	Cotton Improvement	$26,000	$26,000
Barber	Verification Program	$74,208	$74,208
K. Smith	Resistant Pigweed	$20,000	$20,000
Oosterhuis	Nitrogen Inhibitors	$8,150	$10,000
Oosterhuis	Heat Tolerance Screening	$5,250	$5,250
Teague	Extension Sustainability	$30,000	$30,000
Akin	Rainfastness of Insecticides	$18,495	$18,495
Barber	Management of New Cultivars	$23,275	$23,275
Lorenz	Evaluating New Insecticidal Traits	$24,364	$24,364
Norsworthy	Modeling Glyphosate-Resistant Barnyardgrass	$12,251	$12,251
Barber	Replant Decision		$13,500
Akin	Herbicide, Insecticide Interactions		$13,500
		$326,145	$275,843
Uncommitted		$67,202	$55,359
Total		**$393,347**	**$331,202**

ACKNOWLEDGMENTS

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

SUMMARIES OF ARKANSAS COTTON RESEARCH

— 2012 —

University of Arkansas Cotton Breeding Program: 2012 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, 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 (2012) provided the most recent update of the current program. The breeding program has primarily focused on conventional genotypes. The recent advent of glyphosate-resistant pigweed has renewed some interest in conventional cotton cultivars, but no highly adapted conventional cultivars have been available. 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 progeny grown from seed of individual plants. Once segregating populations

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

are established, each sequential test provides screening of genotypes to identify ones with specific host-plant resistance and agronomic performance capabilities. Selected progeny are carried forward and evaluated in replicated strain tests at multiple Arkansas locations to determine yield, quality, host-plant resistance and adaptation properties. Superior strains are subsequently evaluated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm or cultivars. Bourland (2004) described the selection criteria presently being used.

RESULTS AND DISCUSSION

Breeding Lines

The primary objectives of the 2006 through 2012 crosses (F_1 through F_6 generations) have included development of enhanced nectariless lines (with 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). Breeding line development is entirely focused on conventional cotton lines.

Each of the 24 sets of crosses made in 2012 was between conventional cotton lines. The primary focus of these crosses was to combine lines having specific morphological traits, enhanced yield components and improved fiber characteristics. The 2012 breeding line effort also included evaluation of 24 F_2 populations, 24 F_3 populations, 24 F_4 populations, 960 1^{st} year progeny, and 132 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, 690 progeny from the individual plant selections will be evaluated in 2013. Also, 240 superior F_5 progeny were advanced, and 72 F_6 advanced progeny were promoted to strain status.

Strain Evaluation

In 2012, 108 conventional and 4 transgenic strains (preliminary, new and advanced) were evaluated at multiple locations. Screening for host-plant resistance included evaluation for resistance to seed deterioration, bacterial blight, verticillium wilt, tarnished plant bug, and root knot nematode (in greenhouse). Work to improve yield stability by focusing on yield components and to improve fiber quality by reducing bract trichomes continued.

Two approaches for improving cotton yield stability are being used. The first approach focuses on yield components. Increased lint index and fiber density are being used as selection criteria to improve yield stability (Groves and Bourland, 2010). The second approach focuses on host-plant resistance, with specific emphasis on improving heat tolerance and resistance to tarnished plant bug. A method for evaluating heat tolerance is being refined. Response of all entries in the Arkansas Cotton Variety Test, two Regional Strain Tests, and two Arkansas Strain Tests to tarnished plant bug was evaluated. Consistent response over years has been found. Lines resistant to tarnished plant bug, as determined in these small plot tests, have been found to reach treatment threshold at a slower rate and require less insecticides than more susceptible lines.

Germplasm Releases

Germplasm releases are a major function of public breeding programs. Since 2004, a total of 43 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 Midsouth 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 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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Development of an Available Soil Moisture Index to Characterize Drought Stress Experienced in Cotton Variety Trials

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RESEARCH PROBLEM

Although a large number of dryland cotton variety trials are located throughout the United States Cotton Belt, these are typically characterized by rainfall amounts alone. Due to runoff, leaching, and lack of information on soil moisture at planting and rainfall timings, accumulated seasonal rainfall amounts fail to fully describe drought. Specific drought parameters necessary to accurately characterize seasonal growing conditions include timing, magnitude, frequency, and length of water deficit. A drought-stress index which utilizes in-field, sensor measurements has the potential to define these parameters, and therefore serve as the framework for compiling regional yield responses to drought stress. The main benefit of this compiled dataset would be the ability of the producer to examine the relative varietal yield response to a range of drought timings, magnitudes, and lengths. This type of dataset would be much more powerful than single point observations of individual variety trials.

BACKGROUND INFORMATION

The concept of a drought-stress quantifying index was first comprehensively defined by Hiler and Clark (1971) as a method of increasing water use efficiency by optimizing irrigation scheduling. Proposed parameters to calculate this index were either coarse-resolution plant measurements or meteorological data. Jackson et al. (1981) advanced this concept by developing the Crop Water Stress Index (CWSI) which utilized the much higher-resolution plant measurement of canopy temperature as the main stress indicator. Still, this index was developed in

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climates which rarely experience cloud cover or afternoon thunderstorms. These conditions greatly contrast conditions of the humid Southeast and Midsouth regions where a large percentage of dryland cotton is produced.

The recent development of capacitance-based, dielectric constant soil-moisture monitoring sensors have been shown to accurately quantify soil moisture at a very high temporal frequency. These sensors are characterized by a small field of influence; but due to their low cost, large deployments are feasible in many situations (Czarnomski et al., 2005). Deployment of these sensors in cotton variety trials have the potential to characterize soil-moisture-deficit stress and therefore give insight into drought timing, magnitude, frequency, and length of water deficit. Therefore, the main objectives of this research were to develop a soil moisture-based index to quantify drought stress in dryland cotton variety trials and determine the plausibility of extrapolating accumulated index readings to the field scale from a limited number of point measurements.

RESEARCH DESCRIPTION

Soil moisture sensor trials were deployed in Marianna, Ark., Maricopa, Ariz., Gainesville, Fla., Tifton, Ga., Lubbock, Texas, and Florence, S.C. during the 2012 growing season. A more complete description of methods and results can be found in Raper et al. (2013). Trials were designed as randomized, complete blocks with variety as treatment. Two of the three planted varieties differed by region; however, Phytogen (PHY) 499 was planted as a standard at each location. Meteorological data, including rainfall, humidity, temperature, and estimated daily potential evapotranspiration was recorded by an in-field weather station. Decagon 5TE sensors (Decagon Devices Inc., Pullman, Wash.) were deployed at 4 depths in every plot relative to the effective rooting depth of each location. Sensor readings were converted to volumetric water content by a modified Topp equation (Topp et al., 1980). Canopy temperature was also monitored at the Marianna, Ark. location. This equipment was installed and data were collected and analyzed by SmartField Inc. (Lubbock, Texas).

Plant stress was assumed to begin when the soil fell below a threshold of 50% plant available water. Plant available water was determined by two separate methods. First, soil samples were taken at the time of sensor installation and laboratory analyses were conducted to determine field capacity and wilting point. The second method used to determine field capacity and sensor lower limit was based on in-season sensor readings, similar to methods of Colaizzi et al. (2003). Field capacities were defined as sensor reported readings 2-3 days after a saturating rainfall or irrigation event. Lower limits were defined as sensor readings during periods of extended drought or at the end of the growing season after defoliation. Since a plant growing at 50% available water was assumed to experience less stress than a plant growing at 10% available water, stress units were weighted as available water declined below the threshold. Stress unit weights increased linearly as total available water decreased from 50% to 0% available water.

A seasonal stress index (the "Available H_2O Stress Index") was defined by summing hourly plant stress values during the active growing season, from squaring to defoliation. Although data analysis is currently underway, included are preliminary results from the Ark., Ariz., and S.C. soil moisture datasets. Not included are the results from the Fla., Ga., and Texas soil moisture trials or the Ark. canopy temperature trials.

RESULTS AND DISCUSSION

Soil samples were taken at the time of sensor installation and analyzed for texture analysis to determine field capacity and wilting point values. Resulting relationships of seedcotton yields and accumulated stress index values were very poor, most likely due to the substantial changes in soil properties between each soil moisture sensor (Fig. 1). In comparison to laboratory determined field capacity and wilting point values, using in-field observed values as boundaries to calculate plant available water resulted in stronger relationships between accumulated available H_2O stress index units and yield (Fig. 1).

After calculating accumulated available H_2O stress index units for the Ark., Ariz., and S.C. locations, the paired site-relative yields and accumulated stress values were combined to test response of the index to location. This relationship was characterized by a coefficient of determination of 0.593 (Fig. 2). Currently, the index assumes one stress unit at flowering results in the same yield reduction as one stress unit prior to squaring. As indicated by previous research, the impacts of stress units at the aforementioned times on seedcotton yield are not equal. Inclusion of a crop susceptibility factor should remove much of the location-related variability in the combined datasets and further solidify varietal response.

Preliminary analysis of relationships between relative seedcotton yield and accumulated available H_2O stress index units suggests most varieties significantly affect regression intercept but not slope. These responses suggest sensor deployment for the purpose of characterizing drought stress in dryland variety trials should be under one standard variety. This will remove varietal response until the response is more fully understood. This research will be repeated on a larger scale during the 2013 growing season.

PRACTICAL APPLICATION

The utilized accumulated available H_2O index does seem to be a practical method of characterizing drought stress experienced during the growing season. As a result, calculation of the available soil-moisture-stress index in local dryland variety trials has the potential to provide information on combined, regional varietal water use efficiencies. Alternatively, this technology has significant potential in irrigation scheduling.

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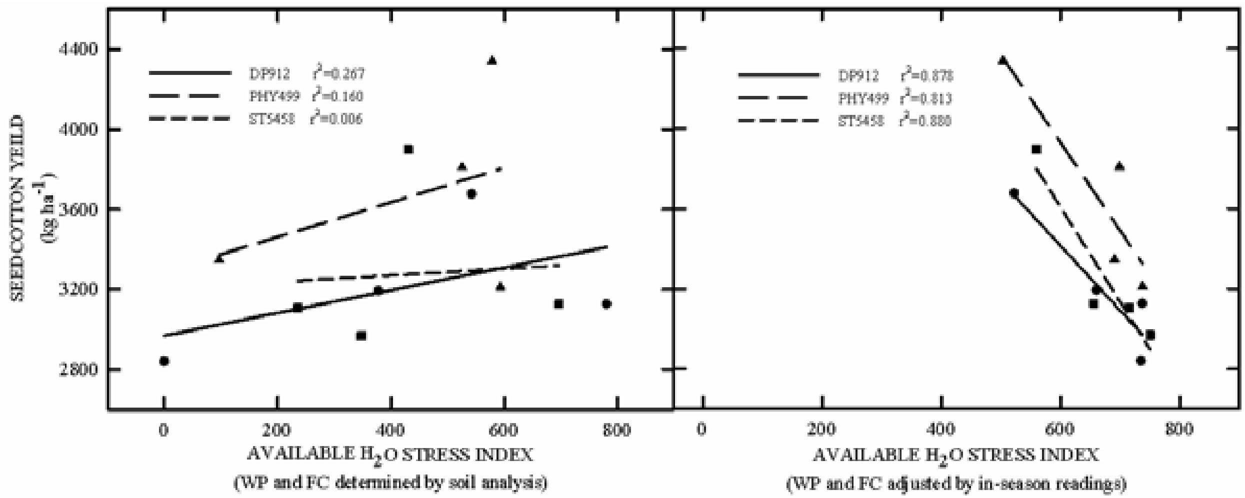

Fig. 1. Florence, SC 2012 relationships between seedcotton yield and accumulated available H_2O stress index units. LEFT: Wilting point and field capacity as determined by laboratory analysis. RIGHT: Wilting point (WP) and field capacity (FC) as determined by in-season observations.

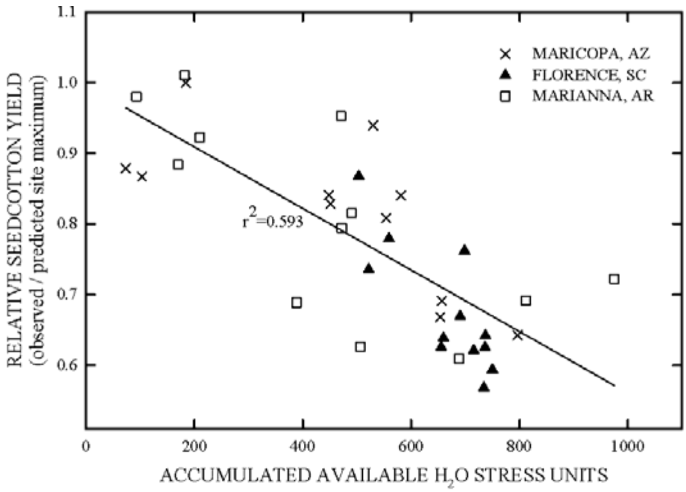

Fig. 2. Relationship between accumulated available H_2O stress units and relative seedcotton yield, where relative seedcotton yields represent the observed plot yield divided by the measured (if available) or estimated maximum yield of the location.

Varietal and Short-Term Drought Impacts on Soil Compaction in a Memphis Silt Loam

T.B. Raper, D.M. Oosterhuis[1], R.L. Raper[2], and D.H. Pote[3]

RESEARCH PROBLEM

Cotton production in the Mississippi River Delta Region consists largely of conventional tillage and bedded rows to support furrow irrigation. Soil compaction in this region has the potential to inhibit directly not only root growth but also decrease water infiltration from both irrigation and rainfall events, thereby resulting in a twofold decrease in system water use efficiency. The objectives of this research were to examine end-of-season soil compaction in bedded cotton production and determine the implications of drought during flowering with differing varieties on soil compaction in trafficked middle, untrafficked middle, and in-row positions.

BACKGROUND INFORMATION

Soil compaction, defined as a reduction in soil pore space and an increase in soil density, is most often associated in row-crop agriculture with vehicle traffic events. The impact of vehicle traffic on soil compaction and therefore crop yield is complex, but many mechanisms influencing this relationship are well understood (Raper, 2005). Cotton root growth has been shown to be completely inhibited at soil penetrometer readings of 2500 kPa (Rosolem et al., 1998), with reports of 50% reductions in root growth observed at 720 kPa (Dexter, 1987). Measureable increases in soil compaction and decreases in water infiltration can occur after multiple traffic events, but most compaction and decreases in infiltration are associated with the first traffic event (Cooper et al., 1969; Allen and Musick, 1997). Furthermore, traffic events occurring during conditions of greater than 60% of field capacity decrease the ability of the soil to resist compaction (Raper, 2005). A more thorough understanding of the relationship between irrigation regime, varieties, and soil compaction may help explain some seasonal variations in seed-cotton yields.

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RESEARCH DESCRIPTION

A randomized, complete block design trial was conducted at the Lon Mann Cotton Research Station in Marianna, Ark. on a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalf) during the 2012 growing season. This trial was conventionally tilled and bedded on 96-cm row spacing. A deep tillage event (~35 cm) under the bed was conducted prior to planting by a curved-shank subsoiler (Ripper-Hipper, Dickey Machine Works, Pine Bluff, Ark.). The only tillage event after emergence occurred on 19 June 2012, and consisted of four small, shallow-running (<10 cm) middle-plows to break crusting and increase irrigation water infiltration. Treatment consisted of three popular cotton varieties (Stoneville 5458 B2RF, DeltaPine 0912 B2RF, and Phytogen (PHY) 499 WRF) planted in a randomized complete block design with 4 replications. An adjacent, 4-row control strip was planted in PHY 499 WRF. Water was withheld from the randomized complete block design area beginning after first flower (12 July 2012) and continuing through peak flower (9 August 2012). The adjacent strip of PHY 499, however, maintained sufficient irrigation during this period to serve as a water-stress free control. All other field inputs were maintained to ensure water was the main yield-impacting input. Pest thresholds were set and maintained as specified in Extension publications.

On 13 December 2012, a Veris P4000 VIS-NIR-EC-Force probe (Veris Technologies Inc., Salina, Kan.) was used to collect cone index and electrical conductivity measurements. Five measurements were taken in each un-trafficked middle, row, and trafficked middle row per plot. Measurements were taken to a depth of 1 m unless sustained forces of greater than 5000 kPa were noted at shallower depths. Furrow and row soil samples were taken from 0-15 cm and 15-30 cm to determine soil moisture content at the time of data collection.

RESULTS AND DISCUSSION

In-field measurements determining field capacity and wilting points suggested water content at the time of sampling was greater than field capacity (average of 120% FC). Analysis of gravimetric water content indicated no significant differences associated with irrigation treatment ($P \leq 0.10$). Effect of block was also insignificant, although a weak trend of increasing water content with increasing latitude was noted across the field. Effect of variety on gravimetric water content was also insignificant. As a result, soil moisture was considered to be consistent at each sampling point and therefore not a factor in analysis of soil cone penetrometer data.

Treatments of variety (Fig. 1) and irrigation (Fig. 2) did not significantly affect cone index readings at any sampled position. Failure of cone index readings to respond to irrigation treatment may be explained by treatment timing. Until 12 July 2012, both irrigation treatments received equal irrigation timings and quantities. Prior to irrigation treatment initiation, several traffic events occurred in both the water-stressed and well-watered treatments during moist soil conditions. Therefore, additional resistance to soil compaction associated with soil drying during the water-stressed treatment did not significantly impact cone index values as, most likely, prior traffic events had already created a substantial layer of soil compaction (Fig. 2).

In comparison with in-row and untrafficked positions, trafficked positions were characterized by increased cone index readings at depths up to 35 cm (Fig. 3). Highest values of cone index readings were noted at the 15-cm depth. These results are similar to those of Raper et al. (1998) and Raper et al. (2000), who observed root-impeding layers in excess of 3500 kPa within the top 20 cm of the trafficked soil profile in a Decatur silt loam.

PRACTICAL APPLICATION

Levels of compaction described to result in complete root inhibition were noted in 15 of 16 trafficked middles. These conditions may limit root exploration in soil middles where many inputs are applied and decrease water infiltration. Reduction in traffic events and all-together avoidance during periods of soil moisture in excess of 60% of field capacity may reduce soil compaction. More research should be conducted to determine the potential for increased soil compaction associated with a well-watered irrigation regime.

ACKNOWLEDGMENTS

The authors thank Cotton Incorporated project funding (#10-791). Also, the authors thank Tammy Horton and the staff of the Dale Bumpers Small Research Farm in Booneville, Ark. for their assistance in data collection and analysis, and the staff at the Lon Mann Cotton Branch for field maintenance and support.

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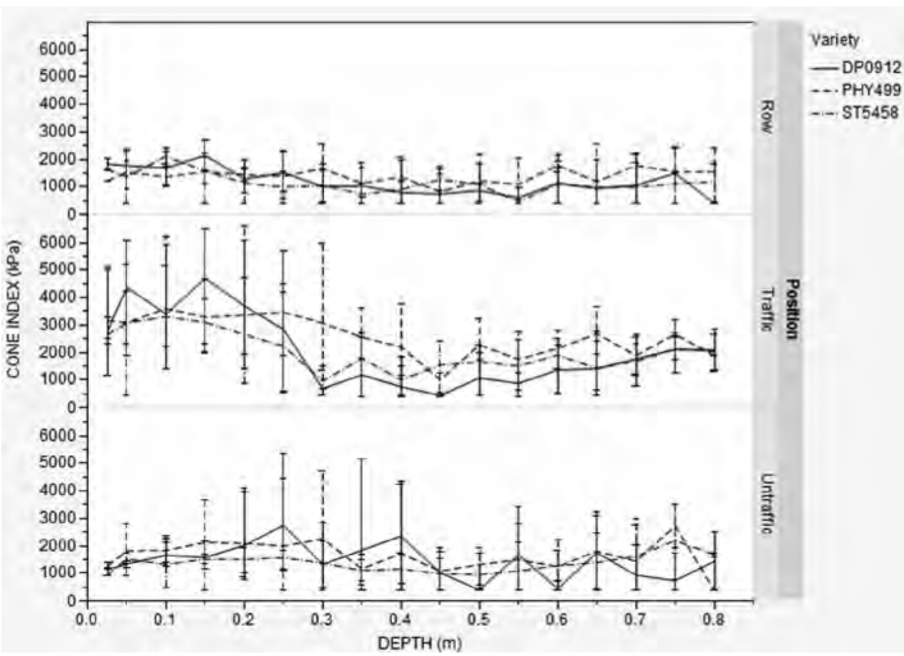

Fig. 1. Cone index (kPa) response to increasing depth by variety and sampling position, including only water-stressed treatments. Error bars represent range of observed readings.

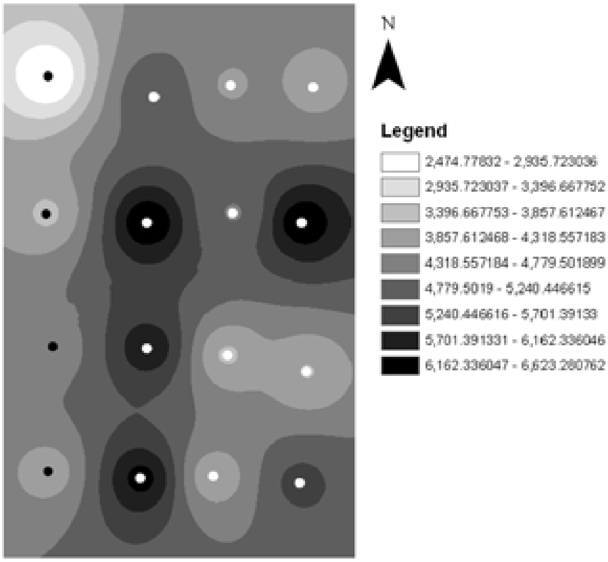

Fig. 2. Inverse distance weighted interpolation of maximum measured cone index readings at depths shallower than 30 cm. Values represent kPa. Black points represent plots in well-watered treatment and white points represent the water stress during flowering treatment. Irrigation treatment effect on maximum cone index readings were not significant ($P \leq 0.10$).

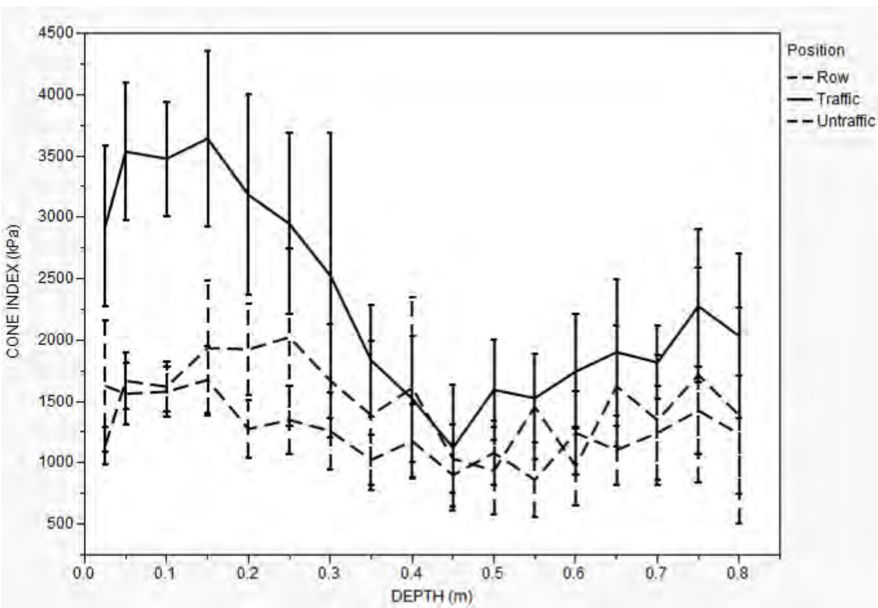

Fig. 3. Cone index (kPa) response to increasing depth by sampling position, averaged across all varietal and irrigation treatments. Error bars represent 95% confidence interval of the mean.

Effect of Water-Deficit Stress on Photosystem II Thermosensitivity in Cotton

C. Pilon, D.M. Oosterhuis, and D.A. Loka[1]

RESEARCH PROBLEM

Cotton is highly sensitive to drought and high temperatures. Cotton thermosensitivity is directly related to the photosynthetic process of the leaves by affecting the photosystem II function of photosynthesis. Earlier studies have shown that plants exposed previously to high temperatures and drought conditions can acclimate with increased thermostability of PSII, but contrasting results have been reported for cotton. Also, the narrow genetic base present in modern *G. hirsutum* breeding programs limits genotypic differences in PSII thermostability between commercially available cultivars. Therefore, more information is need on the response of photosystem II to water stress and the ability of the cotton plant to acclimate to the stress, and also on genotypic variation.

BACKGROUND INFORMATION

Water is one of the most important factors for crop growth and productivity (Kramer, 1983) and water-deficit stress affects morphological and physiological characteristics and yield development of plants worldwide (Boyer, 1982). Although modern cotton cultivars are considered to be relatively drought tolerant, compromises in growth and yield still occur under conditions of scarce water availability. In addition, drought stress induces high-temperature stress indicating a linear relationship between both stresses.

Photosynthesis is the most sensitive function to high-temperature stress and the optimum temperature for photosynthesis is at about 30 °C, with significant declines in assimilation for each additional degree increase due to stomatal closure (Wise et al., 2004). Reduced stomatal conductance under drought stress limits water loss via transpiration and the evaporative cooling capacity of the leaf (Radin et al., 1994) resulting in increased leaf temperatures. Photosystem II (PSII) is the initial complex in the photosynthetic electron transfer chain, being responsible for oxidation of water and generation of molecular oxygen (Rengstl et al., 2013) and has been shown to be the most sensitive process to high-temperature stress (Berry and Bjorkman, 1980).

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Differences in drought tolerance exist between commercial cultivars and wild types (Nepomuceno et al., 1998; Oosterhuis et al., 1987), but the metabolic reasons for this that could be used to find trait for enhancing drought tolerance have not been clearly elucidated. The flowering stage is considered to be the most sensitive stage to drought stress (Loka et al., 2011), but there is evidence that the early stage 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 specific effects of the stress on the thermotolerance of leaves during the early reproductive developmental stage.

The purpose of this study was to determine the relationship between leaf water status and response to temperature increases of contrasting cotton genotypes under water-deficit stress during the early reproductive developmental stage, and also to verify the existence of genetic variability and find possible candidates for gene selection to drought tolerance.

RESEARCH DESCRIPTION

A growth room study was conducted in 2012 in the Altheimer Laboratory at the University of Arkansas in Fayetteville, Ark. Plants were grown in 2-L pots containing a horticultural mix (Sun-Gro horticulture mix, Sun Gro® Horticulture, Agawam, Mass.), and pots were arranged in a 2 × 4 complete randomized factorial with 5 replications in each treatment. The growth chamber was set for normal conditions of 32/24 °C (day/night), ± 60% relative humidity, and 14 h photoperiod. The treatments consisted of two water regimes, well-watered and water-stressed and four cotton cultivars, Pima 32, Siokra L23, DP0912, and T1521. Half-strength Hoagland's nutrient solution was applied daily in order to maintain adequate nutrients and water during conduction of the experiment. Water stress was imposed at squaring by withholding water from the water-stressed plants at the pinhead square stage approximately four weeks after planting (it depended on each cultivar development) until stomatal conductance (g_s) reached approximately 10 mmol $m^{-2}s^{-1}$. Well-watered control plants received optimum quantity of water throughout the duration of the experiment. Stomatal conductance was measured daily from the fourth main-stem leaf from each plant using a leaf porometer (Decagon SC-1, Decagon Devices, Inc., Pullman, Wash.) during induction of the stress. Once the plants reached the desired stress level ($g_s \approx 10$ mmol $m^{-2}s^{-1}$) they were re-watered and recovery was measured. Photosystem II yield was measured the last day of the stress and one day after recovery from the fourth main-stem leaf from each plant using a LeafTech heating block assembly linked to a Multi-mode Chlorophyll Flourometer OS5p (OptiScience, Hudson, N.H.).

RESULTS AND DISCUSSION

Water-deficit stress significantly decreased DP0912 and Siokra L23 stomatal conductance rates compared with the control both at the last day of the stress and one day after recovery (Table 1). Also, Pima 32 and T1521 had lower stomatal conductance rates under water-deficit stress in relation to the control at the last day of the stress. Under well-watered conditions, Pima 32 and T1521 had stomatal conductance rates significantly lower compared with the other cultivars at both days of measurement and one day after recovery, respectively. However, under water-deficit stress, stomatal conductance rates were lower in Siokra L23, Pima 32 and T1521 compared with DP0912 at the last day of the stress; whereas one day after recovery, the lowest stomatal conductance rates were found in Pima 32.

Cultivar Pima 32 showed a lower response curve in the stressed plants than the control indicating lower PSII quantum yield (ΦPSII) in plants under stress (Fig. 1A). At one day after recovery, curves of control and stressed plants were similar (Fig. 1A) showing that Pima 32 has the ability of recovering after a period of drought stress by increasing quantum efficiency. Siokra L23 showed higher ΦPSII in all temperatures both on the last day of the stress and one day after recovery, indicating that drought stress reduces quantum yield in this cultivar's plants (Fig. 1B). In DP0912, on the last day of the stress, the control had higher ΦPSII than the stressed plants. However, between 30 °C and 35 °C, an inversion occurred and stressed plants increased the quantum yield as temperature increased (Fig. 1C). A similar response occurred at one day after recovery, with an inversion in quantum yield of stressed plants after 35 °C compared with the control (Fig. 1C). In the T1521, on the last day of the stress, the control had higher ΦPSII values until temperatures around 38 °C, when an inversion occurred and ΦPSII was higher in the stressed plants (Fig. 1D). At one day after recovery, stressed plants showed higher ΦPSII at all temperatures indicating an ability to recover after a period of drought stress (Fig. 1D). Genetic variability was found among the genotypes used and, even though Pima 32 had the lower stomatal conductance, it appears to have better acclimation under stress, being a good candidate to have genes selected for drought tolerance.

PRACTICAL APPLICATION

Past studies have shown that various crop plants exposed previously to high temperatures and drought conditions have exhibited increased thermostability of PSII, but this has not been clearly shown in cotton. Examination of high-temperature thresholds for ΦPSII revealed variability in PSII thermostability among cultivars. We speculate that the knowledge of genetic variability of cotton cultivars based on traits such as stomatal conductance and PSII function, could contribute to selection of genes for drought tolerance.

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Table 1. Stomatal conductance (mmol $m^{-2}s^{-1}$) of four cotton cultivars (DP0912, Siokra L23, Pima 32, and T1521) measured at the last day of the stress and one day after recovery for well-watered plants (Control) and water-stressed plants (WS).

	Stomatal Conductance			
	Last day		Recovery	
Cultivar	Control	WS	Control	WS
Pima 32	55.63Ba†	11.82Bb	52.39Ba	41.20Ba
Siokra L23	157.43Aab	12.09Bc	190.08Aa	93.16Ab
DP0912	136.15Aa	28.40Ab	182.14Aa	65.80ABb
T1521	114.89Aa	19.62Bb	61.13Bab	76.48Aab

†Rows, within each cultivar, with the same lowercase letter are not significantly different (*P* = 0.05). Columns, within each water regime, with the same capital letter are not significantly different (*P* = 0.05).

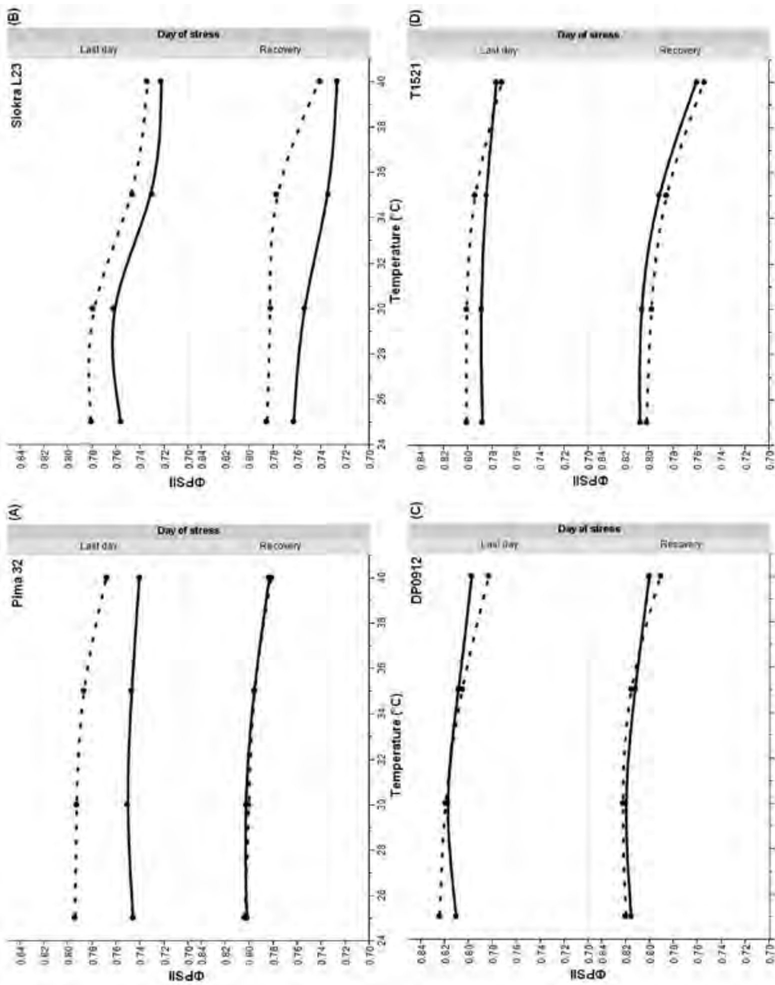

Fig. 1. Effect of drought stress on ΦPSII at the last day of the stress and one day after recovery in (A) Pima 32, (B) Siokra L23, (C) DP0912 and (D) T1521 cultivars. - - - - - = Control; ——— = Water stress.

Water-Deficit Stress Effects on Polyamine Metabolism of the Cotton Flower and Subtending Leaf Under Field Conditions

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

RESEARCH PROBLEM

Water-deficit stress is a major abiotic factor limiting more than one third of the arable land around the world. Polyamines are endogenous plant growth promoters that affect a variety of physiological and metabolic functions, and are particularly involved in the flowering process. Research in other crops has indicated a relationship between changes in polyamine metabolism and drought tolerance. However, no information exists on polyamine metabolism of cotton under conditions of limited water supply. This study was aimed at quantifying the effect of water deficit on polyamine metabolism and resulting changes in their concentrations.

BACKGROUND INFORMATION

Polyamines (PA) are low-molecular-weight organic polycations with two or more primary amino groups $-NH_2$ and they are present in bacteria, plants and animals. In plants, the diamine putrescine (PUT) and its derivatives, the triamine spermidine (SPD) and the tetramine spermine (SPM) are the most common polyamines and they have been reported to be implicated in a variety of plant metabolic and physiological functions (Kakkar et al., 2000). Additionally, PAs play a significant role in flower induction (Bouchereau et al., 1999) along with flower initiation (Kaur-Sawhney et al., 1988), pollination (Falasca et al., 2010), fruit growth and ripening (Kakkar and Rai, 1993). Research in other crops has indicated that changes in PA concentrations is a common plant response to a variety of abiotic stresses, including salinity, high or low temperatures, and drought, as well as biotic stresses (Boucehereau et al., 1999).

Drought is a major abiotic factor reducing plant growth and crop productivity around the world (Boyer, 1982). Cotton (*Gossypium hirsutum* L.) is considered to be relatively tolerant to drought, i.e. by osmotic adjustment (Oosterhuis and Wullschleger, 1987). Since projections anticipate that water-stress episodes are going

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to intensify in the future (IPCC, 2007), tools to help with selection of drought-tolerant genotypes are greatly needed. Polyamine metabolism is an enticing target; however, despite the extensive research on other crops, limited information on PA metabolism exists for cotton with the only reports being on the distribution of polyamines in the cotton plant (Bibi et al., 2012), polyamine content just prior to rapid fiber elongation (Davidonis, 1995), the effect of heat stress on PAs (Bibi et al., 2010), and the occurrences of uncommon polyamines (norspermidine, norspermine, pentamine, and hexamine) (Kuehn et al., 1990).

The objectives of our study were to monitor and evaluate the alterations caused by water-deficit stress on the polyamine metabolism of the cotton pistil and its subtending leaf under field conditions.

RESEARCH DESCRIPTION

Cotton cultivar ST5288B2F seeds were sown at a density of ten plants per meter in a Captina silt loam (Typic Fragidult) soil on 6 June 2011 at the University of Arkansas Agricultural Experimental Station in Fayetteville, Ark. and in a sandy loam (Typic Amarillo) soil on 30 May 2011 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, Ark. were irrigated by furrow irrigation to soil saturation every six days in the absence of saturating rainfall; while in Lubbock, Texas, 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 when plants reached the flowering stage which was 20 July in Fayetteville, Ark. and 13 July in Lubbock, Texas. First sympodial branch fruiting position white flowers and their subtending leaves were sampled at 1200 h at the end of the first and second week after irrigation was withheld and analyzed for polyamine content according to Bibi et al. (2010). Measurements of soil moisture content and stomatal conductance were taken also at the end of each week from the Arkansas site.

RESULTS AND DISCUSSION

Water-deficit stress resulted in significant decreases in leaf stomatal conductance (Table 1) and soil moisture content (Table 2) in Fayetteville, Ark. In Lubbock, Texas, no significant differences were detected in soil moisture content between control and water-stressed plots (Table 2); however, we speculate that this was due to a sampling mistake since vapor-pressure deficit in this location was consistently higher compared to Fayetteville, Ark. (Table 3).

Polyamine analysis showed that both leaf and ovary metabolism was significantly affected by limited water supply in both locations (Tables 4 and 5). Specifically, water-stressed ovary and leaf PUT concentrations were significantly higher compared to the control at the end of the second week in both locations (Tables

4 and 5), and a similar pattern was observed in water-stressed ovary and leaf SPD concentrations at the end of the second week in both locations (Tables 4 and 5). However, ovary and leaf SPM concentrations remained unaffected under conditions of water stress compared to the control in Fayetteville, Ark. (Table 4); whereas the opposite was observed in Lubbock, Texas with both ovary and leaf SPM levels being significantly higher under conditions of water-deficit stress compared to the control at the end of the second week (Table 5).

PRACTICAL APPLICATION

The results of our study indicated that leaf and ovary polyamine metabolism were affected significantly by limited water supply, suggesting that polyamines have a critical role in cotton protection under adverse environmental conditions. This indicated that polyamine metabolism, PUT and SPD especially, could provide useful tools for drought-tolerant genotype selection. However, more research needs to be conducted in order to elucidate the exact function of each polyamine and the ways polyamines can be used to enhance drought tolerance in cotton.

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Table 1. Effect of water-deficit stress on leaf stomatal conductance in Fayetteville, Ark.

Stomatal Conductance (mmol/m²s)			
---------------Week I---------------		---------------Week II---------------	
C	WS	C	WS
697.1 a†	432.2 b	640.7 a	373.1 b

†Different letters indicate statistical significance at ***P*** = 0.05.
Notes: Water-deficit stress (WD) and control (C).

Table 2. Effect of water-deficit stress on soil moisture content in Fayetteville, Ark. and Lubbock, Texas.

Soil Moisture Content (%)							
-----------------Fayetteville-----------------				-------------------Lubbock------------------			
-----Week I-----		-----Week II-----		-----Week I-----		-----Week II-----	
C	WS	C	WS	C	WS	C	WS
0.89 b†	0.93 a	0.89 b	0.94 a	0.95 a	0.97a	0.97 a	0.98 a

†Different letters indicate statistical significance at ***P*** = 0.05.
Notes: Water-deficit stress (WD) and control (C).

Table 3. Vapor pressure deficit in Fayetteville, Ark. and Lubbock, Texas.

Vapor Pressure Deficit	
Fayetteville	Lubbock
27.75	39.46

Table 4. Effect of water-deficit stress on polyamine concentrations of ovary and subtending leaf in Fayetteville, Ark.

Polyamine Content (nmoles/g FW) Fayetteville											
Ovary						Leaf					
PUT		SPD		SPM		PUT		SPD		SPM	
C	WS	C	WS	C	WS	C	WS	C	WS	C	WS
Week I						Week I					
311.0 a[†]	349.1 a	429.6 a	297.1 b	288.1 a	200.5 a	14.0 b	43.3 a	92.63 b	117.6 a	69.0 a	61.5 a
Week II						Week II					
338.2 b	519.5 a	400.5 b	533.4 a	188.6 a	184.5 a	57.1 b	203.7 a	232.9 a	288.6 a	104.0 a	109.4 a

[†]Different letters indicate statistical significance at $P = 0.05$.
Notes: Water-deficit stress (WS), control (C), putrescine (PUT), spermidine (SPD), and spermine (SPM).

Table 5. Effect of water-deficit stress on polyamine concentrations of ovary and subtending leaf in Lubbock, Texas.

Polyamine Content (nmoles/g FW) Lubbock											
Ovary						Leaf					
PUT		SPD		SPM		PUT		SPD		SPM	
C	WS	C	WS	C	WS	C	WS	C	WS	C	WS
Week I						Week I					
275.4 b[†]	666.7 a	89.5 b	131.6 a	89.6 b	578.1 a	14.7 b	125.6 a	104.1 b	198.6 a	93.5 b	131.3 a
Week II						Week II					
516.9 b	1076.7 a	1192.3 b	1354.4 a	131.6 a	506.7 a	58.8 b	990.6 a	144.1 b	241.3 a	72.7 b	97.9 a

[†]Different letters indicate statistical significance at $P = 0.05$.
Notes: Water-deficit stress (WS), control (C), putrescine (PUT), spermidine (SPD), and spermine (SPM).

A Review of Irrigation Termination Practices in Northeast Arkansas

M.L. Reba[1], T.G. Teague[2], and E. Vories[3]

RESEARCH PROBLEM

The alluvial aquifer supplies 80-90% of the irrigation water in eastern Arkansas. Declines in the alluvial aquifer west of Crowley's Ridge have long been documented, while east of the ridge the declines have been minimal. However, a report from USGS shows two depressions east of the ridge in the 2008 mapping that were not evident in 2006 (Schrader, 2010). A reduction in readily accessible irrigation water will force producers to go deeper in the alluvial aquifer or into deeper formations for irrigation, which will increase production costs. The prudent use of irrigation for cotton production is merited across the state given documented reductions in groundwater levels. The objective of this study was to characterize irrigation practices for both furrow and center-pivot irrigated cotton and to use historic cotton growth and furrow irrigation data for cotton to determine adherence to current guidelines for irrigation termination.

BACKGROUND INFORMATION

Early research on optimizing the timing of irrigation termination was confounded by the many factors that affect a cotton crop (Unruh and Silvertooth, 1997). COTMAN, a COTton MANagement system, is used across the Cotton Belt to monitor crop development and enhance cotton crop management (Oosterhuis and Bourland, 2008). The system uses select plant indicators to follow plant development and document cutout, which is defined as the flowering date of the last effective boll population (Oosterhuis and Bourland, 2008). Current recommendations for Arkansas cite accumulated heat units (60 °F base) past cutout, i.e., 5 nodes above the uppermost first position white flower (NAWF = 5), of 350 in northeast and 500 in south Arkansas, based, in part, on research reported by Vories et al. (2011).

RESEARCH DESCRIPTION

This study took place on Wildy Family Farms in Mississippi County, Ark. Information was gathered from 7,405 acres from 2005-2012 on both furrow (# or

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% of total fields) and pivot-irrigated fields (# or % of total fields). The data used for the presented analysis came from four sources: meteorological information, irrigation logs from the producer, plant monitoring data, and lint yield. Irrigation logs were used to determine the final irrigation date. The plant monitoring and meteorological data were used to determine the date when 350 HU had accumulated past cutout (nodes above white flower 5 + 350 heat units). The difference between these dates illustrated how closely the eventual guideline was followed.

RESULTS AND DISCUSSION

Termination guidelines were generally followed within two weeks at all sites (Fig. 1). In all study years except 2010, furrow irrigation termination occurred, on average, before the guidelines suggested. Irrigation was terminated on average 14, 9, 13, and 15 days earlier than the accumulated heat units (DD60s) reached 350 for the furrow fields in 2006, 2009, 2011, and 2012, respectively (Fig. 1a). DD60s are the accumulated heat units above 60 °F per day. The guidelines were based on furrow irrigated field research and may vary for pivot systems due to the smaller application amounts; however, the comparisons should yield similar trends for pivot systems. In pivot-irrigated fields, irrigation terminated 5, 7, 16, 11, and 2 days earlier than the accumulated DD60s reached 350 in 2005, 2006, 2007, 2009 and 2012, respectively (Fig. 1b). In 2010, irrigation continued past the guideline date by 13 and 8 days for furrow and pivot fields, respectively.

PRACTICAL APPLICATION

Termination of irrigation occurred within two weeks of the eventual guidelines for 7 of the 8 study years in furrow-irrigated fields. Termination practices in pivot-irrigated fields appear to be later than furrow fields by 8 days on average for the study years, which may have been done to compensate for the smaller application amounts associated with pivot-irrigation. Since the research was based on furrow irrigation, further research in pivot irrigation termination would refine the pivot termination guidelines.

Incorporating the guidelines for irrigation termination at the end of the production season is critical. This is due in part to the fact that the end of season is the most expensive pumping period of the production season due to increasing depth to groundwater after a season of pumping throughout the region. Selection of the proper date also allows producers to prepare for harvest without sacrificing yield.

ACKNOWLEDGMENTS

This study would not have been possible without the cooperation of the producer, David Wildy, and Wildy Family Farms. This study was supported by a Conservation Innovation Grant from the USDA-Natural Resource Conservation Service through the University of Arkansas System, Division of Agriculture with matching support from Cotton Incorporated.

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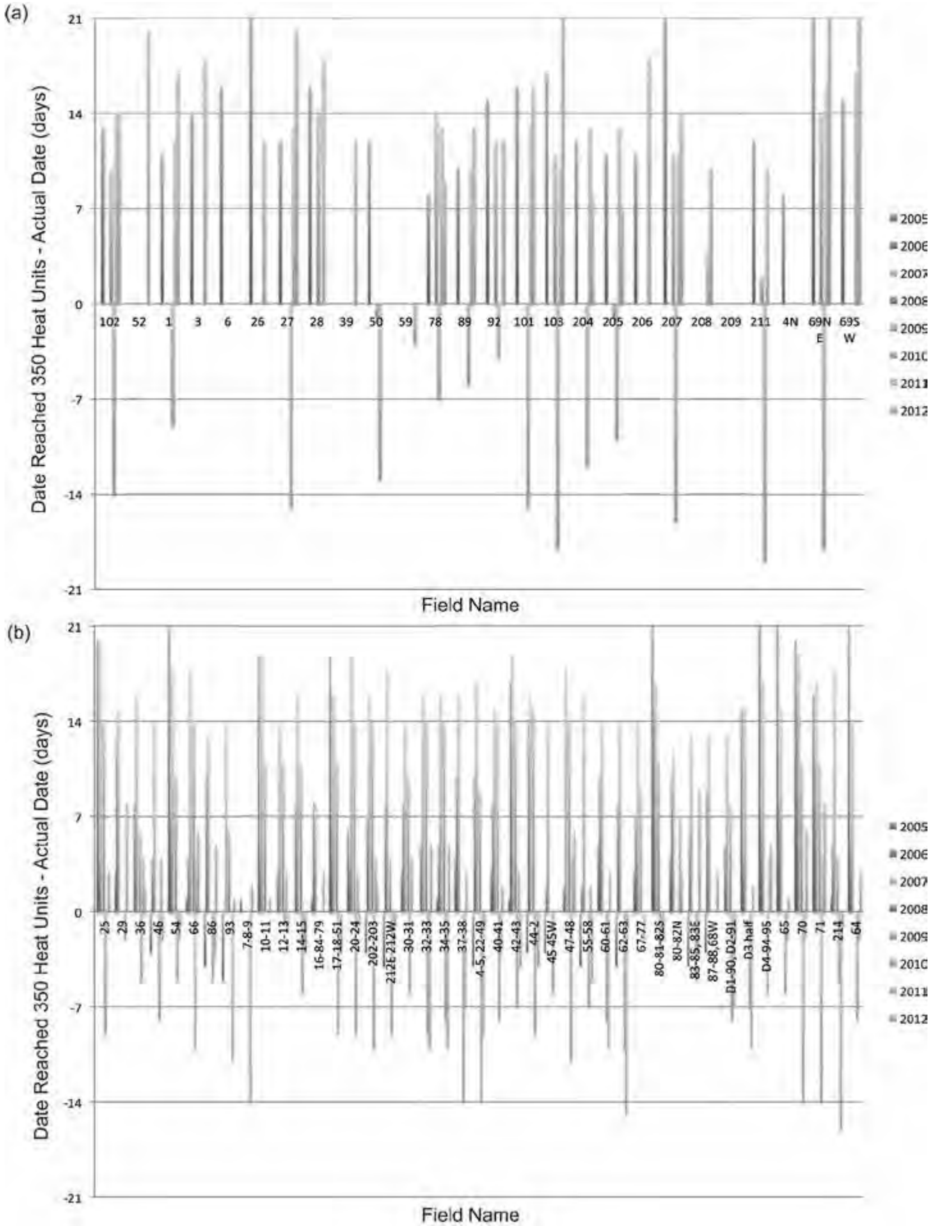

Fig. 1. Number of days between the date 350 DD60s was reached and the actual date of final irrigation for (a) furrow- and (b) pivot-irrigated study fields. DD60s are the accumulated heat units above 60 °F per day.

Screening for Temperature Tolerance in Cotton

M.M. Pretorius, D.M. Oosterhuis, D.A. Loka and T.R. FitzSimons[1]

RESEARCH PROBLEM

Cotton originates from hot climates, but does not necessarily yield best at excessively high temperatures. The ideal temperature range for cotton is reported to be from 68 ˚F to 86 ˚F (Reddy et al., 1991). However, average daily maximum temperatures during boll development in July and August in the U.S. Cotton Belt are almost always above 95 ˚F, well above the optimum for photosynthesis and reproductive development. This is considered a major reason for lowered and variable yields experienced in cotton production. Cotton yields in Arkansas are less than half of the theoretical maximum (Baker and Hesketh, 1969). Therefore, the overall objectives of this study were (1) to determine the best technique to screen cotton germplasm for tolerance to high temperature, and (2) to use this information to evaluate contrasting cotton genotypes for temperature tolerance in a controlled environment, the results to be used in cotton breeding selection for temperature tolerance.

BACKGROUND INFORMATION

A negative correlation between yield and high temperature during boll development has been reported, with *high* temperatures being associated with *low* yield and *cooler* temperatures being associated with *high* yields (Oosterhuis, 1999, 2002). High temperatures decrease carbohydrate, and reduce boll size by decreasing the number of seeds per boll and the number of fibers per seed. High temperatures can affect pollination (Burke et al., 2004) and subsequent fertilization resulting in fewer seeds per boll (Snider et al., 2009, 2010).

This is an on-going project with the overall objective of developing a reliable and practical method for screening for high temperature tolerance in cotton germplasm lines for selection and improvement in cotton tolerance to high temperature (Bibi et al., 2005). In the first part of this study we studied the most suitable physiological and biochemical methods to detect accurately and reliably plant response to high temperature (Bibi et al., 2008). Two measurements were selected: chlorophyll fluorescence and membrane leakage as the best indicators of plant response to high-temperature stress. This information was used to develop a technique for

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measuring plant response to high-temperature stress and recovery for screening for high-temperature tolerance (Oosterhuis et al., 2009).

RESEARCH DESCRIPTION

In the current study, two contrasting cotton cultivars were used: ST4288 a thermo-sensitive cultivar selected from our previous growth room screening, and VH260 a thermo-tolerant cultivar from Pakistan that grows at temperatures of 45 ˚C. Heat tolerance was determined using previously identified techniques (membrane leakage and fluorescence) and a new method utilizing the antioxidant enzyme glutathione reductase. Measurements were made on seven-week-old plants in a controlled environment in a randomized complete block design with 10 replications.

The plants were grown in a large walk-in growth chamber at the Altheimer Laboratory in Fayetteville, Ark. at 30/24 ˚C day/night temperature until six weeks after planting. At which time the temperature on half the plants, in a separate growth chamber, was raised to 40/24 ˚C for one week.

Measurements were made of glutathione reductase, fluorescence and relative cell injury (a modified membrane leakage technique). For glutathione reductase measurements, the first expanded true leaf was stored in ziploc bags at -80 ˚C until subsequent measurement.

RESULTS AND DISCUSSION

Membrane Leakage

The thermo-sensitive cultivar ST4288 showed more membrane leakage than the thermo-tolerant cultivar VH260 (Fig. 1). A loss of cell integrity was obtained in the high-temperature condition, i.e. 26.9% relative leakage on day one, to 37.9% on day three of the heat stress for VH260. For ST4288, relative leakage increased from 30.2% on day one after heat stress to 41.6% on day three of the heat stress.

Fluorescence

The thermo-sensitive cultivar ST4288 showed a greater loss of electron transport in photosystem II compared to the more tolerant cultivar VH260 (Fig. 2) indicating lower photochemical efficiency of photosystem II. Fluorescence increased as the heat stress persisted and the plant appeared to be acclimating to the heat stress (data not shown).

Glutathione Reductase

Antioxidant enzymes (Glutathione reductase) provide protection against oxidative damage that results under heat stress. The thermo-tolerant cultivar VH260 had a greater amount of glutathione reductase present under the heat stress condition than the thermo-sensitive cultivar ST4288 (Fig. 3), showing that VH260 has a greater ability to increase antioxidant enzyme activity during heat stress.

Glutathione reductase appeared to decrease as the heat stress persisted, presumably as the necessity of reactive oxygen species (ROS) removal decreased with acclimation to the heat stress (data not shown).

The measurement of membrane leakage appears to be more sensitive and more reliable (repeatable) than measurement of fluorescence. This agrees with our previous findings (Bibi et al., 2008). The antioxidant glutathione reductase functions by helping to detoxify, remove excess ROS, when a plant is under stress. However, measurements of glutathione reductase are difficult to interpret, because some cultivars have a high glutathione reductase level prestress; whereas tolerant plants are able to increase their glutathione reductase levels as needed during high-temperature stress. Snider et al. (2010) reported that maintenance of a sufficient antioxidant enzyme pool prior to heat stress was an innate mechanism for coping with rapid leaf temperature increases. Current commercial cotton cultivars do not appear to have significant tolerance to high temperatures compared to older obsolete cultivars (Brown and Oosterhuis, 2005).

PRACTICAL APPLICATION

This project continued to quantify the effects of high temperature on cotton growth and compared methods of measuring the effects on high-temperature stress on cotton. Membrane leakage provided the most reliable and accurate indication of heat stress in cotton. Measurements of fluorescence also showed the effects of heat stress were more variable. Plant glutathione reductase levels , while related to response to stress, are difficult to interpret due to plants having different strategies for responding to stress, i.e. prestress antioxidant levels already high, or levels rising according to the stress. This is an on-going project to screen available cotton germplasm for high-temperature tolerance, with the aim of improving the performance of cotton cultivars under conditions of high temperatures which are often experienced in the U.S. Cotton Belt.

ACKNOWLEDGMENTS

Support for this research was provided by Cotton Incorporated.

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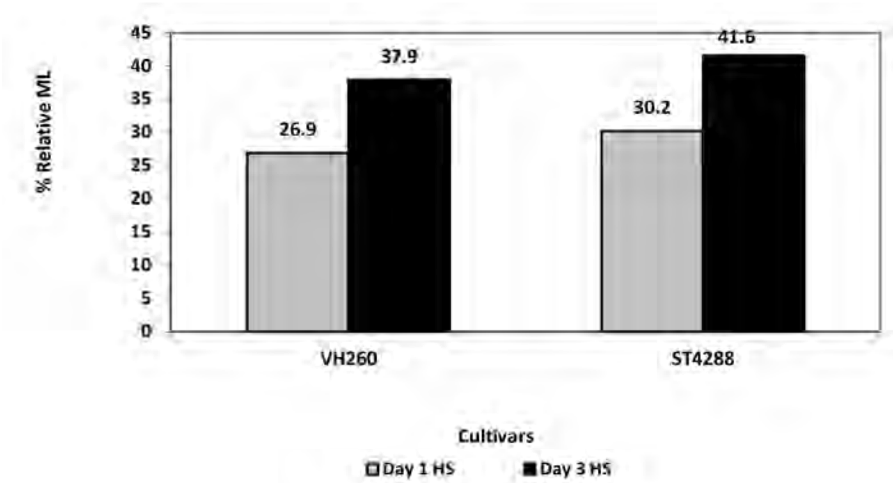

Fig. 1. Membrane leakage of cultivars VH260 (thermo-tolerant) and ST4288 (thermo-sensitive) as an indication of the effects of heat stress on cell integrity measured one and three days after the start of the heat stress.

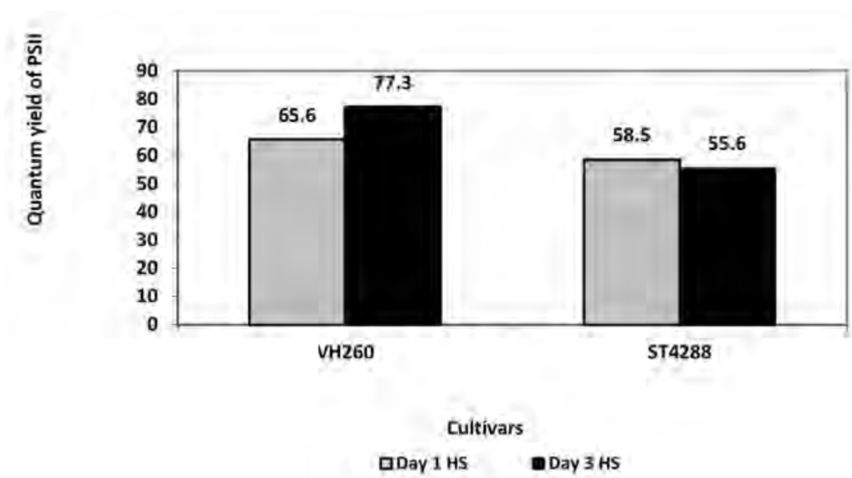

Fig. 2. Fluoresence of cultivars VH260 (thermo-tolerant) and ST4288 (thermo-sensitive) as an indication of the effects of heat stress on electron transport rate measured one and three days after the start of the heat stress.

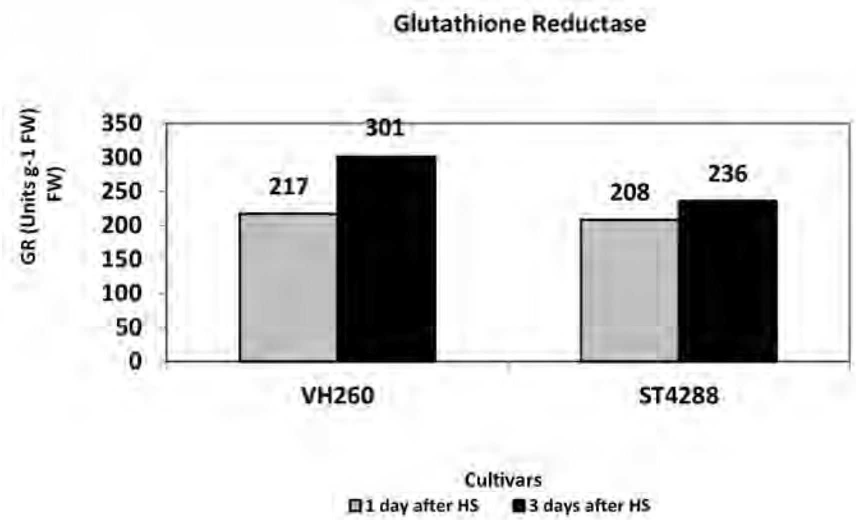

Fig. 3. Glutathione reductase of cultivars VH260 (thermo-tolerant) and ST4288 (thermo-sensitive) as an indication of the effects of heat stress on antioxidant enzyme activity measured one and three days after the start of the heat stress.

Acclimatization of Cotton Exposed to High-Temperature Stress

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

RESEARCH PROBLEM

Abiotic stress accounts for a large proportion of total harvest yield losses every year. Like any plant, cotton must adapt accordingly to the conditions at hand and likewise mitigate possible future effects. High-temperature stress is commonly experienced across the Mississippi river delta regions of Arkansas multiple times during the season. Higher temperatures above a critical threshold do generally correlate with decreased yields (Oosterhuis et al., 2000; Bibi et al., 2008). However, what has not been sufficiently investigated is the speed at which modern cultivars can adapt to changing conditions in the field. Therefore, the objective for this study was to examine possible acclimation of cotton to high-temperature stress using established screening techniques for temperature tolerance of membrane leakage and fluorescence.

BACKGROUND INFORMATION

High temperature negatively affects both metabolic (Mahan and Mauget, 2005) and reproductive (Snider et al., 2010) efficiencies. Ideal temperatures for cotton are between 23 °C and 32 °C with the optimal growth rates achieved when temperatures do not exceed 35 °C (Oosterhuis, 2002). Plants grown in conditions that exceed 35 °C exhibit a decrease in both photosynthetic efficiency and carbohydrate production (Bibi et al., 2008). Respiration and photosynthesis do not share similar ideal temperature curves with photosynthesis exhibiting a narrower temperature band than respiration due to the increased sensitivity of thylakoid membranes (Reddy et al., 1997). Fluorescence investigation of photosynthesis indicate that it becomes less efficient as temperatures exceed 28 °C (Brown and Oosterhuis, 2004). This drop in efficiency creates alternate pathways for electrons to flow leading to higher rates of oxidative stress (Kotak et al., 2007).

Bibi et al. (2008) demonstrated that using chlorophyll fluorescence and membrane leakage were most effective to identify a plant's response to stress. These techniques have been developed as potential screening techniques to identify cultivars that are tolerant to heat stress (Oosterhuis et al., 2000). This study exam-

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ined the daily changes of membrane leakage and fluorescence to determine how rapidly a plant may show signs of stress and its acclimation response in two areas: a primary response to temperature stress and a secondary response a week following.

RESEARCH DESCRIPTION

A growth chamber study was conducted at the Altheimer Laboratory, Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) cultivar ST5288 was grown in two large growth chambers (Model PGW36, Controlled Environments Ltd., Winnipeg, Canada) set for identical temperature and light profiles. The experimental design was a randomized single factor examining high-temperature response and was replicated once. Temperatures were maintained at a 24 °C during the night and 32 °C during the day with a 14 hour light and 10 hour night cycle. Forty plants in 2-L pots were planted in each growth chamber and watered daily with half-strength Hoagland's solution. At first flower, a randomly assigned chamber had the temperature increased during the day to 40 °C and maintained for one week. Membrane leakage and fluorescence measurements were taken daily from ten randomly selected plants in each growth chamber at the first fully expanded main-stem leaf. Temperatures in the treatment chamber were lowered to previous experimental temperatures of 32 °C for one week and then were raised again to 40 °C for one week. Membrane leakage and fluorescence measurements were taken again daily from ten randomly selected plants at the first fully expanded main-stem leaf.

RESULTS AND DISCUSSION

Membrane leakage exhibited a marked increase in relative conductivity the day following the temperature increase (Fig. 1). Thereafter the conductivity steadily decreased to levels that were only within 10% of the controls after three days indicating that the leaves were acclimating to the warmer environment. Carryover of these protective effects were seen in the first day of the second temperature increase when conductivities were more than 40% less than when temperatures were imposed in the first day of week one. It again took three days for the membranes to stabilize and exhibit leakages that were only 10% higher than the controls. It appears that the cotton plant is capable of reaching a modest stabilization with protective effects that are indeed carried over from one extreme temperature period to another. This lends credence to an acclimation effect present in cotton.

There was no clear trend for the effect of high temperature on electron transport (Fig. 2). During the first week of high temperature, relative electron transport rates measured via fluorescence appeared to drop in rates after the first day of temperature stress in week one, and by day three, rates had rose to their highest levels but dropped slowly over the next three days. When the second temperature regime was initiated on the treatment plants, no significant differences were found indicating a possible acclimation effect that was carried over from week one. The rise in rate efficiency corresponds to the stabilization of the membranes by day three, demonstrating the close relationship that exists between the two methods of analysis. The plants exhibited no significant difference in electron rate response during the second week which may be evidence of an adaptation to the higher temperatures presented in week one.

PRACTICAL APPLICATION

High temperature is considered one of the more serious abiotic factors contributing to the reduction in cotton yields. This yield reduction has led to screening techniques that can rapidly assess whether a particular cultivar is tolerant to the high temperature stress. By demonstrating that cotton has the potential to acclimatize to a given effect demonstrates the need to be cognizant when developing sampling periods in future experiments.

ACKNOWLEDGMENTS

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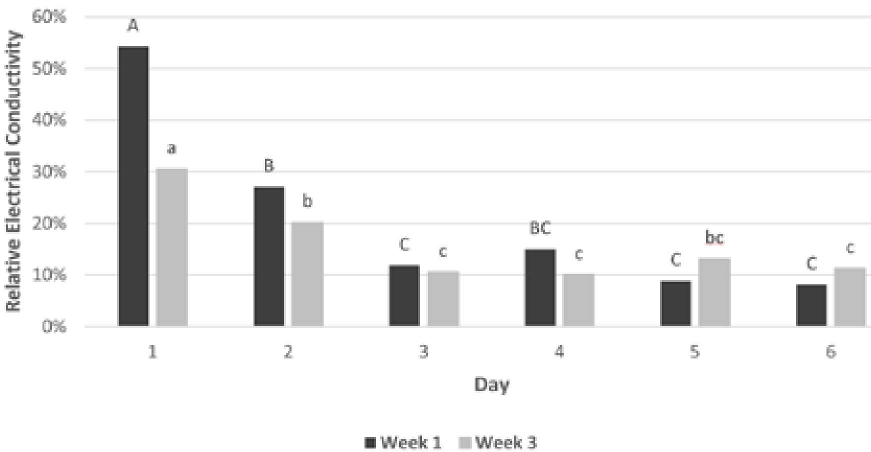

Fig. 1. Daily membrane measurements taken for six days during each high temperature manipulation. Membrane leakage expressed in relative electrical conductivity from the control is shown for week one of the experiment and for the third week of the experiment when temperatures were increased to 40 °C. Dark bars with the same capital letters are not significantly different (*P* = 0.05). Light bars with the same lowercase letters are not significantly different (*P* = 0.05).

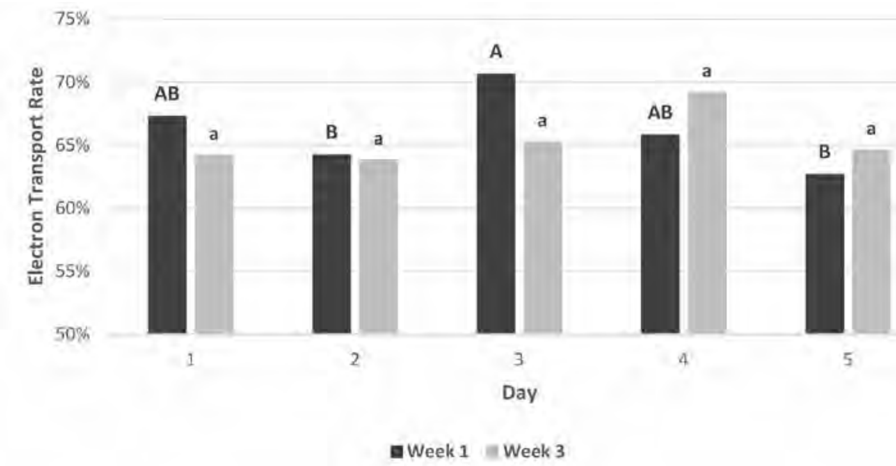

Fig. 2. Electron transport rates are shown for five days of both weeks the third week of the experiment when temperatures were increased to 40 °C. Darker bars with the same capital letters are not significantly different (*P* = 0.05). Lighter bars with the same lowercase letters are not significantly different (*P* = 0.05).

Molybdenum and Abscisic Acid Effects on Cotton Under High Night Temperature Stress

F.R. Echer, D.M. Oosterhuis, D.A. Loka[1], and C.A. Rosolem[2]

RESEARCH PROBLEM

High night temperatures (HNT) have been reported to result in increased respiration and decreased carbohydrate content in cotton (Loka and Oosterhuis, 2010) and lower yields (Arevalo et al., 2008). In addition, shedding rates and reproductive dry matter production are also decreased under HNT occurring during squaring and flowering (Arevalo et al., 2008; Echer et al., 2012). Apart from planting dates and cultivar adoption, producers have few options to deal with temperature stress.

BACKGROUND INFORMATION

High temperatures have a detrimental effect on cotton growth and yield. The optimum temperatures for cotton are reported to be 68-86 °F (Reddy et al., 1991), but both high day temperatures and high night temperatures can affect cotton growth and yield. The cotton plant is particularly sensitive to high day temperatures during the reproductive stage (Snider et al., 2009). However, Gipson and Joham (1969) reported that night temperatures have a greater impact on controlling flowering than day temperatures. High night temperatures are considered responsible for increased fruit shedding (Hesketh and Low, 1968; Arevalo et al., 2008), decreased boll setting (Brown et al., 1995), inhibition of photosynthetic function (Reddy et al., 1991), increased respiration and decreased carbohydrates content (Loka and Oosterhuis, 2010), decreased reproductive dry matter production (Echer et al., 2012) and lower yields (Arevalo et al., 2008).

Molybdenum ions (Mo^{4+} through Mo^{6+}) are components of several enzymes, including nitrate reductase and nitrogenase, and also a cofactor of aldehyde oxidases that are involved in abscisic acid (ABA) synthesis (Taiz and Zeiger, 2010). As a consequence of Mo deficiency, flower formation may be prevented or the flowers may abscise prematurely (Taiz and Zeiger, 2010). Although plants require only small amounts of Mo, some soils may be deficient, mainly acidic soils (Lu-

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cas and Davis, 1961). Abscisic acid is recognized as an important plant hormone, and is involved in growth inhibition and stomatal opening, particularly when the plant is under environmental stress (Taiz and Zeiger, 2010). Abscisic acid has been shown to regulate the expression of numerous genes during seed maturation and under certain stress conditions, such as heat shock, adaptation to low temperatures, and salt tolerance (Rock, 2000). The ABA and stress-induced genes are presumed to contribute to adaptive aspects of induced tolerance. The objective of this study was to investigate the effect of molybdenum and abscisic acid supply on cotton plant growth and reproductive development under elevated night temperatures.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) cultivar Stoneville 5288B2RF was grown in 2-L pots of washed sand (Quikrete®**)** in large growth chambers (Conviron PGW36, Conviron Inc., Winnipeg, Canada) at the Altheimer Laboratory, University of Arkansas, Fayetteville, Ark. The growth chambers were set for 60% humidity and a 12 h photoperiod and plants were grown under normal day/night temperatures (32/24 °C) for 35 days (5 days after first square appearance), after which the night temperature was increased to 30 °C for 4 h (i.e., the dark period was from 20h00 until 00h00) for 3 weeks. The experimental design was complete block design with 6 replications. Treatments consisted of normal and high night temperature and with and without Mo in the Hoagland´s solution which was applied daily:

1. Normal Night Temperature + Molybdenum (Mo)
2. Normal Night temperature – Mo
3. Normal Night temperature + ABA (-Mo) 100 µM ABA
4. Normal Night temperature + ABA (+Mo) 100 µM ABA
5. High Night Temperature + Mo
6. High Night Temperature - Mo
7. High Night Temperature + ABA (- Mo) 100 µM ABA
8. High Night Temperature + ABA (+ Mo) 100 µM ABA

One day before the high night temperature stress was imposed, ABA was sprayed on the 4th true leaf at a concentration of 100 µM, and all plants were sprayed with mepiquat chloride (1.6 ml/L). Measurements of flower appearance and fruit shedding were recorded daily and yield components were determined one week after the stress period. Means were compared using Student’s t-test at $P = 0.05$.

RESULTS AND DISCUSSION

Plants under high night temperature stress supplied with Mo but without ABA yielded less seeds per boll than all other arrangements (Fig. 1). Furthermore the number of reproductive structures was increased by ABA in plants under normal night temperature (24 ºC) and Mo supply (Fig. 2); whereas under the high night temperature treatment, ABA application provided an increased number of reproductive structures in plants that grew without Mo supply. Total reproductive dry weight was increased due to ABA application in plants grown at normal night temperatures with adequate Mo supply (Fig. 3); however no significant effect of ABA or Mo application was observed under high night temperatures. Our results indicated that ABA application prevented high night temperatures from decreasing the number of seeds per boll and the number of reproductive structures per plant whereas Mo supply was not observed to have a significant effect on ameliorating the negative effects of high night temperature stress

PRACTICAL APPLICATION

Abscisic acid and molybdenum have important roles in reducing the effects of high night temperatures on cotton. The understanding of the effects of hormones and their interaction with crop nutrition is important to deal with the stress caused by high night temperatures.

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Table 1. Day/night temperatures in high night (H) and control (C) treatments.

	Time/Temperature °C												
	---am---						---pm---						
	0	**6**	**7**	**9**	**10**	**11**	**12**	**16**	**17**	**18**	**19**	**20**	**23:59**
H	24	24	25	28	29	30	32	32	30	30	30	30	30
C	24	24	25	28	29	30	32	32	30	29	29	24	24

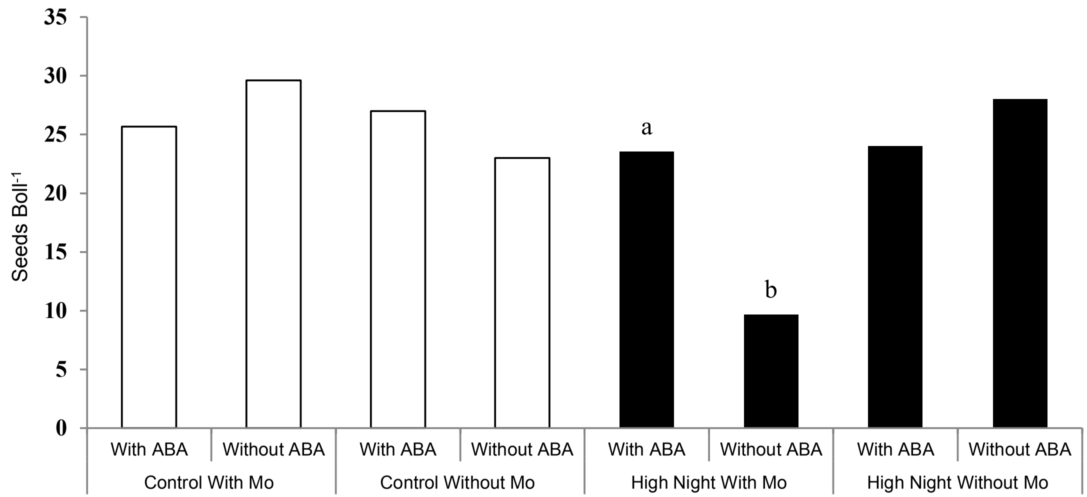

Fig. 1. Effects of high night temperatures, molybdenum and abscisic acid (ABA) on number of seeds per boll. Control = 24 °C (white bars) and high night temperature = 29 °C (black bars). Abscisic acid was applied at a concentration of 100 µM and molybdenum at 0.05 ppm via Hoagland´s solution. Least significant difference (LSD) = 10.85 (0.01).

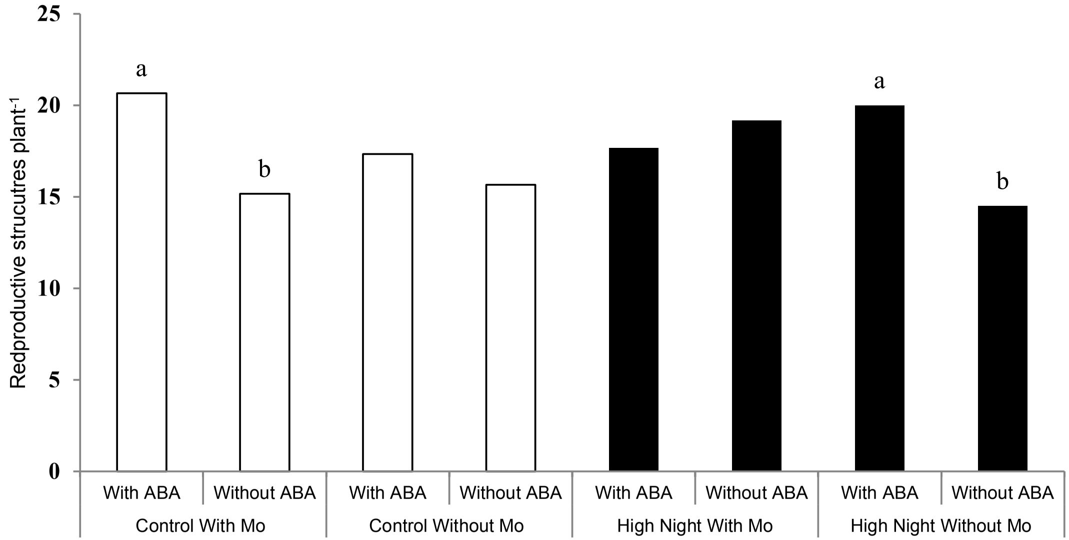

Fig. 2. Effects of high night temperatures, molybdenum and abscisic acid (ABA) on reproductive structures number. Control = 24 °C (white bars) and high night temperature = 29 °C (black bars). Abscisic acid was applied at a concentration of 100 µM and molybdenum at 0.05 ppm via Hoagland´s solution. Least significant difference (LSD) = 3.29 (0.001).

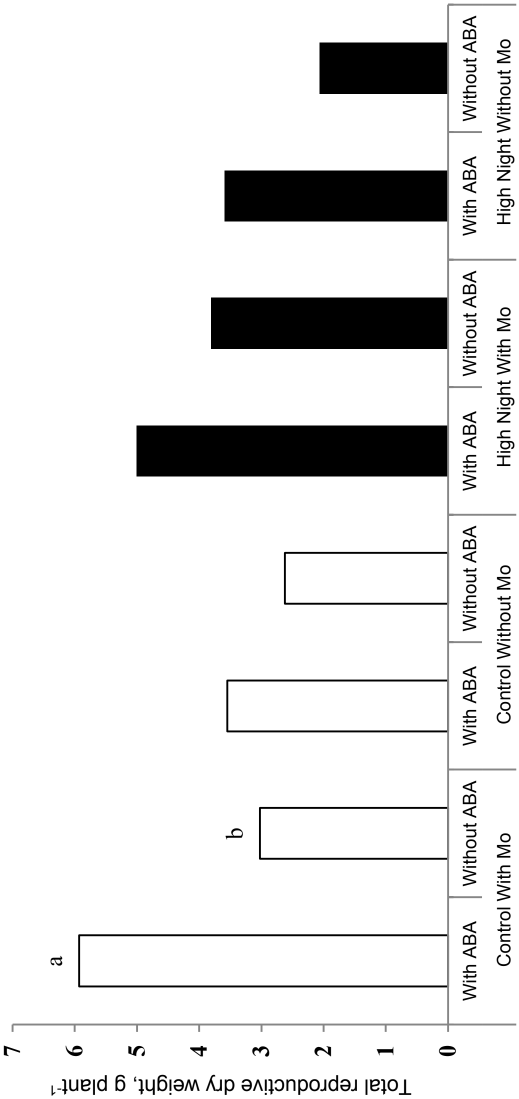

Fig. 3. Effects of high night temperatures, molybdenum and abscisic acid (ABA) on total reproductive dry weight. Control = 24 °C (white bars) and high night temperature = 29 °C (black bars). Abscisic acid was applied at a concentration of 100 µM and molybdenum at 0.05 ppm via Hoagland´s solution. Least significant difference (LSD) = 1.91 (0.003).

Development of 1-Methylcyclopropene Application Triggers in Cotton Production

D.M. Oosterhuis, T.B. Raper, C. Pilon, and J.M. Burke[1]

RESEARCH PROBLEM

One major concern of cotton producers and consumers is the extreme year-to-year variability in yield (Lewis et al., 2000). Variability in cotton yield is associated with many factors and temperature appears to play a major role. High temperatures limit growth and development processes in much of the cotton producing areas (Reddy et al., 2002). Cotton has been shown to be particularly sensitive to high-temperature stress during flowering (Snider et al., 2009). When plants are under stress they increase the production of the plant hormone ethylene, which is a stress hormone known for its role in the regulation of fruit abscission processes (Guinn, 1982). The current project was designed to evaluate the effectiveness of the anti-ethylene compound 1-methylcyclopropene (1-MCP) to counteract the effects of stress and maintain fruit and seed numbers for increased yield. As a result, higher and less variable yields could be achieved without undue changes in management and production costs.

BACKGROUND INFORMATION

The plant growth regulator 1-methylcyclopropene works by occupying the ethylene receptors of plants, and thereby inhibiting ethylene from binding and initiating a response such as abscission or senescence (Sisler and Serek, 1997). The affinity of 1-MCP for the ethylene receptor sites is 10 times greater than that of ethylene. The use of 1-MCP in cherry tomatoes and citrus has been shown to prevent and delay fruit abscission (Beno-Moualem et al., 2004). It has also been reported that a 1-MCP application on field-grown cotton increased yield (Kawakami et al., 2006). However, the response of field-grown cotton to application of 1-MCP is often inconsistent, in part due to application timing and the nature of the stress the cotton crop is experiencing. The objective of this study was to examine plant stress indicators' canopy temperature and ambient temperature to predict crop stress and therefore indicate application timing of 1-MCP.

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RESEARCH DESCRIPTION

Field studies were conducted at the University of Arkansas Lon Mann Cotton Research Station in Marianna, Ark., and the Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. Treatments consisted of two planting dates to increase the potential for heat stress during flowering (18 May and 8 June for Fayetteville, 14 May and 30 May for Marianna). Both trials were planted with cotton (*Gossypium hirsutum* L.) cultivar Stoneville 4288B2RF. Weed and pest management were performed according to University of Arkansas Cooperative Extension Service recommendations. Canopy temperature was measured by Apogee SI-121 infra-red canopy temperature sensors (Apogee Instruments, Inc., Logan, Utah) and data was collected by a Campbell Scientific CR1000 datalogger (Campbell Scientific, Inc., Logan, Utah).

Application of 1-MCP was based on two application triggers. The first consisted of application when canopy temperature rose above the ambient air temperature after first flower. The second application trigger was when there was a forecast of three consecutive days exceeding 35 °C. Under both triggers, the maximum acceptable application was defined as three events; and after each application, a 5-day no-application window was established. Seven days after each application, fruit shed was determined from 2 m of row in each plot. End of season measurements included mechanical harvest (Marianna, Ark.) and hand harvest of a 1-m section of each plot. Measurements included boll number, lint yield, and lint percentage per meter.

RESULTS AND DISCUSSION

The canopy temperature trigger was not met during the trial at either location. This was due in part to relatively mild heat stress during the flowering period in both trials. As a result, only the ambient trigger, defined as three days with forecasted ambient air temperatures greater than 35 °C during flowering, was tested. In Fayetteville, the early planting date (18 May) met the conditional trigger requirements three times during the growing season, resulting in a total of 75 g ai 1-MCP/ha applied to the treated plots. Since the second planting date was planted just over two weeks after the first planting date (6 June), almost all of the heat stress was experienced by the crop in the pre-squaring and squaring stages. Consequently, the second Fayetteville planting date only received one application of 1-MCP, resulting in a total of 25 g ai 1-MCP/ha applied to the treated plots. Similar temperature trends occurred in Marianna, and as a result only one application of 1-MCP was made to the first planting date (14 May).

Analysis of fruit shed after each application resulted in no significant differences due to application of 1-MCP at either location, although planting date effect on fruit shed was significant in Fayetteville ($P \leq 0.05$). Lint yield was also affected significantly by planting date in Fayetteville ($P \leq 0.05$) with the later planting date yielding more lint than the earlier date. In contrast, there was not a significant difference in any measured yield parameter associated with application of 1-MCP. Due to the abnormally high temperatures at squaring, an early-season treatment appears to have been more appropriate for the 2012 season, and this will be investigated in the planned field study for 2013.

PRACTICAL APPLICATION

Although prior studies have reported applications of 1-MCP to be associated with increases in field-grown cotton yield, no significant differences in yield parameters were noted in either Arkansas trial. More research is necessary to better define application triggers during sensitive growth periods.

ACKNOWLEDGMENTS

Support for this research was provided by AgroFresh. Special thanks to the staff at the Lon Mann Cotton Research Station, Marianna, Ark., for field maintenance support.

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Evaluation of a Calcium-Containing, Soil-Applied Nitrogen Source to Increase Cotton Yields

T.B. Raper, D.M. Oosterhuis, C. Pilon, and J.M. Burke[1]

RESEARCH PROBLEM

Nitrogen recovery efficiency (NRE) by cotton (*Gossypium hirsutum*, L.) has been shown to vary from 12% to 30% in furrow-irrigated systems (Bronson, 2008; Constable and Rochester, 1988). Failure of a crop to recover and utilize the majority of the applied N has far reaching financial and environmental implications. Fertilizer input costs have steadily risen with time; annual average fertilizer costs nearly tripled in the period from 2002 to 2012 alone (USDA-ERS, 2012). Environmental repercussions from over-application of N range from accumulation of nitrates in the subsoil to groundwater pollution (Boquet and Brietenbeck, 2000). Although less than optimum N rates reduce the amount of nitrates in the subsoil (McConnell et al., 1993), insufficient N can drastically reduce yields (Bondada and Oosterhuis, 2001; Wadleigh, 1944) and therefore result in poor stewardship through inefficient utilization of other applied inputs.

BACKGROUND INFORMATION

One of the most common fertilizers used on cotton in the Mississippi River Delta is 32% UAN, which is a mixture of urea and ammonium nitrate. The N in this fertilizer is susceptible to volatilization, leaching, and denitrification. As a result, N fertilizer is recommended by the University of Arkansas Cooperative Extension Service to be applied in a split application to reduce N loss and increase NRE. Another method which has been shown to increase NRE, and therefore increase yields at lower applied N rates, is the utilization of fertilizers which contain calcium (Ca) (Ron and Loewy, 2007; Gately, 1994). Research has indicated that the addition of soluble Ca can increase ammonium uptake (Taylor et al., 1985) and reduce ammonia losses (Fenn et al., 1981; Witter and Kirchmann, 1989). Some studies have also shown synergistic effects when Ca and urea were used in combination (Horst et al., 1985). As a result of these studies and others, Yara (Yara North America Inc, Tampa, Fla.) has developed a new liquid N fertilizer containing Ca. This product, UCAN-23, contains a total N concentration of 23%

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N, with 8% in the form of nitrate, 5% in the form of ammonium and 10% in the form of urea. The fertilizer also contains 4% Ca. The main objective of this research was to examine the response of field-grown cotton to UCAN-23 in contrast to the commonly used UAN-32.

RESEARCH DESCRIPTION

A randomized complete block trial with five replications was designed and conducted at two locations in the 2012 growing season. The trial at the Lon Mann Cotton Research Center in Marianna, Ark. consisted of 4-row plots 50 ft in length. The trial at the Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. consisted of 4-row plots 20 ft in length on 36-in wide rows. Soil samples were taken in early February for the Marianna and the Fayetteville sites and sent to the Soil Testing and Research Laboratory at Marianna for analysis.

The cultivar Stoneville 4288 B2RF cotton was planted at a seeding rate of 3.5 seeds per ft on 18 May and 14 May for the Fayetteville and Marianna sites, respectively. Treatments consisted of 0 lb N/acre (control) and rates of 50, 75, and 100 lb N/acre from the N sources UCAN-23 and UAN-32. Fertilizer N applications were surface dribbled within 6 inches of the row and applied in split applications, with 12 lb N/acre applied after emergence and the remaining (38, 63, or 88 lb N/acre) split treatment applied during the second week of squaring. All other inputs were managed to assure that N was the only yield-limiting factor. After defoliation, 39.5 inches of row were hand-picked from the Marianna plots to determine boll number and ginned through a micro-gin to determine lint percentage. After hand-picking, a mechanical picker with a weigh cell harvested the center two rows of each 4-row plot to determine seedcotton yield. At the Fayetteville site, 79 inches of row were hand harvested to determine boll number and after ginning with a micro-gin, lint weight and lint percentage were determined.

Statistical analysis tested fertilizer N rate (0, 50, 75, and 100 lb N/acre), N source (UCAN-23 and UAN-32), and interaction between fertilizer N rate and source on the response variables of lint yield, boll number, and boll weight. Linear and quadratic yield and boll number responses for fertilizer N rate were tested and evaluated at a significance level of $P \leq 0.10$.

RESULTS AND DISCUSSION

Soil test reports from both sites indicated sufficient soil Ca concentrations (Table 1) and recommended a N rate for cotton of 90 lb N/acre. Visible differences between the control and treated plots were evident soon after the application of the second split application in Fayetteville. Unfortunately, the Fayetteville trial received severe hail damage within 2 weeks of the second application, from which the crop never fully recovered. Still, the response of lint yield and boll number to fertilizer N rate were significant at the $P \leq 0.10$ and $P \leq 0.05$ levels, respectively. Both aforementioned significant response variables increased positively and linearly as fertilizer N rate increased (Fig. 1). Source of N did not significantly affect yield. The hail damage at the Fayetteville location prevented the establishment of strong N stress, as yield potential was destroyed.

Visible differences between the control and N-treated plots were also evident at the Marianna site soon after the second N (split) application was made, however a significant rainfall event did not occur to move the fertilizer down the profile from the top of the bed. As a result, the stained fertilizer band was visible on the bed late into the boll-fill stage. Still, the quadratic response of lint yield to fertilizer N rate was significant ($P \leq 0.10$) suggesting the optimum N rate was reached and exceeded by the 100 lb N/acre rate. The agronomically optimum fertilizer N rate was 73 lb N per acre (Fig. 1). Leaf-blade analysis did not indicate significant differences in total N relative to source, but did indicate significant increases associated with increasing rate independent of source ($P \leq 0.05$) (data not shown). No significant differences in leaf Ca concentrations were noted with the calcium containing N source (data not shown). As in the Fayetteville trial, boll number was also significantly increased by increased fertilizer N rate ($P \leq 0.05$), but average boll weight was not significantly affected. This is most likely due to the ability of the cotton plant to shed bolls which it cannot adequately fill. Failure of increased N fertilizer rate to significantly increase average boll weight has also been noted in prior studies (Bondada and Oosterhuis, 2001). Also, the source of fertilizer N did not have a significant impact on seedcotton yield at the Marianna site. Failure of N source to affect yield parameters may in part be due to high concentrations of Ca already present in the soil. According to the University of Arkansas Cooperative Extension Service, Ca deficiencies are not commonly observed in soils above 400 ppm or in soils where the pH is maintained in the recommended range (Espinoza et al., 2012).

PRACTICAL APPLICATION

Lint yield response to fertilizer N at the Marianna site supports results of previous research which suggest excessive N applications can negatively impact yield. Although significant differences were not noted between cotton receiving UAN-32 and UCAN-23 at either tested site, Ca concentrations and soil pH at both sites were within the sufficient range for optimal cotton production. More research must be conducted to determine if UCAN-23 has a positive effect on cotton yield in fields that possess insufficient soil Ca concentrations or low soil pH.

ACKNOWLEDGMENTS

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Table 1. Soil test results from samples taken from both trials in early February 2012. The result for the Marianna site is the value of one composite soil sample. The results for the Fayetteville site represent the range from four composite samples.

Mehlich-3-extractable soil calcium			
Location	Calcium content of soil	Estimated base saturation	pH (1:2 soil-water)
	----------ppm Ca----------	----------% Ca----------	
Marianna, Ark.	967	52.1	7.1
Fayetteville, Ark.	1010-1121	59.6-62.1	6.7-6.9

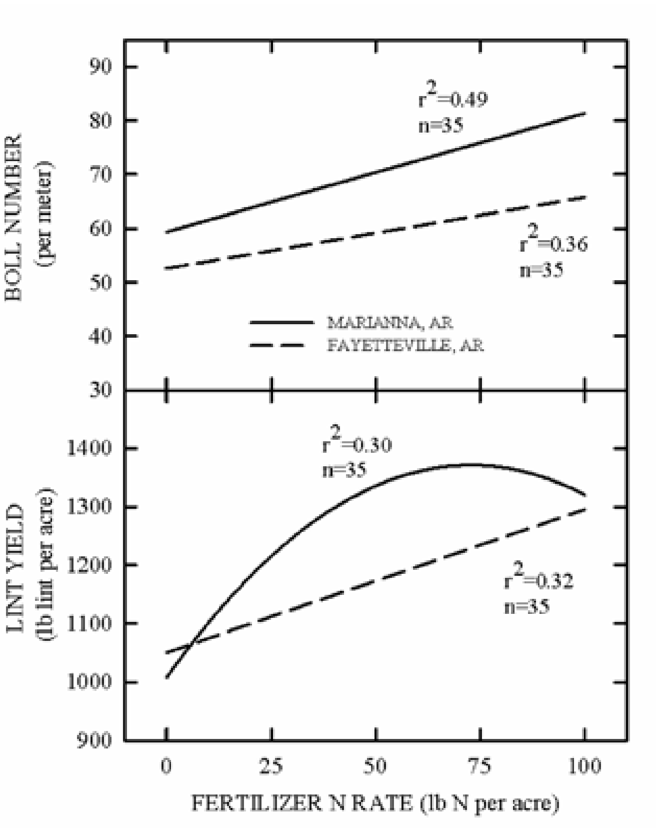

Fig. 1. Response of boll number and lint yield, in bales/acre, to fertilizer N rate during the 2012 growing season.

Yield Response of Cotton to Timing of Potassium Fertilization Under Deficient Soil Test Levels

L. Espinoza[1], M. Ismanov[2], and P. Ballantyne[1]

INTRODUCTION AND BACKGROUND INFORMATION

Potassium (K) plays an important role in fiber development and fiber quality. Deficient amounts of this nutrient will result in reduced yields and short fibers since K provides pressure inside the fiber cell walls, which is necessary for elongation (Ruan et al., 2001). The decrease in root activity after flowering, and the use of high-yielding, faster-fruiting cotton (*Gossypium hirsutum* L.) cultivars requiring a greater demand during boll filling (Oosterhuis, 1995) makes the correction of a nutrient deficiency in cotton difficult. Understanding when soil-applied fertilizers are no longer effective is critical for optimizing cotton yield. The objective of this experiment was to assess the yield response of cotton to K fertilizer applied at different growth stages, under deficient soil K level, and to determine at what growth stage granular K is no longer an option.

RESEARCH DESCRIPTION

An experiment was established at the Lon Mann Cotton Research Station at Marianna, Ark. from 2010 to 2012. The soil has been mapped as a Memphis silt loam (fine silty-mixed, thermic, Typic Hapludalfs). Treatments consisted of 0 and 60 lb K_2O/acre, as muriate of potash, applied once at first square, first flower, and 200, 400, 600, and 800 heat units after first flower in 2010 and at emergence, first pinhead square, first flower, 200, 400, and 600 heat units after first flower during 2011 and 2012. The K-fertilizer was hand broadcast to designated plots and later incorporated with irrigation. Plants began squaring on 15 June, with the K-fertilizer applied on 17 June (first square treatment). The remaining treatments were applied on 7, 15, 21 July and 8 August 2010. During 2011, plants began squaring on 16 June, with K-fertilizer applied on 17 June (first square treatment). The remaining treatments were applied on 11, 18, 26 July and 2 August 2011. In 2012, plants began squaring 5 June, with potassium fertilizer applied 6 June. The remaining treatments were applied 9, 19, 27 July and 6 and 15 August. Each plot consisted of 4 rows, 38 in wide by 45 ft long. Treatments were arranged as a

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randomized complete block design, and were replicated four times. Cotton variety Phytogen (PHY) 375 WRF was planted at the rate of 40,000 seeds per acre on 6 May 2010, with cotton variety Stoneville 5458 B2F planted 7 May 2011. During 2012 two varieties, DPL 0912 and Stoneville 5458 B2F, were planted on 8 May. Nitrogen (N) was applied at the rate of 100 lb N/acre, with 60 lb N/acre applied at emergence and 40 lb N/acre applied at first square. Irrigation (furrow) and weed and insect control were performed according to University of Arkansas Cooperative Extension Service recommendations.

Soil samples (0-6 in deep) were collected prior to planting and analyzed according to Mehlich-3 standard procedure, with soil pH measured in a 1:2 (volume) soil-water mixture. The COTMAN crop monitoring program (Oosterhuis and Bourland, 2008) was used to assess differences in crop development among treatments from squaring to physiological cutout. At harvest, the two middle rows from each plot were harvested with a plot picker equipped with a weight system. Average yields were calculated and analyzed using analysis of variance with mean separation using least significant difference at the 0.10 level.

RESULTS AND DISCUSSION

The levels of selected soil chemical parameters are shown in Table 1. Average soil pH for the surface soil samples was 7.0. The soil test phosphorus level (55.4 ppm) and soil-test K (110.2 ppm) are considered "Optimum" and "Medium", respectively for phosphorus (P) and K, according to Cooperative Extension Service guidelines. The study site had not received K fertilizer since 2005; typical K-deficiency symptoms (interveinal chlorosis initially that changes to a bronze-orange color) were obvious in those plots not receiving any K fertilizer. Potassium deficiency symptoms first appeared during the first weeks of first flower.

The COTMAN graph (Fig. 1) is for DPL 0912. It shows earlier squaring initiation in plants that received no K, or 60 lb K_2O/acre by first flower and first pinhead square. Similarly to the 2010 and 2011 seasons, plants growing under both, deficient and sufficient K, conditions developed similar fruiting structures, with the effect of deficient K levels becoming obvious after the plants had bloomed.

It is commonly accepted that the onset of K-deficiency symptoms in cotton occurs relatively late in the season as most of the demand for K occurs during the boll filling period. During the 2012 season, plants that received potassium later in the season, reached physiological maturity earlier than those receiving K by first flower.

Results from the applications of granular K-fertilizer after flowering were effective in recovering some of the potential yield losses due to suboptimal soil-test K levels (Table 2). However, earlier applications resulted in larger yield gains. When the fertilizer was applied by first square, 665 and 340 lb/acre seed cotton, above the control, were obtained in 2012 for DPL 0912 and STO 5458, respectively. As applications were delayed beyond 400 heat units past first flower, yield gains were significantly reduced. The 2010, 2011, and 2012 growing seasons were characterized by low rainfall and high temperatures, resulting in heat units accumulating significantly faster than in previous years. The yield response of cotton to applications of K-fertilizer during a year that follows historical weather trends could be drastically different than the response observed during the years of these studies.

The detrimental effects of K-deficiency in cotton are not typically obvious by the first or second week of flowering. In this study, plants growing under K-deficient conditions had similar numbers of first position bolls, when compared to plants growing with sufficient K. When yields were separated by boll position on a sympodial node, it was obvious that a significant portion of the yield differences among plants growing under deficient and sufficient K, could be attributed to reduced second and third positions bolls.

PRACTICAL APPLICATION

The objective of this study was to determine when granular K fertilizer is no longer effective for ameliorating a K-deficiency in cotton. Results from the 2010, 2011 and 2012 seasons show that granular K fertilizer applied as late as 400 heat units beyond first flower was effective in reducing the yield loss potential associated with deficient soil-K levels. Higher seed cotton yields were obtained when the fertilizer was applied at first square, and were significantly reduced when the fertilizer was applied 600 and 800 heat units after first flower. Growing cotton at suboptimal soil-test K levels resulted in more than 700 (2010), 400 (2011) and 665 (2012) lb/acre seed cotton that were not realized. These results underscore the importance of soil testing and proper fertilization

ACKNOWLEDGMENTS

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Table 1. Average Mehlich-3 levels for selected soil chemical properties and associated standard deviations at the study site.

Parameter	Average	Std Dev
	------------------ ppm ----------------------	
P	55.4	8.2
K	110.2	19.9
S	15.3	9.2
N-Nitrate (ISE)	20.1	2.9
pH(water)	7.0	0.3

Table 2. Average seed cotton yield response to K treatments. Potassium was applied at a single rate of 60 lb K_20/acre. Yields followed by the same letter are not statistically different.

	Mean Yield			
Treatment Description	-----2010----	----2011-----	------------2012-------------	
	---------------------lb/acre Seed Cotton--------------------			
			DPL 0912	STO 5458
Untreated check	2224 c	2845 c	2998 c	3125 b
Emergence	---	3280 a	3832 a	3410 ba
First PinheadSquare	2945 a	3258 a	3663 ba	3465 a
First Flower	2897 a	3250 a	3580 ba	3505 a
First Flower + 200 Heat Units	2811 a	3231 a	3431 b	3398 ba
First Flower + 400 heat units	2697 ba	3144 ba	3442 b	3291 ba
First Flower + 600 Heat unit	2551 b	2953 b	3300 c	3144 b
First Flower + 800 Heat units	2514 b	---	--	
LSD (0.10)	249	199	346	317
CV (%)	8.8	6.1	8.1	7.8

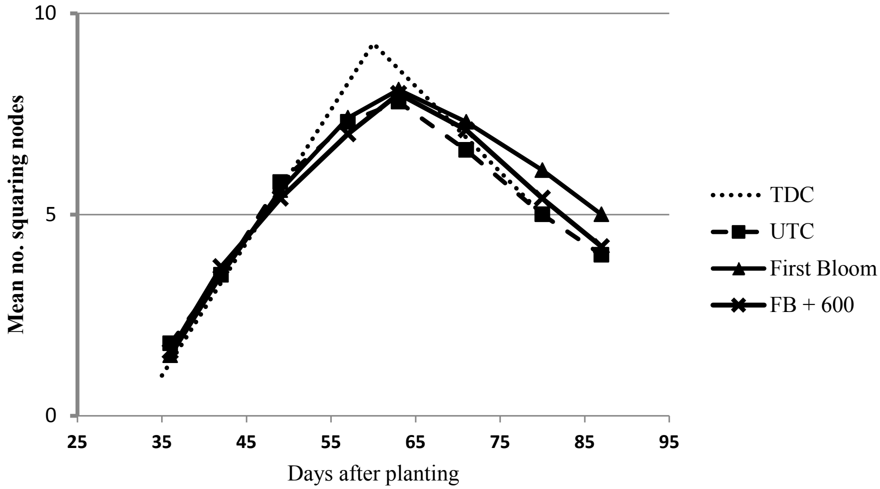

Fig. 1. Average nodes above first square and nodes above white flower development for the control treatment and for the treatment consisting of 60 lb K_2O/acre at first bloom and at 600 heat units past first bloom. Each point in the graph represents the average of 30 plants. The dotted line represents the target development curve (TDC) for cotton growing under optimum conditions. UTC is the untreated check.

Sensitivity Analysis of Two Canopy Nitrogen Stress Indices to Variety and Available Potassium

T.B. Raper, D.M. Oosterhuis, L. Espinoza, C. Pilon, and J.M. Burke[1]

RESEARCH PROBLEM

Recent advances in technology and the increased availability of canopy reflectance hardware has resulted in the development and utilization of vegetation indices to drive on-the-go variable rate applications of fertilizer nitrogen (N). Although the spectral response of crops to N stress has been thoroughly defined (Samborski et al., 2009), the spectral response to differing varieties and available potassium (K) quantities have not been examined in such detail. As a result, sensitivities of these indices to variables other than N deficiency have been shown to result in over application of N when N is not the most limiting yield factor (Zillman et al., 2006).

BACKGROUND INFORMATION

Leaf reflectance measured by a spectrometer is typically sensitive to changes in N status; however, research has shown a deterioration of this relationship when K is not sufficient (Fridgen and Varco, 2004). Further complicating sensor-driven, variable rate applications of N, K deficiency symptoms may appear unpredictably (Oosterhuis and Weir, 2010), even on soils with sufficient soil-test K levels (Cope, 1981). Moreover, the large spectrum of varieties in upland cotton production encompasses vastly different structural features and physiological maturity patterns. The most frequently utilized index, normalized vegetation difference index (NDVI), has been reported to be sensitive to variety during the flowering period, with relationships deteriorating later in the growing season (Benitez Ramirez and Wilkerson, 2010).

Although neither the response to variety nor available K is typically considered in the development of a canopy reflectance-based, N-sensitive index, the responses of each index to these variables must be considered to prevent inaccurate N fertilization and subsequent environmental and financial repercussions. Therefore, the main objective of this research was to examine the response of two contrasting indices to variety and changes in available K.

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RESEARCH DESCRIPTION

A randomized strip, complete block trial with five replications was conducted in 2012 at the Lon Mann Cotton Research Center in Marianna, Ark. A more complete description of methods and results can be found in Raper et al. (2013). Soil samples were taken from bed shoulders at 6-inch depths from each plot (60 total plots) on 31 January 2012 and analyzed by Mehlich-3 extraction. Treatments consisted of an untreated check (0 lb K_2O/acre), 30, 60, and 90 lb K_2O/acre applied to Phytogen (PHY) 499 WRF, Stoneville 5458 B2RF, and DeltaPine 912 B2RF varieties. All other inputs and thresholds were established and maintained to isolate K as the sole yield-restricting input.

Reflectance measurements were taken on two dates (7 and 22 August 2012) after visible deficiency characteristics were evident using the Crop Circle ACS-470 (Holland Scientific Inc., Lincoln, Neb.). The center two rows of each plot were measured at a sensor-to-canopy height of 36 inches. Measured wavelengths were centered in the red (650 nm), red-edge (670 nm) and near infrared (760 nm) regions. Data was trimmed to exclude values taken within 5 feet of the plot ends. These wavelengths were then used to calculate two contrasting indices: NDVI, which has been shown to be sensitive to changes in plant structure and biomass (Bronson et al., 2003), and the Canopy Chlorophyll Content Index (CCCI) which has a heightened sensitivity to N stress and is less responsive to changes in plant biomass than NDVI (Raper and Varco, 2011). Seedcotton yield was determined by mechanical harvest of the center two 50-foot rows of each plot.

Regression analysis tested the response of seedcotton yield and index readings to changes in available K_2O. Analysis of variance was conducted for both reflectance dates and yield data in JMP 10 (SAS Institute Inc., Cary, N.C.). Independent variables in the model included block, available K, variety, and the interaction between available K and variety. The calculated amount of available K was chosen in lieu of the applied K fertilizer rate due to initial differences in soil K concentrations. Available K_2O was calculated as [(ppm soil-test K × 2 × 1.2) + lb K_2O fertilizer/acre] where 1.2 is the factor for converting K to K_2O and 2.0 is the factor for converting ppm to lb/acre assuming 2 million pounds soil/acre furrow slice.

RESULTS AND DISCUSSION

The response of seedcotton to changes in variety and available K_2O were significant ($P \leq 0.05$), as was the interaction between these two terms ($P \leq 0.10$). Results suggest increases in available K_2O did not significantly increase PHY 499 seedcotton yields, but did increase DeltaPine 912 and Stoneville 5458 yields. As evident by the available K_2O levels and relatively high yields, severe K deficiencies were not noted. Sufficient soil K may have contributed to the failure of PHY 499 yields to respond to increased available K_2O. Still, the moderately strong response of Stoneville 5458 and slight response of DeltaPine 912 does suggest that increased K_2O availability could increase yields within this range for these two varieties.

Visible K deficiency symptoms were noted in control plots during the first week of flower in Stoneville 5458 plots but were not consistent across the field until near peak flower. As a result, reflectance was measured at mid-flower (7 August 2012) and after peak flower (22 August 2012). Responses from both sampling dates were similar. The interaction effects between available K_2O and variety on NDVI readings were significant ($P \leq 0.10$; Fig. 1). However, CCCI was affected only by variety significantly, as available K_2O had no significant effect on CCCI ($P \leq 0.05$; Fig. 1).

Results suggest NDVI is sensitive to variety and changes in available K_2O. The interaction between variety and available K_2O suggests that individual models will have to be developed to characterize specific NDVI response to an individual variety's sensitivity to changes in available K_2O. In contrast, CCCI was affected only by variety significantly, which suggests that a variety-specific correction term could be developed and implemented. It should be noted that significant response of an index to variety should be highly preferred over the response of an index to available K_2O, because variety is spatially consistent.

PRACTICAL APPLICATION

The adoption of on-the-go sensor readings to drive variable rate N applications must incorporate some correctional factor for variety if NDVI or CCCI is used. Furthermore, it appears that NDVI-based algorithms have the potential to recommend increased fertilizer N when K deficiencies are present. In contrast, CCCI does not appear to be susceptible to such errors.

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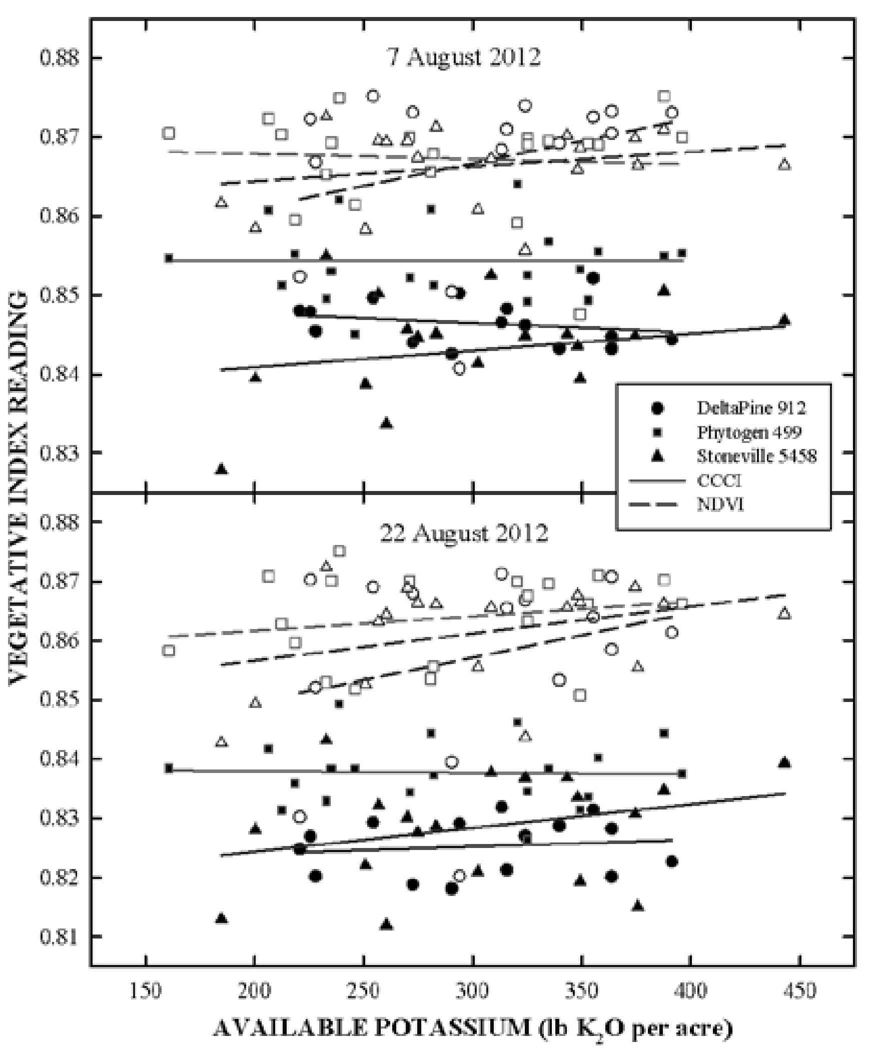

Fig. 1. Response of the Normalized Difference Vegetation Index (NDVI) and the Canopy Chlorophyll Content Index (CCCI) by variety to changes in available K_2O.

Effect of Urea Environmentally Smart Nitrogen on Cotton Yield in a Marvel Silt Loam in Arkansas

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RESEARCH PROBLEM

Nitrogen (N) fertilization is required for producing optimum Cotton (*Gossypium hirsutum* L.) yields in Arkansas. 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 growers with the opportunity to increase their N-use efficiency. A polymer-coated urea (44% N, Agrium Advanced Technologies, Loveland, Colo.) is currently being marketed in Arkansas under the trade name of Environmentally Smart Nitrogen or ESN[5]. The objective of this study was to evaluate furrow irrigated cotton response to ESN and urea fertilizers in two representative Arkansas soils used for cotton production.

RESEARCH DESCRIPTION

Two replicated cotton N fertilization experiments were conducted to evaluate cotton yield response to preplant application of urea, ESN and combinations of urea and ESN in 2012. One experiment was located at the Lon Mann Cotton Research Station (LMCRS) in Marianna on a Calloway silt loam and the other trial was located at Northeast Research and Extension Center (NEREC) in Keiser on a Sharkey silty clay. Before applying any fertilizer, soil samples were collected

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[5]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.

from the 0-to 6-inch depth and composited by replication. Soil samples were tested according to the current methods used by the University of Arkansas Soil Testing laboratory. Agronomically important information for all experiments is presented in Table 1.

Each experiment was a randomized complete block design with a factorial arrangement of four urea-ESN combinations each applied at five rates ranging from 30 to 150 lb N/acre at 30 lb N/acre increments and a no-N control. The four urea and ESN-N combinations were: 100% urea-N; 50% urea-N plus 50% ESN-N; 25% urea-N plus 75% ESN-N, and 100% ESN-N. Each treatment was replicated six times at LMCRS and five times at NEREC. We applied muriate of potash and triple superphosphate to supply 40 lb K_2O and P_2O_5/acre at both locations. All fertilizers (including the N fertilizer treatments) were hand applied before planting onto the soil surface and incorporated immediately with a Do-all cultivator. The cotton was furrow irrigated as needed and closely followed the University of Arkansas Cooperative Extension Service cultural recommendations for irrigated-cotton production. Analysis of variance was performed using the GLM procedure of SAS (SAS Institute, Inc., Cary, N.C.). When appropriate, means were separated by the least significant difference (LSD) method and interpreted as significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

Average soil properties in the 0- to 6-inch depth were 52 ppm P, 139 ppm K, 6.8 pH, 23% clay, and 25 ppm NO_3-N at the LMCRS and 60 ppm P, 237 ppm K, 6.7 pH, and 44% clay at the NEREC. Neither N source, nor the N source × N rate significantly influenced seedcotton yield at either site ($P \leq 0.10$, Table 2). Seedcotton yields at both sites were significantly ($P \leq 0.0001$) affected by N-fertilizer rate. Averaged across the four urea and ESN blends, the seedcotton yield of cotton that received no N fertilizer averaged 2849 lb/acre at the LMCRS and 1278 lb/acre at the NEREC, highlighting the yield potential difference between the two locations. At each site, seedcotton yield increased numerically with increasing N application rate. Application of 150 lb N/acre produced the numerically highest seedcotton yields at both sites. The minimum N rate that produced the statistically greatest seedcotton yield at each site was 120 lb N/acre.

PRACTICAL APPLICATION

The amount of precipitation in the 2012 growing season was well below normal, Nitrogen application rate significantly increased seedcotton yields and maximal yields were produced by 120 lb. N/acre at both the LMCRS and NEREC. Averaged across N rates, seedcotton yields were not different among the various combinations of urea and ESN fertilizers at either site. Averaged across N sources, cotton yields were not different among the various combinations of urea and ESN. These results suggest that ESN can be preplant-incorporated in irrigated cotton production in Arkansas.

ACKNOWLEDGMENTS

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Table 1. Selected agronomically important information for cotton and corn N fertilization trials established at the Lon Mann Cotton Research Station (LMCRS) and Northeast Research and Extension Center (NEREC) during 2012.

Location	Previous crop	Soil series	Cultivar	Planting date	N application date	Harvest date
LMCRS	cotton	Loring silt loam	Phytogen 375	4 May	3 May	29 Oct
NEREC	cotton	Sharkey silty clay	Stoneville 5458	18 May	15 May	4 Oct

Table 2. Seedcotton yield as affected by the non-significant N source and N source × N rate interaction ($P > 0.10$) and significant ($P \leq 0.0779$) N rate (averaged across N sources) effect for two cotton N fertility experiments conducted at Lon Mann Cotton Research Station and Northeast Research and Extension Center in 2012.

	N fertilizer combination (%)				
	100%	50% Urea-N	25% Urea-N	100%	
N rate	Urea-N	50% ESN-N[a]	75% ESN-N	ESN-N	N rate mean
lb N/acre	Lon Mann Cotton Research Station				
	Seedcotton yield (lb/acre)				
0	2849[b]				
30	2786	3159	3215	3059	3042
60	2996	2820	3535	3139	3105
90	2969	3272	2958	3350	3122
120	3380	3467	3297	3154	3324
150	3249	3285	3224	3670	3357
LSD 0.10	NS[c]				214[d]
P value	0.1843				0.0779
lb N/acre	Northeast Research and Extension Center				
	Seedcotton yield (lb/acre)				
0	1278[b]				
30	1922	2009	1701	1886	1878
60	2443	2045	2310	2068	2217
90	2467	2474	2211	2639	2448
120	2870	2595	2771	2779	2754
150	2956	3024	2745	2331	2764
LSD 0.10	NS[c]				183[d]
P value	0.1047				< 0.0001

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

The Effect of Source of Biochar on Cotton Seedling Growth and Development

J.M. Burke, D.E. Longer, D.M. Oosterhuis, E.M. Kawakami and D.A. Loka[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) requires a significant amount of nutrient input in order to achieve proper growth and development. With increasing costs of fertilizers along with heightened awareness of the environmental implications of fertilizer runoff, sustainable fertilization techniques are viewed as a way to alleviate these concerns. Research is needed in alternative and sustainable fertilization sources in order to supply cotton with the nutrients it needs along with providing sound stewardship towards the environment.

BACKGROUND INFORMATION

Biochar is the carbon-rich product resulting from the pyrolysis of biomass materials (Renner, 2007). Biochars can be derived from biomass sources such as hardwood trees, crop residues and poultry litter (Baldock and Smernik, 2002). Biochar has been proposed as a beneficial amendment concerning various agricultural and environmental aspects such as increasing soil fertility, retaining water in the soil and enhancing plant growth and yield (Zimmerman, 2010). Even though various forms of biochar remediation have been practiced in some parts of the world for many years (Tenenbaum, 2009), it is still a relatively new concept for much of the developed world. Studies and experiments have been undertaken to observe the agricultural, environmental and economical benefits that biochar has been proposed to possess. However, many of these trials have either been localized or produced on a small-scale, giving biochar scarce recognition.

RESEARCH DESCRIPTION

Growth chamber experiments were conducted in Fayetteville, Ark. in the fall of 2010 and 2012. Cotton cultivar ST-4288B2RF was planted in a complete randomized design with 9 treatments and 6 replications. A total of 54 1.5-liter pots were each filled with 1.8 kilograms (kg) of a Captina silt loam soil (Typic fragi-

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udult). A fine mixed-hardwood based biochar (EE) and a pelletized poultry litter based biochar (BES) were used as biochar sources in 2010 and 2012 respectively. Both biochar types were added at three equivalent rates: no biochar (control) (C); 5,000 kg/ha (1B); and 10,000 kg/ha (2B); while fertilizer was also added to pots at three equivalent rates: no fertilizer (control); 31-23-49 kg/ha (N-P-K); and 62-46-98 kg/ha (N-P-K). The plants were grown for 8 weeks and then harvested. Data collected at harvest included plant height, chlorophyll concentrations, leaf area, number of main-stem nodes and number of fruits along with plant dry matter. Statistical analysis was performed using JMP software versions 9.1 and 9.3 (SAS Institute, Inc., Cary, N.C.) to determine if the main effect of biochar had any significant effect on cotton growth and development.

RESULTS AND DISCUSSION

Both types of biochars (EE and BES) had significant effects on cotton growth and development. The EE biochar significantly impacted growth and development (Tables 1 and 2) and had higher numerical values in more growth parameters than the BES biochar (Tables 3 and 4). This could possibly be attributed to the fine-textured composition of the EE biochar which may have made the nutrients contained within more accessible to the developing root system. Consequently, the pelletized form of the BES biochar may have inhibited nutrient release and subsequent plant uptake resulting in lower numerical values for most measured variables. Nonetheless, enhancements in areas such as leaf and dry matter indicate that physiological functions vital to cotton growth and development can be benefitted by plant/biochar interaction.

PRACTICAL APPLICATION

Analyses of individual biochar rates demonstrated positive effects on cotton plant development. These experiments have pointed out the direction for the next series of biochar trials in cotton. Additional research is needed concerning the nature and ability of biochar to slowly release nutrients over time that can become made available and in sufficient quantity for cotton production and acceptable yields.

ACKNOWLEDGMENTS

EE biochar was provided by Enginuity, LLC, Mechanicsburg, Penn. and BES biochar was provided by BioEnergy Systems, LLC, Springdale, Ark.

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Table 1. Main-stem node number, fruit number, plant height, leaf area and chlorophyll (Chl.) means for fine mixed-hardwood based biochar (EE).

Treatment	Node number	Fruit number	Plant Height (cm)	Leaf Area (cm^2)	Chl.
C	10.67 a†	2.22 b	43.49 a	654.41 c	53.80 a
1B	10.82 a	3.11 a	40.98 b	695.38 b	51.22 b
2B	10.94 a	3.11 a	42.91 a	748.63 a	50.03 b

†Columns not sharing a common letter are significantly different ($P \leq 0.05$).

Table 2. Average internode node length, stem, leaf, fruit and total plant dry matter (DM) means for fine mixed-hardwood based biochar (EE).

Treatment	Average Internode Length (cm)	Stem DM (g)	Leaf DM (g)	Fruit DM (g)	Total Plant DM (g)
C	4.08 a†	5.08 c	4.49 c	0.20 b	9.78 c
1B	3.79 b	5.61 b	5.42 b	0.51 a	11.52 b
2B	3.92 b	6.08 a	5.75 a	0.52 a	12.36 a

†Columns not sharing a common letter are significantly different ($P \leq 0.05$).

Table 3. Main-stem node number, fruit number, plant height, leaf area and chlorophyll (Chl.) means for pelletized poultry litter based biochar (BES).

Treatment	Node Number	Fruit Number	Plant Height (cm)	Leaf Area (cm^2)	Chl.
C	8.77 a†	1.94 a	32.07 a	434.58 a	45.11 a
1B	8.77 a	2.11 a	31.98 a	454.21 a	44.06 a
2B	8.94 a	2.33 a	32.06 a	482.26 a	45.45 a

†Columns not sharing a common letter are significantly different ($P \leq 0.05$).

Table 4. Average internode node length, stem, leaf, fruit and total plant dry matter (DM) means for pelletized poultry litter based biochar (BES).

Treatment	Average Internode Length (cm)	Stem DM (g)	Leaf DM (g)	Fruit DM (g)	Total Plant DM (g)
C	3.65 a†	2.93 a	3.66 b	0.12 a	6.72 b
1B	3.66 a	3.11 a	3.89 ab	0.14 a	7.15 ab
2B	3.59 a	3.25 a	4.14 a	0.16 a	7.56 a

†Columns not sharing a common letter are significantly different ($P \leq 0.05$).

Effect of Poultry Litter Biochar on Early-Season Cotton Growth

T.D. Coomer, D.M. Oosterhuis, D.E. Longer, and D.A. Loka[1]

RESEARCH PROBLEM

Soil fertility declines with time due to plants' harvesting of the soil's valuable resources for the production of seedcotton and residue. Replacing soil nutrients yearly does put them back into the soil; but over time, the soil will lose organic matter, and its cation-exchange capacity will decline, reducing the soil's ability to hold nutrients (Laird et al., 2010). Yearly soil amendments such as fertilizer and manures can be added to the soil to increase these factors in the soil; but these amendments are easily lost from the soil or broken down by microbes, and they are expensive and time consuming to apply (Uzoma et al., 2011). Other alternatives have been explored to replace these additives. One viable option is the addition of biochar which is produced from biomass. This study was conducted to evaluate the effect of biochar on early-season cotton growth.

BACKGROUND INFORMATION

Biochar (BC) is produced from biomass that has gone through pyrolysis, the process of heating in the absence of oxygen (Chan et al., 2008). Biochar is composed of mostly decomposition-resistant polyaromatic carbon. Scientists estimate that BC can resist total decomposition for hundreds to thousands of years. Biochar can be produced from virtually any biomass including plant wastes such as peanut hulls, coffee husks, animal wastes, industrial wastes, and woody materials. Some data shows that BC from plants is not as nutrient-rich or as effective compared to BC from animal wastes because of lower nitrogen levels in plants.

Research has shown that BC keeps soil fertility high and may increase sequestration of carbon in the soil (Chan et al., 2008). Biochar can support retention of nutrients and other organic material in the soil due to its porosity and high surface area (Laird et al., 2010). Adding BC to a sandy soil can improve soil moisture content and soil cation-exchange capacity because of its high surface area and large charge density (Uzoma et al., 2011). Biochar addition to soil has been shown to increase both plant growth and yield, especially when nitrogen-based fertilizer is also added (Kammann et al., 2010).

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Poultry litter BC is of special interest because of the huge amounts of litter produced by poultry houses in the United States, and especially in northwest Arkansas. Every day, 5,100 tons of poultry manure is produced in chicken farms in Arkansas (Hishaw, 2006). Poultry litter has a high concentration of phosphorus and nitrogen, making it an ideal amendment to agricultural soils. Applying poultry litter directly onto agricultural fields, however, can lead to ammonia volatilization, leaching into the water supply, acidification of soils, and damage to crops that are sensitive to changes in nitrogen levels. Scientists faced with the issue of how to deal with excessive amounts of poultry litter discovered that once poultry litter undergoes pyrolysis to become BC, it not only reduces in volume by 75%, but it becomes a stable soil amendment with few to no hazardous effects.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) cultivar Stoneville 5288 2BRF was planted in 2-L pots in the greenhouse at the Rosen Center at the University of Arkansas. The soil used in the experiment was Captina silty loam (Typic Fragiudult). The study was a randomized complete block design with three replications. Six treatments were administered to the plants with three replications per treatment. The treatments included 0 kg/ha poultry litter BC with fertilizer, 0 kg/ha poultry litter BC without fertilizer, 1500 kg/ha poultry litter BC with fertilizer, 1500 kg/ha poultry litter BC without fertilizer, 3000 kg/ha poultry litter BC with fertilizer, and 3000 kg/ha poultry litter without fertilizer. Treatment combinations of BC and fertilizer are shown in Table 1. The BC employed in the experiment was composed of pyrolysed poultry litter. The poultry litter BC was obtained from a local source, BioEnergy Systems LLC. Once the poultry litter BC was obtained, it was tested for nutrient content, as shown in Table 2.

As soil was added to the pots, the BC was applied. The same amount of soil, approximately 5.2 kilograms dry, was added to each pot. The soils were flushed by pouring water through the pots until water dripped out of the bottom, then draining for 24 hours. Then ten seeds were planted in each pot, and thinned after ten days to one uniform plant in each pot. Pots were watered daily to field capacity. Height of each plant was recorded weekly and plants were randomized on the greenhouse bench to avoid any biases. After four and one half weeks, the nitrogen fertilizer urea (50 lb N/acre) was added to the pots designated for additional fertilizer. After eight weeks of growth, the plants were cut at the soil surface and their leaf area was measured using a LI-COR leaf area meter (LI-COR, Lincoln, Neb.) and the dry weight recorded after drying in an oven for 48 hours.

RESULTS AND DISCUSSION

Fertilizer treatment had a significant effect on plant height, plant dry matter and leaf area. Plant height was significantly affected by the fertilizer treatments (data not shown). The tallest treatment on average was the BC2 with fertilizer at 27.5 cm, and the shortest was the control with fertilizer at 19.9 cm. The BC2 with fertilizer was significantly ($\alpha = 0.05$) taller than the control with and without fertilizer groups. The control with fertilizer was significantly ($\alpha = 0.05$) shorter than the BC1 with and without fertilizer groups and the BC2 with and without fertilizer group.

The effect of fertilizer treatment on plant dry weight is shown in Fig. 1. The heaviest dry weight treatment was the BC2 + urea fertilizer treatment at 1.87 g, and the lightest was the control + fertilizer at 0.87 g. The control + fertilizer was significantly ($\alpha = 0.05$) lighter than the BC1 with and without fertilizer and the BC2 with fertilizer treatments. The BC2 + fertilizer treatment was significantly ($\alpha = 0.05$) heavier than the control + fertilizer, control without fertilizer, and the BC2 without fertilizer treatments.

The largest leaf area was the BC2 + fertilizer group at 419.5 cm^2, which was 25% larger than the next largest leaf area of the BC1 without fertilizer (Fig. 2). The smallest leaf area was the control + fertilizer treatment at 176.3 cm^2. The BC2 + fertilizer had a significantly ($\alpha = 0.05$) larger leaf area than both control groups and the BC2 – fertilizer, while the BC1 with and without fertilizer and the BC2 + fertilizer were all significantly ($\alpha = 0.05$) heavier than the lightest control with fertilizer treatment.

PRACTICAL APPLICATION

The study showed that BC aids in cotton seedling growth and development, even compared to the addition of nitrogen fertilizer alone. The low biochar BC1 treatment (1,500 kg biochar/ha) had better growth than the control (urea fertilizer), but did not grow as well as the higher biochar BC2 treatment (3,000 kg biochar/ha) with fertilizer. In summary, the data indicated that the higher level BC with fertilizer showed significant increases in plant height, dry weight and leaf area over both controls. The highest level of biochar (3,000 kg biochar/ha) with additional urea fertilizer (50 lb. N/acre) provided the best growth response.

ACKNOWLEDGMENTS

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Table 1. Biochar (BC) and Fertilizer (F) Treatment Combinations.

Treatment	Description
Control +F	No biochar + 56 kg/ha N (50 lb/acre N)
Control –F	No biochar – No fertilizer
BC1 +F	1500 kg/ha biochar + 56 kg/ha N (50 lb/acre N)
BC1 –F	1500 kg/ha biochar – No fertilizer
BC2 +F	3000 kg/ha biochar +56 kg/ha N (50 lb/acre N)
BC2 -F	3000 kg/ha biochar – No fertilizer

Table 2. Compositional analysis of BioEnergy Systems LLC (BES) Biochar.

				mg/kg					
pH	EC	P	K	Ca	Mg	S	Na	Fe	Mn[1]
10.2	16680	7076	26412	3271	3071	3525	6880	32	190

				mg/kg					
P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu[2]
46915	72298	67904	15298	10486	19919	2453	1397	1261	801

%TN	%TC[3]
3.00	32.02

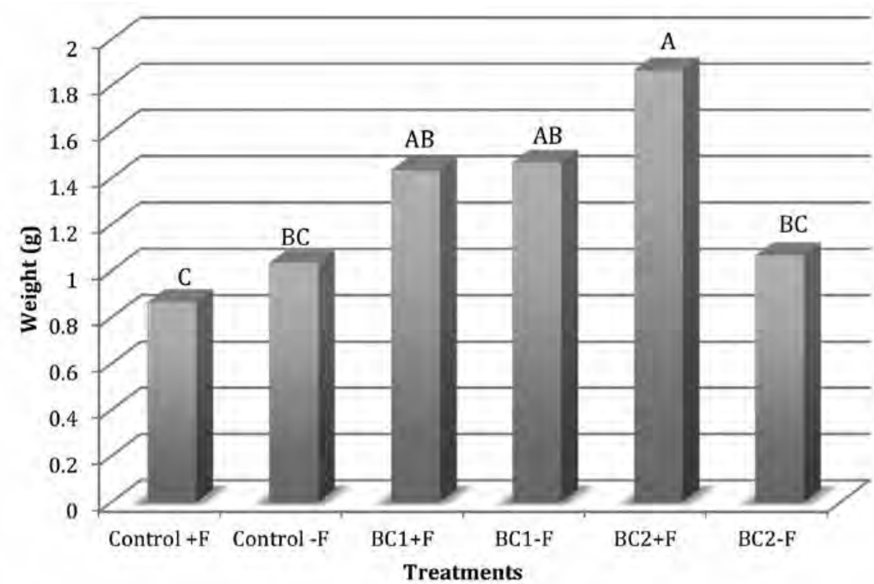

Fig. 1. Average dry weight after eight weeks of growth with significant differences indicated by letters (α = 0.05) determined by least significant difference values. + F= fertilizer added, F = no fertilizer added; BC1+F = 1500 kg/ha biochar + urea; BC1-F = 1500 kg/ha biochar with no urea; BC2+F = 3000 kg/ha biochar + urea; BC2-F = 3000 kg/ha biochar with no urea.

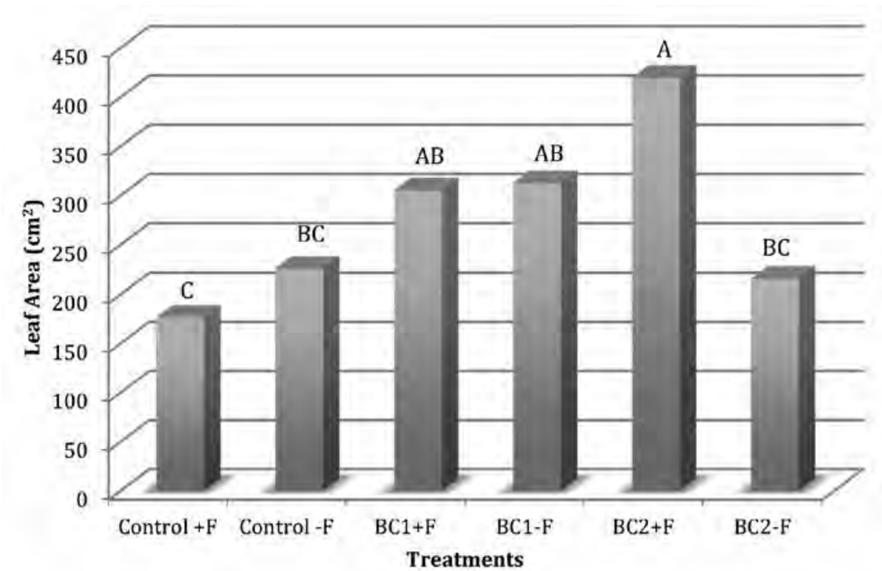

Fig. 2. Average leaf area after eight weeks of growth with significant differences indicated by letter (α = 0.05) determined by least significant difference values. + F= fertilizer added, - F = no fertilizer added; BC1+F = 1500 kg/ha biochar + urea; BC1-F = 1500 kg/ha biochar with no urea; BC2+F = 3000 kg/ha biochar + urea; BC2-F = 3000 kg/habiochar with no urea.

Management Considerations for Reducing the Risk of Barnyardgrass Evolving Resistance to Glyphosate in Midsouth Cotton

M.V. Bagavathiannan[1], J.K. Norsworthy[1], K.L. Smith[2], and P. Neve[3]

RESEARCH PROBLEM

The evolution of glyphosate-resistant (GR) weeds challenges the sustainability of GR cotton-based production systems of the U.S. Midsouth. Glyphosate-resistant Palmer amaranth is the most serious weed management issue in Midsouth cotton fields. The modeling work by Neve et al. (2011a, b) was helpful in understanding the risks of glyphosate-resistance evolution in Palmer amaranth and developing strategies for resistance management in this species. Had the model been available earlier, much of the damage caused by GR Palmer amaranth could have been avoided. One has to be proactive, rather than reactive, in preventing and managing herbicide-resistant weeds. Barnyardgrass is the most important grass weed in Midsouth cotton fields and is also a weed species known to have a high tendency for evolving resistance to herbicides, but little is known about the likelihoods of glyphosate-resistance evolution in barnyardgrass in Midsouth cotton and ways to prevent such a situation. A simulation model was developed to understand the risks of barnyardgrass evolving resistance to glyphosate and to identify production/weed management strategies that can prevent or delay the evolution of resistance.

BACKGROUND INFORMATION

Barnyardgrass is the sixth most important herbicide-resistant weed worldwide, with confirmed resistance to at least six herbicide modes of action (Heap, 2013). In the Midsouth, the vast majority of cotton (> 90%) is GR and is grown largely as a monoculture crop, leading to frequent applications of glyphosate in this system. High reliance on glyphosate for weed management has coincided with a reduction in non-chemical weed management strategies. As a result, the selection pressure for glyphosate resistance has been escalating among the weed communities com-

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monly present in Midsouth cotton fields. Given the economic costs associated with alternative weed management programs to control GR Palmer amaranth, there is an increasing awareness that proactive resistance management strategies are crucial to sustain the productivity and profitability of the cotton-based production systems of the Midsouth.

RESEARCH DESCRIPTION

A simulation model was developed, following the model framework and approach of Neve et al. (2011a). The model simulates the evolution of glyphosate resistance in barnyardgrass among 1000 hypothetical cotton production fields with an average size of 150 acres in three important cotton growing areas (Blytheville, West Memphis, and Monticello) in the Mississippi River Delta region of eastern Arkansas, for a period of 30 years. Barnyardgrass emergence was simulated based on the growing degree day accumulation, predicted using historical weather data (25 years) for each region. The model assumes that glyphosate resistance in barnyardgrass is endowed by a single, completely dominant gene with a Mendelian pattern of inheritance. The initial frequency of resistance was considered to be 5×10^{-8} (i.e., 5 seeds in 100 million seeds). The model is stage structured and simulates the transition from seed to seed of individual genotypes (SS, RS, and RR) pertaining to various cohorts. Monte-Carlo simulations were performed to understand the risk of resistance for a given management scenario across the 1000 experimental fields. The worst-case management scenario included a sole application of glyphosate, five times a year, in continuous GR cotton. The model was subsequently used to understand how alternative management options (cultural and tillage practices, crop/trait rotations, and herbicide rotations) could be used in combination with glyphosate to reduce the risks of glyphosate-resistance evolution in barnyardgrass.

RESULTS AND DISCUSSION

The model predicts that resistance would evolve in nine years of adopting the worst-case management strategy, with about 20% risk by year 11, reaching to the maximum risk of 48% by year 18 (Fig. 1). The risk could be greatly reduced by integrating alternative management strategies. Advancing cotton planting to April 15 (instead of usual planting on May 1) delayed the evolution of resistance by 3 years, with about 10 percentage points less risk over the 30-year period (Fig. 2A). Early planting favors cotton canopy formation prior to the peak emergence of barnyardgrass in this region. Replacing glyphosate application with inter-row cultivation at the second POST or third POST delayed the onset of resistance by 5 to 7 years, with about 25% to 30% lower risk of resistance, whereas cultivation at both the second and third POSTs delayed resistance by 12 years, with a 40% reduction in risk. Inter-row cultivation is a valuable strategy because cultivation can eliminate weed escapes that are not controlled by herbicides.

Crop or trait rotations were effective in reducing the rate and risk of glyphosate-resistance evolution in barnyardgrass (Fig. 2B). By rotating GR cotton with GR or glufosinate-resistant (LL) corn, resistance could be delayed for up to 6 yr, with about 25% reduction in risk. Rotating GR cotton with LL cotton (glufosinate-only program or a diversified herbicide program) or conventional, non-transgenic cotton with a standard herbicide program provided similar benefits in reducing the rate of glyphosate-resistance evolution as growing GR or LL corn in rotation. However, adopting a diversified herbicide program in the rotational LL cotton or growing a non-transgenic cotton crop in rotation that eliminates glyphosate use has greatly reduced the risks of resistance compared to the herbicide options used in the corn crop (Fig. 2B). Crop rotation is a valuable strategy, which provides a number of ecosystem benefits including improved weed management (Liebman and Dyck, 1993). In the context of herbicide-resistance management, the diversity of weed management options in the rotational crop is more important than the rotation *per se*. In the present case, GR cotton- GR corn rotations are less effective in preventing resistance because both crops contain GR traits, with frequent glyphosate use.

Increasing the mechanism of action (MOA) diversity by including alternative herbicides greatly delayed the evolution of resistance with a considerable reduction in risks (Fig. 2C). The degree of benefit, however, depends on the number of glyphosate applications being replaced with alternative herbicides, time of application, and the choice of alternative herbicide (i.e., efficacy). Replacing three glyphosate applications with glufosinate in continuous cultivar resistance to both glyphosate and glufosinate cotton was more effective than replacing two glyphosate applications. Simply increasing MOA diversity is not sufficient as some application timings are more critical than others. Tank-mixing glyphosate with clethodim applied at the second POST was more effective in reducing the risks than glyphosate plus clethodim applied at the first POST, because the application at second POST coincided with the peak emergence of barnyardgrass. The use of herbicides with soil residual activity is particularly helpful in preventing/delaying resistance to glyphosate. Timing of residual herbicide application and timely activation are critical to achieving maximum benefits. Tank-mixing glyphosate with residual herbicides at all POST applications (i.e., POST-only residuals) failed to delay resistance; whereas application of fomesafen prior to planting followed by fluometuron applied at planting (i.e., early-season residuals) was effective in preventing resistance (Fig. 2C). Early-season residual herbicides are particularly valuable because they provide effective control of the individuals that possess high seed production potential. More diversified herbicide rotations are very effective in preventing GR barnyardgrass. However, herbicide rotations alone are not sufficient because they do not address metabolism-based resistance and the herbicide-only weed management programs are not always preferable. Integration of non-chemical strategies is the key to sustaining cotton production and preserving the longevity of glyphosate.

PRACTICAL APPLICATION

The management principles and strategies discussed here will assist the development of integrated weed management programs that can greatly prevent the evolution of glyphosate resistance in barnyardgrass and other weeds with comparable life-history traits. Such a strategy will help preserve the long-term utility of glyphosate and ensure the sustainability of cotton-based production systems of the Midsouth U.S.

ACKNOWLEDGMENTS

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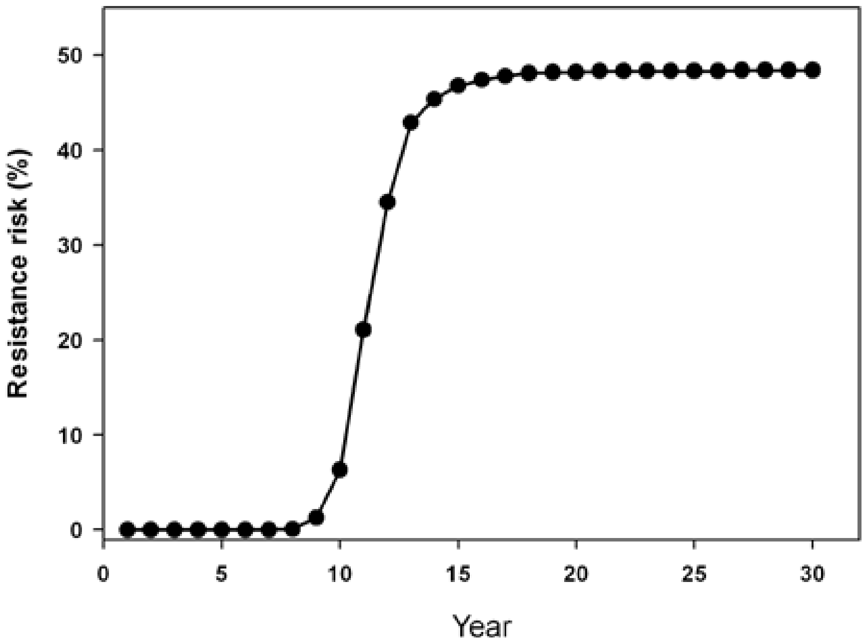

Fig. 1. Risk of barnyardgrass evolving resistance to glyphosate under a worst-case scenario of five glyphosate applications (glyphosate [at-plant] followed by (fb) glyphosate [1st POST] fb glyphosate [2nd POST] fb glyphosate [3rd POST] fb glyphosate [layby]) in a continuous glyphosate-resistant (GR) cotton.

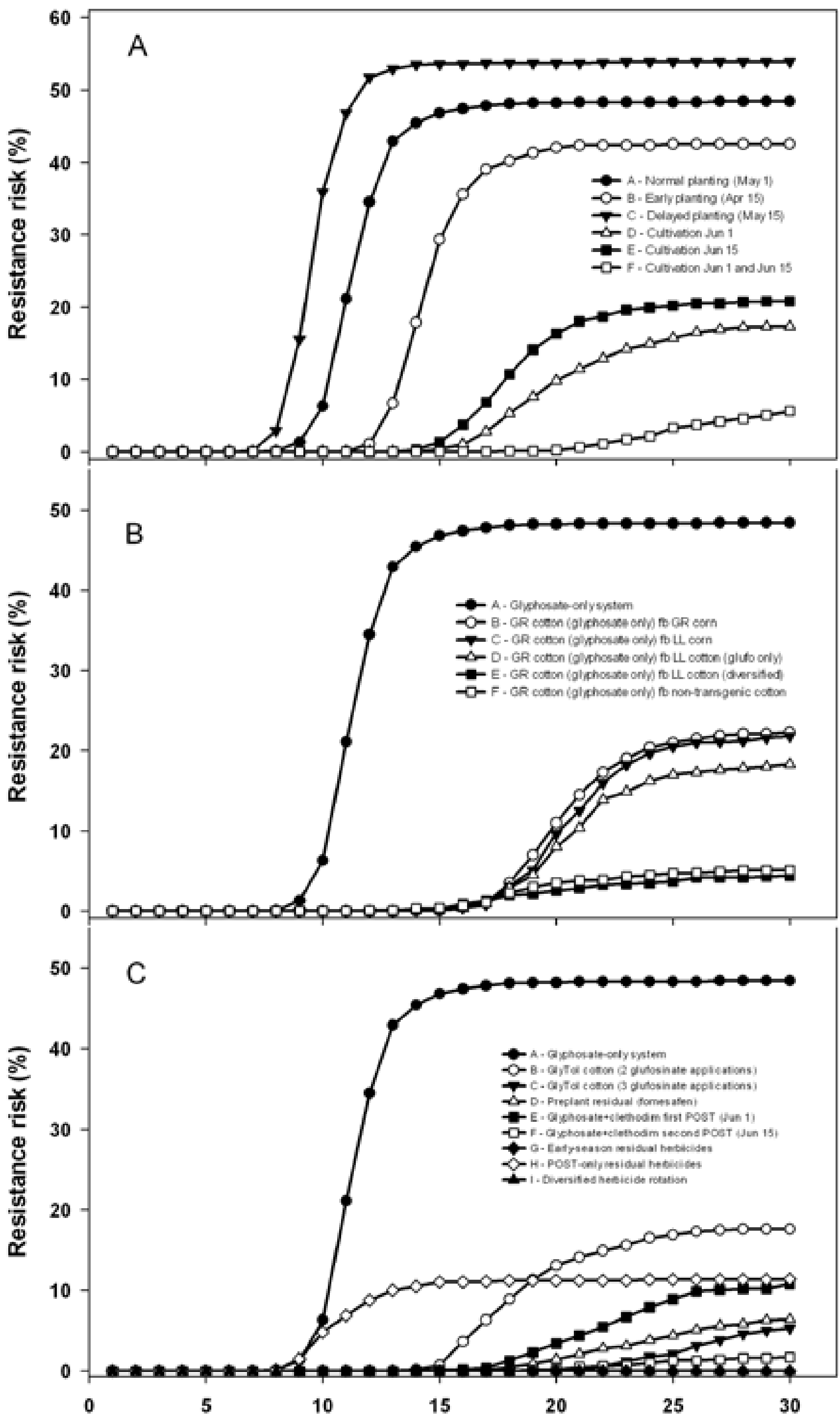
A
Resistance risk (%)
A - Normal planting (May 1)
B - Early planting (Apr 15)
C - Delayed planting (May 15)
D - Cultivation Jun 1
E - Cultivation Jun 15
F - Cultivation Jun 1 and Jun 15
B
Resistance risk (%)
A - Glyphosate-only system
B - GR cotton (glyphosate only) fb GR corn
C - GR cotton (glyphosate only) fb LL corn
D - GR cotton (glyphosate only) fb LL cotton (glufo only)
E - GR cotton (glyphosate only) fb LL cotton (diversified)
F - GR cotton (glyphosate only) fb non-transgenic cotton
C
Resistance risk (%)
A - Glyphosate-only system
B - GlyTol cotton (2 glufosinate applications)
C - GlyTol cotton (3 glufosinate applications)
D - Preplant residual (fomesafen)
E - Glyphosate+clethodim first POST (Jun 1)
F - Glyphosate+clethodim second POST (Jun 15)
G - Early-season residual herbicides
H - POST-only residual herbicides
I - Diversified herbicide rotation
0
5
10
15
20
25
30

Fig. 2A. Impact of altered planting dates and inter-row cultivation: It is assumed that cotton is cultivated as a monoculture crop year after year and is treated with five glyphosate applications each year. A = cotton is planted during usual planting time (May 1); B = cotton is planted a two weeks earlier (Apr 15); C = cotton is planted two weeks later (May 15); D = A glyphosate application is replaced with cultivation on Jun 1 (second POST); E = A glyphosate application is replaced with cultivation on Jun 15 (third POST); and F = glyphosate applications at both the second and third POSTs were replaced with cultivation.

2B. Impact of crop/trait rotations: A = glyphosate-only system where glyphosate-resistant (GR) cotton monoculture is treated with five glyphosate applications each year; B = GR cotton with glyphosate-only herbicide program is rotated with GR corn at each cycle; C = GR cotton is rotated with glufosinate-resistant (LL) corn; D = GR cotton is rotated with LL cotton, where LL cotton is treated with a glufosinate-only herbicide program; E = GR cotton is rotated with LL cotton, where LL cotton is treated with a diversified herbicide program; and F = GR cotton is rotated with conventional (non-transgenic) cotton, where a standard non-glyphosate herbicide program is used.

2C. Impact of herbicide rotations: A = glyphosate-only system where monoculture GR cotton is treated with five glyphosate applications each year; B = GlyTol™ cotton with two glufosinate and three glyphosate applications each year; C = GlyTol™ cotton with three glufosinate and two glyphosate applications each year; D = preplant residual: preplant application of fomesafen, followed by five glyphosate applications; E = glyphosate-only system (option A) with clethodim tank-mixed with glyphosate at first POST; F = glyphosate-only system (option A) with clethodim tank-mixed with glyphosate at second POST; G = early-season residual herbicides: fomesafen applied prior to planting and fluometuron applied at planting, followed by four glyphosate applications; H = POST-only residual herbicides: glyphosate (at planting), glyphosate tank-mixed with *S*-metolachlor applied at first and second POSTs, glyphosate tank-mixed with prometryn applied at third POST, followed by MSMA tank-mixed with flumioxazin at layby application; I = diversified herbicide rotation: fomesafen applied prior to planting, paraquat tank-mixed with fluometuron applied at planting, glyphosate tank-mixed with *S*-metolachlor applied at first and second POSTs, glyphosate tank-mixed with prometryn applied at third POST, followed by MSMA tank-mixed with flumioxazin at layby application.

Factors Contributing to Cotton Injury from Soil-Applied Residual Herbicides

B.W. Schrage[1], J.K. Norsworthy[1], K.L. Smith[2], D.B. Johnson[1], M.V. Bagavathiannan[1], and D.S. Riar[1]

RESEARCH PROBLEM

There is narrow selectivity in cotton with regards to soil-applied herbicides, meaning that rates needed for effective weed control can likewise cause cotton injury, especially when environmental conditions are less than optimal for cotton emergence and growth. The objective of this research was to determine the influence of seed size, vigor, and planting depth on cotton injury from soil-applied residual herbicides.

BACKGROUND INFORMATION

Extensive use of glyphosate has led to the evolution of glyphosate-resistant weed species, of which glyphosate-resistant Palmer amaranth is the most notable (Heap, 2012). Glyphosate-resistant Palmer amaranth is the most problematic weed cotton producers throughout the Midsouth are facing, with 87% of the cotton acreage in Arkansas infested with this resistant biotype (Norsworthy et al., 2012). Glyphosate resistance has prompted a return to the use of soil-applied residual herbicides. Most often, early-season cotton injury from soil-applied herbicides occurs on under cool, moist conditions (Askew et al., 2002; Hayes et al., 1981). Conversely, other researchers have reported no or slight cotton injury with residual herbicides in other environments (Faircloth et al., 2001; Riar et al., 2011). For the soil types and production practices common to the Midsouth, little research has been conducted to determine the reasons for inconsistent cotton tolerance under different microenvironments. Therefore, an assessment of factors responsible for cotton injury caused by preemergence-applied residual herbicides is important.

RESEARCH DESCRIPTION

Field studies were conducted at the Arkansas Agricultural Research and Extension Center, Fayetteville, Ark. and at the Rohwer Research Station, Rohwer,

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Ark. in 2012 evaluating the influence of cotton seed size, planting depth, and seed vigor on cotton injury from various soil-applied herbicides (diuron, fomesafen, and fluometuron). In Fayetteville, seed sizes, ranging from 0.33 to 0.46 oz/100 seed were planted into Taloka silt loam soil. Treatments were applied immediately after planting and included a nontreated control, and diuron applied at 1 and 2 lb ai/acre. In Rohwer, low- and high-vigor cotton seed were planted at shallow and normal planting depths in early-April. Herbicide treatments were made immediately after planting and included diuron, fomesafen, and fluometuron at 1 and 2× rates. Experiments were irrigated regularly, and estimates of injury to cotton were visually rated at 1, 2, 3, and 4 weeks after treatment (WAT). All above-ground cotton biomass was collected, oven-dried, and weighed. In both experiments, data was subjected to analysis of variance (ANOVA) and means were separated using Fisher's protected least significant difference test (LSD).

RESULTS AND DISCUSSION

Injury was significantly reduced when soil-applied herbicides were applied to high-vigor cotton plots. The ability of the high-vigor seeds to rapidly germinate, freeing the seedling from the herbicide zone and shortening the window of contact, enabled high-vigor seed to tolerate application more effectively than low-vigor seed (Fig. 1). Results from the planting depth study suggest variation among herbicide chemistries. Planting depth (either at 0.25 in or 1.0 in) did not affect injury in plots treated with fluometuron, although injury from diuron was 11% less when cotton was planted deeper. In contrast, fomesfen injury increased 15% in deep planting (Fig. 2). Seed sizes, ranging from 0.33 to 0.46 oz/100 seed, did affect cotton injury from diuron. The four larger seed sizes exhibited no statistical difference though there was a trend for decreased injury with increased seed size in both the 1× and 2× rates. Statistical differences were observed between the smallest seed size (0.33 oz/100 seed) and the largest (0.46 oz/100 seed). At 1× rates, injury was reduced by 13% by using larger seed. At 2× rates, injury was reduced 37% by using larger seed (Fig. 3). Larger seed possess a greater endosperm and can therefore better survive uptake of herbicides from the preemergence zone. In summary, cotton seed size, seed vigor, and planting depth influenced injury from soil-applied herbicides.

PRACTICAL APPLICATION

The objective of this research was to evaluate genetic and agronomic factors that potentially influence cotton tolerance to soil-applied residual herbicides. By selecting larger seed with high vigor and planting at depths best suited to individual herbicide chemistry, these soil-applied herbicides can be implemented to control problem weeds in cotton while minimizing potential injury.

ACKNOWLEDGMENTS

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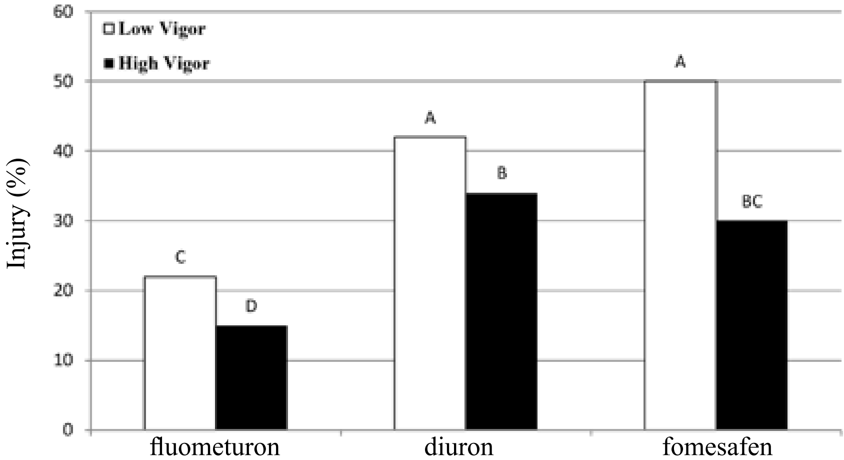

Fig. 1. Injury at 6 weeks after treatment (WAT) of low- and high-vigor cotton when applied with different soil-applied herbicides.

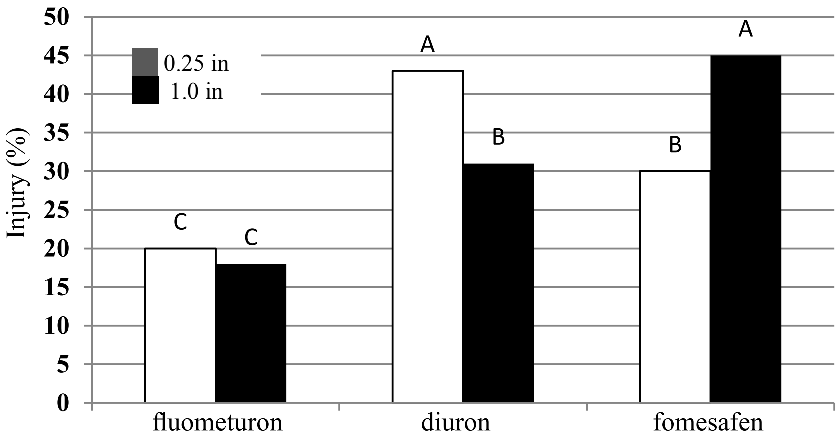

Fig. 2. Injury at 6 weeks after treatment (WAT) from soil-applied herbicides to cotton at different planting depths.

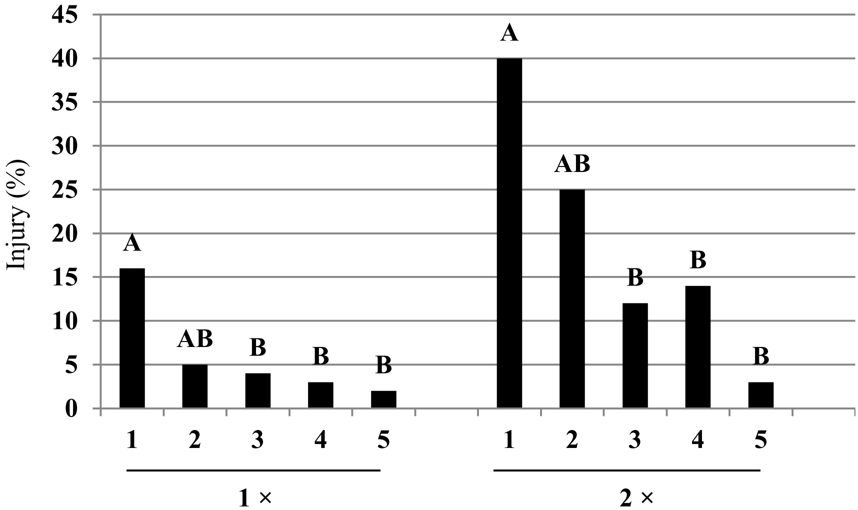

Fig. 3. Injury at 30 days after treatment (DAT) from 1 and 2× rates of diuron applied to cotton of different seed sizes.

Activation and Length of Residual Herbicides Under Furrow and Sprinkler Irrigation

D.S. Riar, J.K. Norsworthy, M.T. Bararpour, H.D. Bell, and B.W. Schrage[1]

RESEARCH PROBLEM

Evolution and spread of glyphosate-resistant Palmer amaranth across the U.S. Midsouth has increased the cost of weed management in glyphosate-resistant cotton systems. Palmer amaranth emerges throughout the growing season and is hard to control after emergence because of its rapid growth (Garvey, 1999; Jha and Norsworthy, 2009). Widespread prevalence of resistance to acetolactate synthase (ALS)-inhibiting herbicides in the U.S. Midsouth has rendered control of Palmer amaranth in cotton ineffective with over-the-top applications of postemergence (POST) applied ALS herbicides such as Envoke (trifloxysulfuron) and Staple (pyrithiobac) (Norsworthy et al., 2008). Therefore, season-long residual control of Palmer amaranth is needed.

BACKGROUND INFORMATION

The activity and length of residual soil active herbicides depends on soil type and available soil moisture. Soil-applied herbicides need 0.5 to 1.0 inch of precipitation or irrigation within 7 to 10 days of application (Hager et al., 2011). Most of the cotton area planted in Arkansas is irrigated through furrow or sprinkler irrigation. Variable soil moisture can lead to differences in the residual herbicide activity and ultimately Palmer amaranth control in furrows and on beds.

RESEARCH DESCRIPTION

Studies were conducted in 2011 and 2012 to determine activation and length of residual herbicides under both furrow and sprinkler irrigation at the Northeast Research and Extension Center, Keiser, Ark. and at the Lonn Mann Cotton Research Station, Marianna, Ark. The soil texture at Keiser was clay and at Marianna was silt loam. Both furrow and sprinkler irrigation studies were laid out in a randomized complete block design with a 2 (site: bed vs. furrow) by 18 factorial arrangement of treatments (soil-applied herbicides applied at labeled rate

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for cotton, corn, or soybean: AAtrex, Balance Flexx, Callisto, Caparol, Cotoran, Direx, Dual Magnum, Envoke, Laudis, Outlook, Prowl, Reflex, Sencor, Staple, Valor, Warrant, Zidua, and a nontreated control). Data for two years were pooled and analysis of variance was conducted to assess differences in Palmer amaranth control among herbicides and between furrows and beds using Fisher's protected least significant difference test ($\alpha = 0.05$). Palmer amaranth control data were analyzed as repeated measures to determine length of residual herbicide activity over a 6-week period [2, 3, and 6 weeks after treatment (WAT)].

RESULTS AND DISCUSSION

Furrow Irrigation Study

Averaged over herbicides, no biological difference was observed for Palmer amaranth control between beds and furrows at both locations (data not shown). Averaged over beds and furrows, Palmer amaranth control at Keiser with all herbicides except Envoke (76%) and Staple (80%) was ≥ 92% at 2 WAT (Table 1). Palmer amaranth control with all herbicides at 3 WAT was similar to 2 WAT but decreased for all herbicides by 2 to 17 percentage points by 6 WAT, except Callisto (94% vs. 93%), Dual Magnum (98% vs. 96%), Sencor (99% vs. 98%), and Staple (80% vs. 75%). At Marianna, control with all herbicides except Envoke (63%), Staple (70%), Laudis (85%), Balance Flexx (88%), and Prowl (87%) was ≥ 90% at 2 WAT (Table 2). By 6 WAT, the only herbicide with control similar to 2 WAT was Direx (95% vs. 93%). These studies demonstrated that the length of residual activity for Palmer amaranth control varied for herbicides depending upon soil type and more herbicides at Keiser (AAtrex, Balance Maxx, Callisto, Caparol, Dual, Outlook, Reflex, Sencor, Valor, Warrant, and Zidua) compared to Marianna (Caparol, Direx, and Zidua) provided ≥ 90% residual control over a 6-wk period.

Sprinkler Irrigation Study

Averaged over herbicides, a small reduction in Palmer amaranth control on beds compared to furrow was observed at 2 WAT (97% vs. 99%, respectively) and 3 WAT (95% vs. 99%, respectively), but no difference in control was observed at 6 WAT (92% vs. 93%, respectively) (data not shown). The subtle difference in control may be attributed to greater moisture being retained in furrows. Averaged over beds and furrows, Palmer amaranth control with all herbicides, except Cotoran (89%) at 2 WAT was >90% (Table 3). Palmer amaranth control with all herbicides at 3 WAT remained similar to 2 WAT, except for a decrease in control with Envoke (84% vs. 97%). By 6 WAT, only AAtrex, Callisto, and Sencor controlled Palmer amaranth similar to 2 WAT. Palmer amaranth control with all other herbicides at 6 WAT was less than at 2 WAT, but control with AAtrex, Callisto, Sencor, Dual, Zidua, Valor, Outlook, and Warrant was ≥90%.

PRACTICAL APPLICATION

In both furrow and sprinkler irrigation studies, no cotton residual herbicide provided complete control at 2, 3, or 6 WAT. Dual Magnum, Valor, and Warrant were the only herbicides labeled in cotton that provided at least 90% Palmer amaranth control at Keiser under both furrow and sprinkler irrigation through 6 WAT. Additionally, Caparol and Reflex at Keiser and Direx and Caparol at Marianna were the cotton herbicides that controlled Palmer amaranth ≥90% in furrow irrigation. Unfortunately, 90% control is unacceptable in fields of Roundup Ready cotton with high populations of glyphosate-resistant Palmer amaranth; hence, residual herbicides should be applied every 2 to 3 weeks from planting through crop canopy formation (layby) to overlay residual control and minimize the number of Palmer amaranth escapes that must be removed either chemically (when possible), mechanically, or manually.

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Table 1. Palmer amaranth control with soil-applied residual herbicides at the Northeast Research and Extension Center, Keiser, Ark., under furrow irrigation averaged over site (beds and furrows) and years at 2, 3, and 6 weeks after treatment (WAT).

	Palmer amaranth control			Difference in residual Palmer amaranth control		
Herbicide[†]	2 WAT	3 WAT	6 WAT	2 vs 3 WAT	2 vs 6 WAT	3 vs 6 WAT
	---------------------------%---------------------------					
AAtrex	100 a[‡]	100 a	93 b-d	NS[§]	**	**
Balance	99 a	98 ab	95 ab	NS	**	**
Callisto	94 de	95 b-d	93 a-c	NS	NS	NS
Caparol	98 a-c	96 b-d	90 c-e	NS	**	**
Cotoran	95 cd	94 cd	84 ef	NS	**	**
Direx	94 de	92 de	87 d-f	NS	**	**
Dual	98 ab	97 a-c	96 ab	NS	NS	NS
Envoke	76 g	71 g	59 h	NS	**	**
Laudis	92 e	90 e	88 ef	NS	*	NS
Outlook	98 ab	98 a-c	94 bc	NS	**	**
Prowl	92 e	88 e	79 fg	NS	**	**
Reflex	95 cd	95 b-d	92 b-d	NS	*	NS
Sencor	99 a	99 a	98 a	NS	NS	NS
Staple	80 f	80 f	72 g	NS	NS	NS
Valor	96 b-d	96 b-d	92 b-d	NS	**	**
Warrant	98 ab	97 a-c	94 a-c	NS	**	**
Zidua	98 ab	98 a-c	96 ab	NS	**	*

[†]All herbicides were applied at labeled field rates based on soil type.
[‡]Columns with the same letter are not significantly different ($P \le 0.05$).
[§]Abbreviations: NS, not significant at α = 0.05; *, significant at α = 0.05; **, significant at α = 0.01.

Table 2. Palmer amaranth control with soil-applied residual herbicides at the Lonn Mann Cotton Research Station, Marianna, Ark., under furrow irrigation averaged over beds and furrows and years at 2, 3, and 6 weeks after treatment (WAT).

	Palmer amaranth control			Difference in residual Palmer amaranth control		
Herbicide[†]	2 WAT	3 WAT	6 WAT	2 vs 3 WAT	2 vs 6 WAT	3 vs 6 WAT
	--------------------------%	--------------------------				
AAtrex	99 a[‡]	99 a	85 c-e	NS[§]	**	**
Balance	88 ef	77 gh	62 hi	**	**	**
Callisto	96 a-c	95 c-f	85 b-e	NS	**	**
Caparol	99 a	99 a	90 a-c	NS	**	**
Cotoran	94 b-d	92 ef	76 fg	NS	**	**
Direx	95 a-d	96 a-e	93 a	NS	NS	NS
Dual	97 ab	94 d-f	78 ef	NS	**	**
Envoke	63 h	53 j	43 j	**	**	NS
Laudis	85 f	73 h	56 i	**	**	**
Outlook	97 ab	95 c-f	83 b-e	NS	**	**
Prowl	87 f	83 g	70 gh	NS	**	**
Reflex	92 cd	92 f	85 b-e	NS	**	**
Sencor	98 ab	97 a-c	87 b-d	NS	**	**
Staple	70 g	64 i	42 j	*	**	**
Valor	92 cd	95 b-f	85 b-e	NS	*	**
Warrant	91 de	96 a-d	82 d-f	NS	**	**
Zidua	99 a	98 ab	91 ab	NS	**	**

[†]All herbicides were applied at labeled field rates based on soil type.
[‡]Columns with the same letter are not significantly different ($P \leq 0.05$).
[§]Abbreviations: NS, not significant at $\alpha = 0.05$; *, significant at $\alpha = 0.05$; **, significant at $\alpha = 0.01$.

Table 3. Palmer amaranth control with soil-applied residual herbicides at the Northeast Research and Extension Center, Keiser, Ark., under sprinkler irrigation averaged over beds and furrows and years at 2, 3, and 6 weeks after treatment (WAT).

	Palmer amaranth control			Difference in residual Palmer amaranth control		
Herbicide[†]	2 WAT	3 WAT	6 WAT	2 vs 3 WAT	2 vs 6 WAT	3 vs 6 WAT
	----------------------------%----------------------------					
AAtrex	100 a[‡]	100 a	99 a	NS[§]	NS	NS
Balance	98 ab	96 ab	89 a-d	NS	**	*
Callisto	100 a	100 a	99 a	NS	NS	NS
Caparol	93 b-d	86 c-e	66 fg	NS	**	**
Cotoran	89 d	82 de	68 e-g	NS	*	NS
Direx	96 b-d	91 b-d	82 d-f	NS	**	*
Dual	100 a	100 a	97 ab	NS	*	*
Envoke	97 a-c	84 e	72 g	**	**	**
Laudis	97 a-c	94 b-d	84 c-f	NS	**	**
Outlook	97 a-c	95 a-c	93 a-d	NS	*	NS
Prowl	91 d	92 a-c	84 c-e	NS	*	*
Reflex	94 b-d	93 b-d	87 b-d	NS	*	NS
Sencor	100 a	100 a	99 a	NS	NS	NS
Staple	92 cd	90 c-e	63 g	NS	**	**
Valor	98 a-c	99 ab	93 a-d	NS	*	*
Warrant	98 a-c	94 a-c	91 a-d	NS	*	NS
Zidua	99 ab	96 ab	94 a-c	NS	*	NS

[†]All herbicides were applied at labeled field rates based on soil type.
[‡]Columns with the same letter are not significantly different ($P \leq 0.05$).
[§]Abbreviations: NS, not significant at α = 0.05; *, significant at α = 0.05; **, significant at α = 0.01.

Weed Control Cost Estimates from the 2012 Cotton Budgets: Implications of Glyphosate Resistance

K. Bryant[1], J. Trauger[2] and R. Hogan[3]

RESEARCH PROBLEM

The incidence of weeds resistant to glyphosate across the Cotton Belt has no doubt impacted the cost of weed control in cotton fields. As land grant universities prepare their cotton budgets each year, they make assumptions regarding the technology, chemistries, rates and timings required to adequately control weeds in a typical cotton field for the scenario being budgeted. It is hypothesized that states with higher incidence of weed resistance will budget higher relative costs for weed control than was the norm before herbicide resistance appeared.

BACKGROUND INFORMATION

Each year land grant universities develop cost of production estimates for the major agricultural enterprises in their state. In the case of cotton, these are commonly called cotton budgets. Usually the agricultural economics faculty cooperates with other specialists working in cotton to describe a production scenario to be budgeted. Most states produce multiple cotton budgets, each representing a different cotton-producing region in their state and/or a different cotton-production practice commonly used by their cotton growers. Budgets differ in their estimates of the cost of production due to the production practices assumed in each budget and the input prices assumed from state to state.

RESEARCH DESCRIPTION

In the summer of 2012, cotton enterprise budgets from nine land grant universities were collected to compare herbicide cost estimates from state to state. The nine states represented by their respective universities were Texas, Louisiana, Arkansas, Mississippi, Tennessee, Alabama, Georgia, South Carolina and North Carolina. The budgets and supporting information were collected from Extension websites. These web addresses are included in the literature cited section of this manuscript.

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RESULTS AND DISCUSSION

North Carolina was represented by three cotton budgets in 2012 (Unknown, 2012). They were titled conventional, strip-till, and tidewater. Total cost for herbicide and application was $57.90 for the conventional budget; $52.73 for strip-till; and $81.67 for the tidewater budget. Glyphosate was used in every budget and Prowl and Direx were used in the conventional and strip-till budgets. The tidewater budget had a different herbicide usage which included Valor, 2,4-D, and Staple. Generic glyphosate and Roundup Max were used in the tidewater budget as well.

South Carolina was represented by four cotton budgets, but all had the same total cost for weed control (Ferreira, 2011). Glyphosate, Prowl, and Caparol were used in these budgets. An application of Prowl during the month of March was included followed by three in-season applications consisting of glyphosate and Caparol.

Georgia has four cotton budgets; two are conventional tillage (irrigated and non-irrigated) and the other two are strip-till (irrigated and non-irrigated) (Shurley and Smith, 2012). The conventional budgets have 3 herbicide applications and the strip-tillage budgets have 4 herbicide applications. The authors of these budgets state that a herbicide program designed to control glyphosate-resistant Palmer Amaranth (pig weed) is assumed in each budget. They go on to say these management practices are expensive, costing the land owner $65 per acre without a Monsanto rebate program or $45 per acre with the rebate for the herbicide alone. The total cost for weed control once applications costs are included was $108 per acre.

Alabama has four cotton budgets; two for north Alabama (conventional and reduced tillage) and two for south Alabama (conventional and reduced tillage) (Runge, 2011). All four budgets have three herbicide applications including burndown/planting, post, and lay-by. All four budgets utilize the Roundup Ready Flex technology and their weed control costs range from $39 to $50 per acre. A quick reference guide is available on the web site to address resistant weeds in cotton.

Tennessee has four cotton budgets (Danehower, 2012). Two budgets utilize the Roundup Ready Flex technology (conventional and no-till) and two utilize the BG II technology (conventional and no-till). The conventional tillage budgets use Cotoran 4L, Roundup Power Max, Dual Magnum, Gramoxone SL, and Valor herbicides. The no-till budgets use these same herbicides plus Roundup Power Max and Clarity in a burndown operation. The burndown operation adds $6.42 to the total cost of herbicides for these two budgets. The four budgets have an average price of $50 for total cost of herbicides and application. The total costs of the two no-till budgets are approximately $7 per acre more than the conventional till budgets.

Arkansas has six cotton budgets, three of which are Roundup Ready Flex and three of which are Liberty Link (Flanders, 2011). Both sets of budgets have different irrigation methods (furrow, center pivot and dryland). Weed control cost in the Roundup Ready Flex budgets was $56.76 per acre. The cost of weed control in the Liberty Link budgets was $75.93 per acre. The Liberty Link budgets use Ignite in the place of glyphosate.

Mississippi also has six cotton budgets, three of which are for the Delta region and three for the non-Delta region (Gillis, 2011). Each of these two areas has three budgets, two Roundup Ready Flex budgets (conservation till and no-till) and one Liberty Link budget utilizing conservation tillage. Weed control costs in the Roundup Ready Flex budgets are $67.72 and $63.94 for the Delta and non-Delta regions respectively. The Delta budget has an applied by air application method that was not used in the non-Delta budgets. Weed control costs in the Liberty Link budgets are $95.19 and $91.41 for the Delta and non-Delta regions respectively..

Louisiana has four cotton budgets, all of which utilize the Roundup Ready Flex technology and all contain $80.46 for weed control (Paxton, 2011). The budgets are divided by irrigation method and soil type.

Texas has nine cotton budgets (Klose, 2012). One is Roundup Ready Flex; three are Roundup Ready (with different irrigation methods); and four budgets are conventional. Weed control costs range from $10.46 per acre to $31.30 per acre across the nine scenarios. Glyphosate resistance was apparent in Texas for the first time in the 2012 crop. There will probably be more Liberty Link budgets in 2014, particularly in District-2 (Lubbock area) and in District-6 (far West Texas area).

PRACTICAL APPLICATION

Dollar amounts budgeted for weed control in 2012 in nine Cotton Belt states were greatest in Georgia and Louisiana at $108 and $81 per acre, respectively. Mississippi also had two Liberty Link budgets that contained $95 and $91 per acre in weed control. The remaining Mississippi budgets plus those in Arkansas and South Carolina had weed control costs ranging from $57 to $76 per acre. Alabama and Tennessee had more modest amounts budgeted for weed control ranging from $39 to $53 per acre. The Texas budgets had $30 per acre or less budgeted for weed control.

South Carolina, Georgia, Alabama and Louisiana utilized the Roundup Ready Flex technology exclusively in all of their 2012 cotton budgets. Arkansas and Mississippi had cotton budgets for the Roundup Ready Flex technology and the Liberty Link technology. Tennessee and Texas still had some cotton budgets that utilized the Roundup Ready technology and varieties that were conventional with regard to weed control technology.

Weed resistance and transgenic cotton seed have certainly changed the face of cotton budgets. Land grant universities are taking varied approaches to budgeting for these changes.

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Impact of Foliar Herbicide Application on Cotton with Selected Insecticide Seed Treatments

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RESEARCH PROBLEM

Thrips (*Frankliniella fusca* and *Frankliniella occidentalis*) are one of the most important pest families during the early growing season of Midsouth U.S. cotton (*Gossypium hirsutum* L.). In most years it is not uncommon to over spray 20-30% of cotton acres for thrips. However, within the last two years, thrips pressure has increased. In 2011 and 2012 more than 70% of cotton acreage was over sprayed for thrips control, independent of insecticide seed treatments. In this early development stage of cotton, the first application of an herbicide system is also being applied. With insecticide seed treatments not working as well as they have in the past, many growers have questions about seed treatment efficacy.

BACKGROUND INFORMATION

The tobacco thrips is the most common thrips species on cotton in the Midsouth, comprising more than 90% of collections from seedling cotton (Layton and Reed, 2002). Due to mild winters the last couple of years, Western Flower Thrips (WFT) are becoming more prevalent. This presents a problem in that WFTs have developed more resistance to normal thrips control methods (Kirk and Terry, 2003).

RESEARCH DESCRIPTION

A preliminary trial was conducted at the Lonn Mann Cotton Research Station, Marianna, Ark. during the 2012 growing season. Various rates of commonly used insecticide seed treatments were applied to cotton seed before planting (Table 1). Plots were planted in a randomized complete block design, measuring 50 ft. by 4 rows. Dual Magnum herbicide was sprayed at approximately the 2-4 leaf stage. Measurements of thrips populations were recorded twice, once 5 days pre-appli-

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cation and once 5 days post-application. Injury by herbicide was also recorded 5-7 days after application in the two categories of chlorosis and necrosis. Changes in maturity were determined by taking nodes above white flower counts. Yield was not taken due to delayed planting.

RESULTS AND DISCUSSION

No significant differences were observed in stand counts, plant height, chlorosis damage, or nodes above white flower. Thrips populations increased after the application of Dual Magnum herbicide in all treatments (Fig. 1). Both rates of Gaucho seed treatments had fewer thrips than other treatments before application of the herbicide. However, after application of the herbicide, Gaucho treatments had the highest increase in thrips, spiking at 474% and 415% increase in numbers compared with preherbicide thrips counts (Fig. 2). In comparison, the thrips population in the untreated check had a 32% increase. Cruiser seed treatment at 0.51 mg ai/seed had less control compared to Gaucho both before and after herbicide application. Higher populations of thrips were observed in treatments with greater necrosis. There were differences in necrosis damage based on seed treatment (Fig. 3). Untreated check exhibited no necrosis, while both Gaucho treatments exhibited the most damage at 8.7% and 6.3%.

PRACTICAL APPLICATION

These results suggest that thrips populations increase after the application of a post-emergence herbicide application, and that there may be some interaction between the insecticide seed treatment and herbicide application. However, there are many different factors that can cause this increase in thrips populations such as: planting date, weather patterns, loss of active ingredient, herbicide injury, plant stress, as well as antagonism. In order to make conclusions on efficacy of changes of seed treatments after the application of an herbicide, more tests must be conducted.

ACKNOWLEDGMENTS

The authors thank, Cotton State Support Committee, Syngenta, Bayer Crop Science, and the seasonal crew at the University of Arkansas Experiment Station in Lonoke, Ark. for making this project possible.

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Table 1. Treatments applied to cotton seed.

Treatment Number	Herbicide Treatment
1	UTC (fungicide only)
2	Gaucho 600 FS 0.375
3	Gaucho 600 FS 0.51
4	Cruiser 0.375
5	Cruiser 0.51
6	Cruiser 0.375 + Gaucho 600 FS 0375
7	Cruiser 0.375 + Orthene (Foliar)

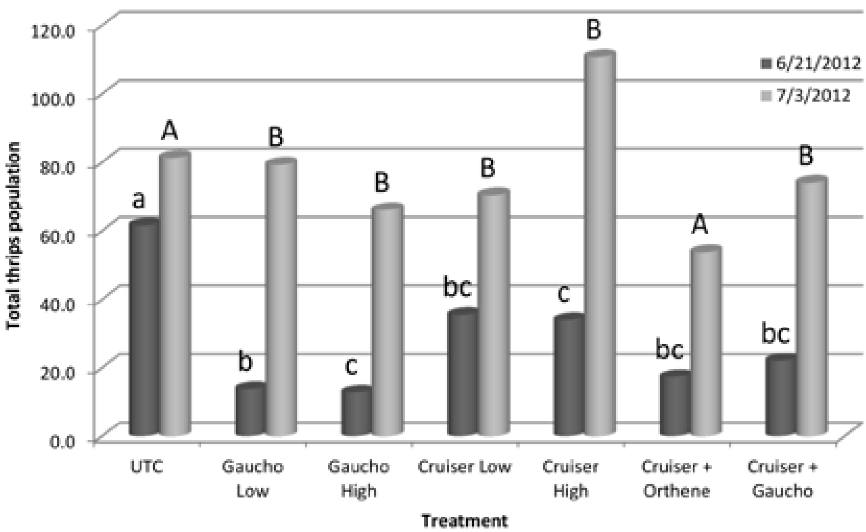

Fig. 1. Total thrips population before (6/21) and after (7/3) herbicide application. (Letters represent significant differences attained using least significant difference analysis).

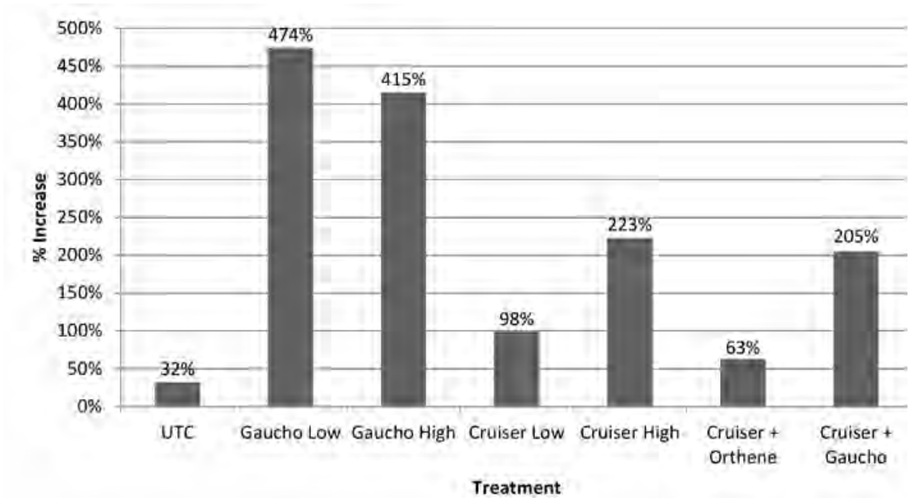

Fig. 2. Increase in thrips populations after herbicide application. (% = percent thrips population grows after herbicide application).

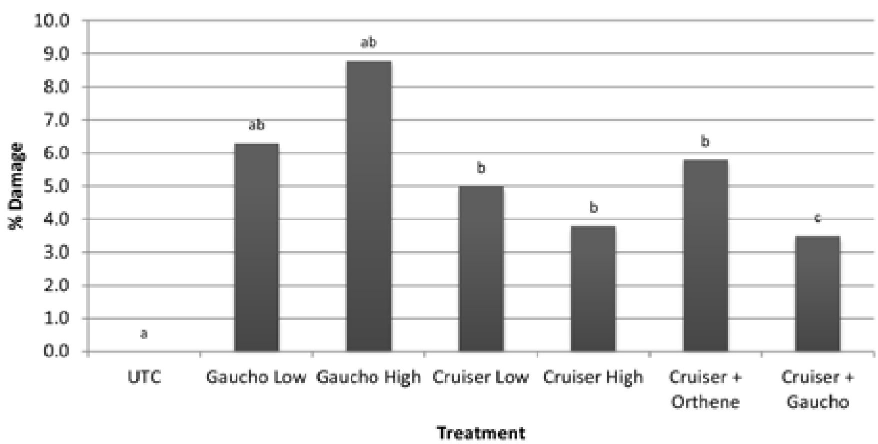

Fig. 3. Necrosis damage by treatment. (Letters represent significant differences attained using least significant difference analysis).

Full-Season Weed Control Systems in Arkansas Cotton

R.C. Doherty[1], T. Barber[2], and J.R. Meier[1]

RESEARCH PROBLEM

Cotton growers in Arkansas still struggle to gain complete control of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*). Palmer amaranth control programs must contain overlapping-residual herbicides used throughout the growing season. The application timing of the residual herbicides in the system can influence season long control of this troublesome pest. The objective was to determine the herbicide system that would provide optimum season-long Palmer amaranth control in Arkansas cotton.

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. More information was needed on the timing and herbicides used for control of Palmer amaranth with overlapping-residual full-season herbicide systems.

RESEARCH DESCRIPTION

One trial was established at the Rohwer Research Station, Rohwer, Ark. in a Hebert silt loam soil in 2011 and 2012 to evaluate Palmer amaranth control in cotton. The trial was arranged in a randomized complete block design with four replications. Eight herbicide systems were evaluated at one or more of the three layby timings (8, 10, or 12 leaf cotton). Parameters evaluated were visual control ratings of Palmer amaranth and cotton yield. Weed control was recorded on a 0-100 scale with 0 being no control and 100 being complete control.

RESULTS AND DISCUSSION

At 80 days after the 12 leaf application in 2011 Cotoran at 1 lb ai/acre PRE followed by (fb) Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb

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ai/acre applied at 2 leaf cotton fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 6 leaf cotton fb MSMA at 2 lb ai/acre plus Valor at 0.064 lb ai/acre applied at 12 leaf cotton provided 100% control of Palmer amaranth. All other herbicide systems applied at 10 and 12 leaf layby timings provided 93-100% control of Palmer amaranth (Figs. 1 and 2). Cotoran at 1 lb ai/acre PRE fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 2 leaf cotton fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 6 leaf cotton fb MSMA at 2 lb ai/acre plus Valor at 0.096 lb ai/acre applied at 8 leaf cotton provided the highest cotton yield numerically with 3320 lb/acre of seed cotton. All other herbicide systems applied at 10 and 12 leaf layby timings provided statistically equal cotton yields (Fig. 3). Herbicide systems that contained a 12 leaf layby did provide numerically higher weed control than the same system with the layby applied at 8 or 10 leaf cotton.

At 76 days after the 12 leaf layby application in 2012, all herbicide programs applied at all three timings provided 95% to 100% control of Palmer amaranth. Cotoran at 1 lb ai/acre PRE fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 2 leaf cotton fb MSMA at 2 lb ai/acre plus Valor at 0.064 lb ai/acre applied at 8 leaf cotton yielded higher than the untreated check but lower than all other systems (Figs. 4 and 5). Cotoran at 1 lb ai/acre PRE fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 2 leaf cotton fb Roundup PowerMax at 0.77 lb ae/acre plus Dual Magnum at 0.95 lb ai/acre applied at 6 leaf cotton fb MSMA at 2 lb ai/acre plus Reflex at 0.375 lb ai/acre applied at 10 leaf cotton provided the highest cotton yield numerically with 3574 lb/acre of seed cotton (Fig. 6).

PRACTICAL APPLICATIONS

Residual herbicides are necessary in zero-tolerance weed control systems. These herbicide systems can provide full-season Palmer amaranth control and will aid in providing a sustainable cotton production system. The information from this trial will be used to make Palmer amaranth control recommendations throughout the state.

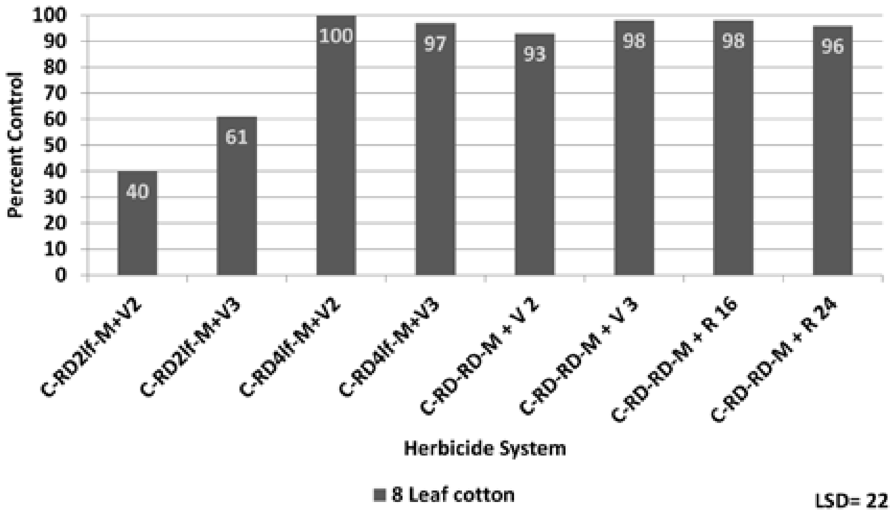

Fig. 1. 2011 Palmer Control 94 days after herbicide application 8 leaf.

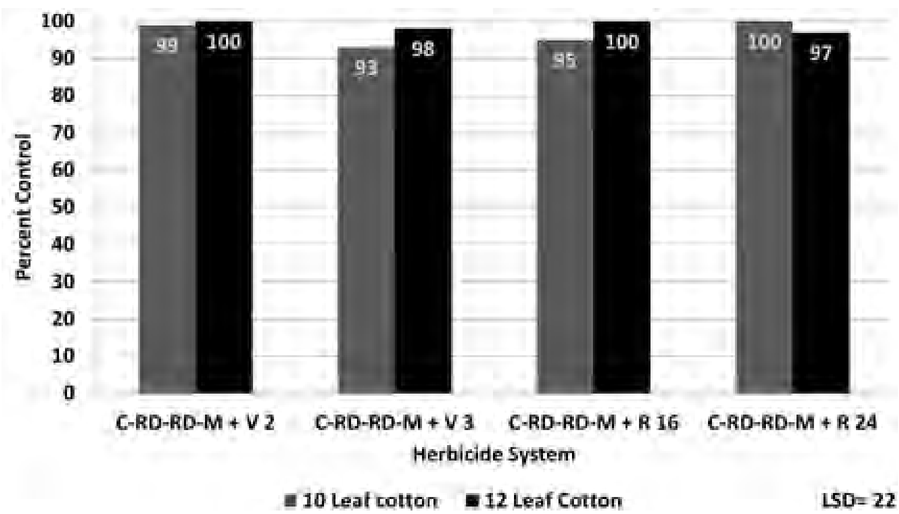

Fig. 2. 2011 Palmer Control 91 days after herbicide application (DA) 10 leaf 80 DA 12 leaf.

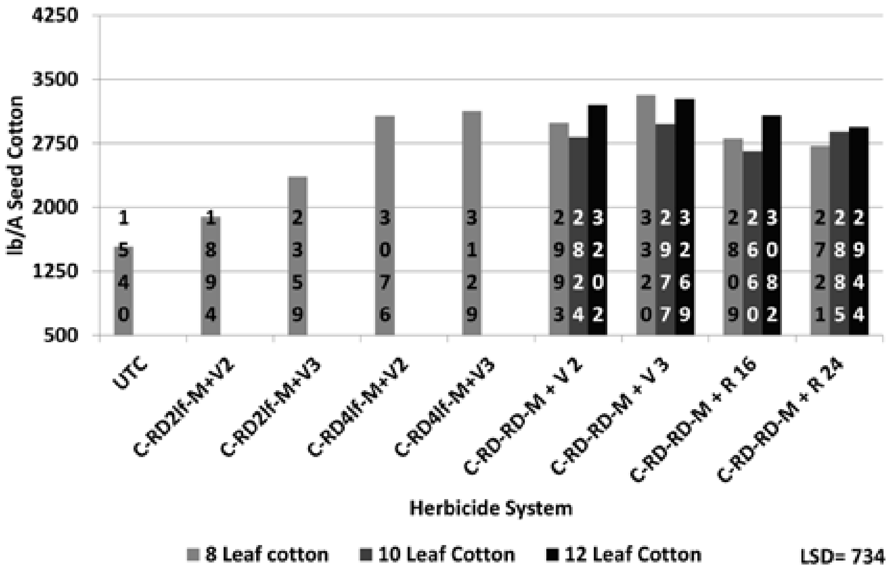

Fig. 3. Cotton Yield 2011.

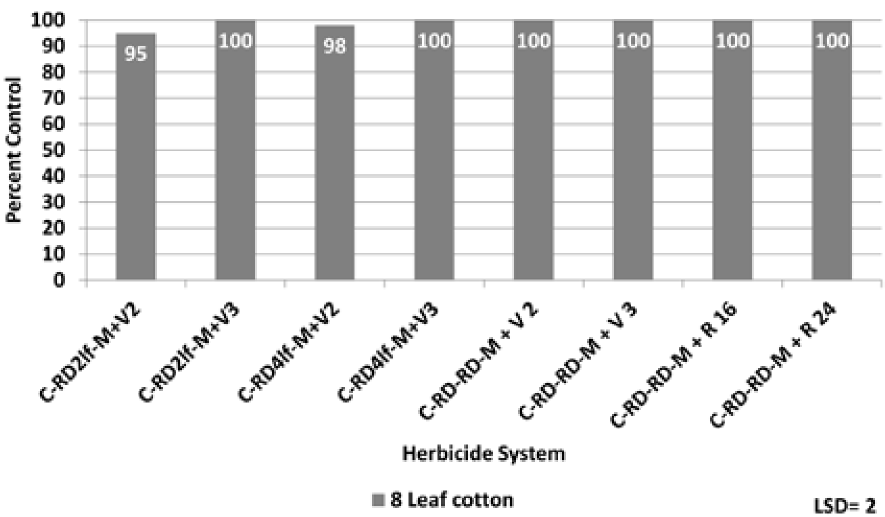

Fig. 4. 2012 Palmer Control 91 days after herbicide application 8 leaf.

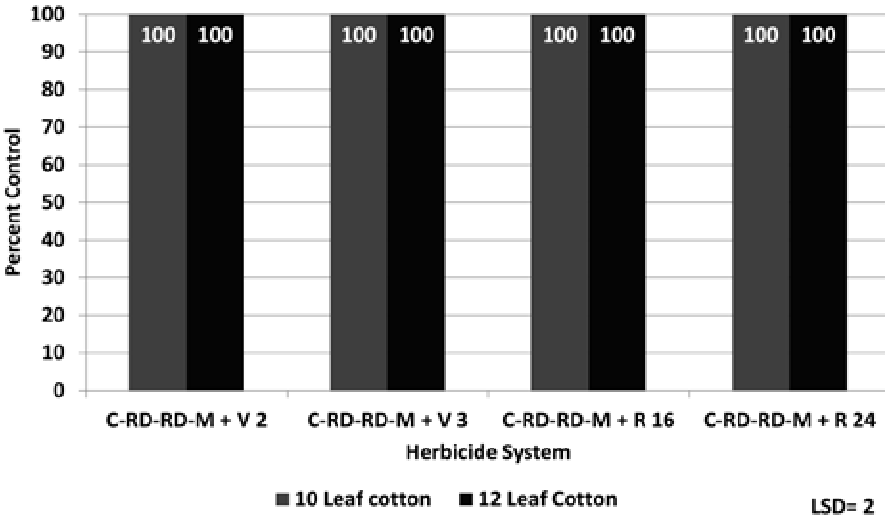

Fig. 5. 2012 Palmer Control 81 days after herbicide application (DA) 10 leaf 76 DA 12 leaf.

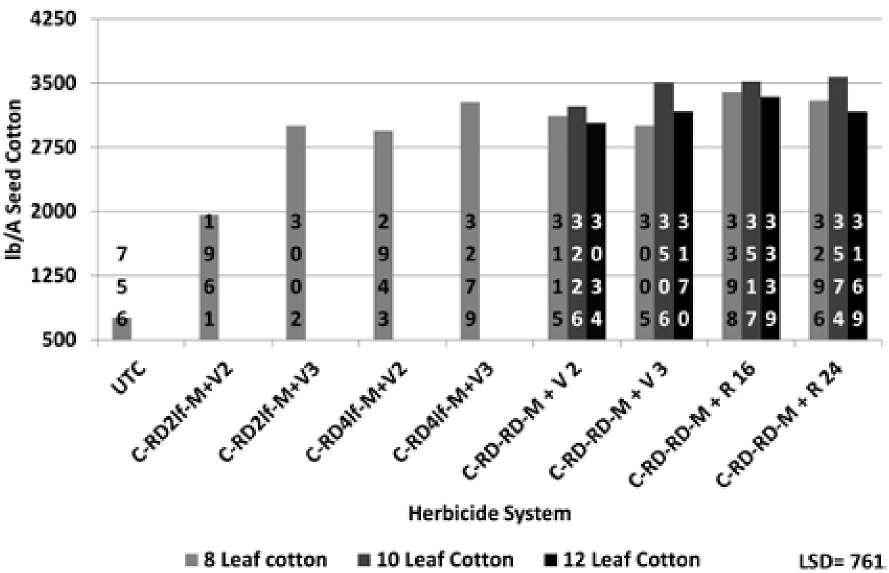

Fig. 6. Cotton Yield 2012.

Rainfastness of Selected Insecticides Used for Control of Tarnished Plant Bug in Arkansas Cotton

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RESEARCH PROBLEM

The tarnished plant bug, *Lygus lineolaris (Palisot de Beauvois, 1818),* (TPB) has become the most destructive pest in Arkansas cotton since the eradication of the boll weevil and the development of Bt cotton. Before 1995, TPB were controlled with insecticides targeting other insect pests such as the tobacco budworm, cotton bollworm and boll weevil. Reduced applications for these pests have established the TPB as the primary insect pest of cotton in the Midsouth U.S. Recently, TPB has become resistant to several classes of insecticides, further compounding the issue (Catchot, et. al., 2009).

BACKGROUND INFORMATION

In 2010, Arkansas growers treated 92% of the cotton acreage planted an average of 2.58 times at a cost of $18.06/acre, with a total of 38, 946 bales of cotton lost to the TPB, 48% of the total bales lost for the year (Williams, et al., 2011). In 2011, these numbers increased to 100% of cotton acreage treated an average of 4.4 times with an average cost of $30.48/acre. In spite of the increase in cost of control and number of applications, growers were reported losing a total of 55,208 bales of cotton to the TPB, equaling 53% of the total bales lost for the year (Williams, et al., 2012). The problem controlling TPB is exacerbated with the situation of "pop up" rain events that often occur in the Midsouth U.S. that can cause wash off of insecticide applications that can occur at any time after application. Also, many growers that have overhead irrigation may need to irrigate their crop to meet water demand of the crop as soon as possible behind applications. Labels do not provide adequate information on rainfastness, or the amount of time that is needed after an application before a rainfall event or overhead irrigation event can take place for the insecticide to still provide acceptable level of control. Overestimating wash-off can cause unwarranted re-applications of insecticide applica-

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tions, while underestimating wash-off may result in inadequate crop protection (Pimentel, et al. 1992).

RESEARCH DESCRIPTION

Studies were conducted in both the greenhouse and field to evaluate the rainfastness of five insecticides: Centric (thiamethoxam), Acephate, Bidrin (dicrotophos), Diamond (novaluron) (2011), and Transform (sulfoxaflor) (2012), currently recommended for control of tarnished plant bug (*Lygus lineolaris*) in Arkansas and the Midsouth U.S. Greenhouse trials were located at the Lonoke County Cooperative Extension Service, Lonoke, Ark. Field trials were located at the Northeast Research and Extension Center in Keiser, Ark. Both studies simulated one inch of rainfall at 0, 1, 3, 6, 12, and 24 h after application, as well as no rain for comparison. Mortality was checked at 24 h (greenhouse) and 48 h (greenhouse and field) after infestation. Plant bug nymphs were collected 24 h prior to testing using a shake sheet and aspirator, placed in cages and kept overnight on broccoli cleaned with a 0.1% bleach solution. Third and fourth instar nymphs were used for the studies. Treatments included an untreated control, Centric 2.5 oz/acre, Acephate 1lb ai/acre, Bidrin 8 oz/acre, Diamond 9 oz/acre (2011), and Transform 1.5 oz/acre (2012). In the greenhouse study, cotton plants were sprayed with a CO_2 backpack sprayer and hand-held boom fitted with TX6 hollow cone nozzles, spray volume of 10 gallons per acre (GPA) at 40 psi. One inch of rainfall was simulated with overhead boom irrigation at 0, 1, 3, 6, 12, and 24 h after application, as well as no rain for comparison using a minimum of 2 plants per timing/per treatment to ensure adequate leaf samples for testing. After the “rain” dried, the three uppermost leaves were removed within each treatment and placed in separate petri dishes for three replications per treatment. Each dish was infested with three plant bug nymphs. Mortality was checked at 24 and 48 h after infestation. Field trials were conducted similarly using overhead lateral irrigation at 10 GPA, TX6 hollow cone nozzles 50 psi to simulate 1/2 in. rain. The highest four terminals were selected and caged using sleeve cages. Five plant bug nymphs were placed in each cage with six replications per treatment. Mortality was checked 48 h after infestation. Data was processed using ARM 8 and ARM ST 7 (Gylling Data Management, Inc., Brookings, S.D.), Duncan’s New Multiple Range Test, and Analysis of Variance to separate means (P = 0.10). Greenhouse data is a summary of 7 trials and field data is a summary of 5 trials.

RESULTS AND DISCUSSION

In 2011 studies, results were inconclusive with Diamond. Diamond, (Novaluron) is an insect growth regulator and is not a contact type insecticide. Because of this, Diamond requires more time to observe efficacy and the effects of rain; therefore, it was replaced with Transform in 2012. In both the greenhouse and field portions of the study, the efficacy of all treatments was diminished at varying levels by rain events. Bidrin achieved a higher level of control in the greenhouse when compared to the field when no rain was applied. Similar levels of reduction in control (~43%) in both the greenhouse and field were observed when rain occurred immediately after application (Tables 1 and 2).

At the 12 h and 24 h timings, there was no difference in the amount of control lost in both greenhouse and field studies respectively; however, the field study had a control loss of only 3% while the greenhouse still had a loss of 24% control. Acephate also had a higher mortality rate in the greenhouse than it did in the field, with similar control loss percentages to Bidrin at the 0 h rain timing; however, by the 12 h timing Acephate had no loss of control in either the greenhouse or the field. Centric showed the same level of control (~54%) in both the greenhouse and field trials and the amount of control lost when rain occurred at 0 h was the same at ~18%. At the 6 h rain timing, Centric regained all but 4% of control in the greenhouse while in the field control was slower to return to the same level as the no rain observation with 12% control lost at 12 h and 6% lost at 24 h. Initially, Transform gave better control in the field than it did in the greenhouse with mortality rates dropping from 76% (field) and 59% (greenhouse) to between 20% and 30% respectively when rain occurred at 0 h. At 12 h, Transform showed no loss of control in the greenhouse while never fully regaining control in the field. It seems that at the 24 h timing, when loss of control was higher than the 12 h timing, the age of the plant bugs may have come into play. Some of the differences between the greenhouse data and the field data could have been caused by the differences in procedure as well as the different types of exposure used by the treatments. Studies in the greenhouse relied primarily on the plant bugs coming into contact with the insecticides by walking on the leaves while the field studies allowed plant bugs to behave more naturally within the confines of the cages. Bidrin and Acephate rely on contact while Centric and Transform utilize both contact and feeding. Regardless, results indicate that if a rain event does not occur before 12 h after application of these insecticides, it is safe to assume that they are rainfast.

PRACTICAL APPLICATION

Greenhouse results indicated that all treatments experienced reduced mortality when rain occurred prior to 12 h after application. Field studies indicated that all treatments experienced reduced mortality compared to no rain at all rain event timings from 0 to 24 h after application with the exception of Bidrin having no loss of control compared to no rain at 12 h after application. Results of this study will assist entomologists in giving recommendations to cotton growers who are making key insect pest management decisions about which insecticide to use when there is a “chance” of rain, whether or not to re-spray if rain occurs after an insecticide application is made, as well as determine what period of time needs to pass before using overhead irrigation.

ACKNOWLEDGMENTS

We thank the Arkansas Cotton State Support Committee and Cotton Incorporated for funding this project.

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Table 1. Percent loss of control when compared to the no rain application in the greenhouse.

Greenhouse							
	Rain Timing						
Treatment	0 hour	1 hour	3 hour	6 hour	12 hour	24 hour	no rain
	-------------------------% loss of control-------------------------						% control
Bidrin 8 oz/acre	42.9	40.5	25.4	38.7	23.7	23.7	**90.4**
Acephate 1 lb ai/acre	42.9	23.9	25.4	14.9	0	0	**88.9**
Centric 2.5 oz/acre	15.9	19.1	20.7	4	0	15.1	**53.9**
Transform 1.5 oz/acre	29.6	26.1	29.6	34.3	0	15	**59.3**

Table 2. Percent loss of control when compared to the no rain application in the field.

Field							
	Rain Timing						
Treatment	0 hour	1 hour	3 hour	6 hour	12 hour	24 hour	no rain
	------------------------ % loss of control------------------------						% control
Bidrin 8 oz/acre	47.8	43	30.5	19.7	2.6	2.6	**81.9**
Acephate 1 lb ai/acre	34.7	26.7	21.57	19	0	3.7	**66.27**
Centric 2.5 oz/ace	19.4	25.5	15.6	20.8	11.5	6	**53.74**
Transform 1.5 oz/acre	55.9	52	38.3	35	33.8	22.3	**76.44**

Control of Tarnished Plant Bug, *Lygus lineolaris*, in Cotton with Transform in Arkansas, 2012

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RESEARCH PROBLEM

The tarnished plant bug has become a more difficult pest to control in the last several years. Multiple insecticide applications are needed to achieve control which makes it one of the most expensive pests in Arkansas. Transform (sulfoxaflor), a new insecticide, was evaluated across several trials in the 2012 growing season for control of tarnished plant bug in cotton.

BACKGROUND INFORMATION

Tarnished plant bug (TPB) is an important insect pest of Midsouth U.S. cotton. It has potential to cause severe damage that can lead to square shedding and abnormal growth of bolls and terminals. The amount of damage this pest causes varies depending on population intensity from year to year. Growers and consultants have relied on repeated foliar applications to minimize TPB numbers. In 2012 the average number of applications per acre of treated fields was 6.5 (Williams, 2012). The reliance on insecticides for control of plant bugs has led to resistance of some commonly used insecticides, particularly pyrethroids, and new chemistries are needed (Snodgrass and Scott, 2000). Transform is the first insecticide from the sulfoximine chemical class. The 2012 growing season was the first year Transform received a Section 18 in Arkansas. The purpose of this study was to compare Transform to current standards.

REARCH DESCRIPTION

Trials were conducted in 2012. All trials were conducted at the Lon Mann Cotton Branch Experiment Station, Marianna, Ark. and producer fields in Lee County, Ark. Plot size was 12.5 ft (4 rows) by 50 ft. in a randomized complete block with 4 replications. Insecticide treatments were applied with a Mud Master

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ground applicator. The spray boom was fitted with TX6 cone jet nozzles at 19 in nozzle spacing. Spray volume was 10 gal/acre, at 40 psi. Plant bug numbers were determined by taking 2 shakes per plot with a 2.5 ft drop cloth, for a total 10 row ft. The data was processed using Agriculture Research Manager V.8 (Gylling Data Management, Inc., Brookings, S.D.) and Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

RESULTS AND DISCUSSION

In Efficacy of Transform 1 trial, 9 days after the second application (9 days after treatment, DAT2), no treatments reduced plant bug numbers below threshold (6 per 10 row ft). However, all treatments separated from the untreated control (UTC) which was over 22 times threshold (Fig 1). Transform (1.5 oz/acre) + Bidrin (8 oz/acre) reduced population better than all treatments but did not differ from Transform (1.5 oz/acre) + Bidrin (6.4 oz/acre) + Discipline (6.4 oz/acre), Bidrin (6.4 oz/acre) + Discipline (6.4 oz/acre) + Diamond (6 oz/acre), Bidrin (8 oz/acre) + Diamond (6.4 oz/acre), Endigo (5 oz/acre) and Leverage 360 (3.2 oz/acre) + NIS (.25% v/v). All treatments increased yields compared to the UTC (Fig. 2). Both treatments containing Transform had higher yields than the other treatments and showed at least a 27% yield increase over the control.

In the Mayhem Transform 2012 trial, at 3 days after the first application (3DAT1), no treatments reduced numbers below threshold, although all treatments separated from the UTC (Table 1). At 6 days after the first application (6DAT1), Mayhem (6 oz/acre ABCD) + Transform (1.5 oz/acre ABCD), Mayhem (6 oz/acre ABCD) + Transform (2.125 oz/acre ABCD) and Mayhem (6 oz/acre ABCD) + Transform (2.75 oz/acre ABCD) were the only treatments that reduced populations below threshold. At 4 days after second application (4 DAT2), all treatments reduced TPB numbers below threshold, at 7 days (7 DAT2) Transform alone at 2.75 oz/acre (ABCD), Mayhem (6 oz/acre ABCD) + Transform (1.5 oz/acre ABCD) and Mayhem (6 oz/acre ABCD) + Transform (2.125 oz/acre ABCD) remained below threshold. At 7 days after the third application (7DAT3), the only treatments that were able maintain control of TPB were Transform 2.75 oz/acre (ABCD), Mayhem (6 oz/acre ABCD) + Transform (1.5 oz/acre ABCD), Mayhem (6 oz/acre ABCD) + Transform (2.125 oz/acre ABCD) and Mayhem (6 oz/acre ABCD) + Transform (2.75 oz/acre ABCD). At 3 days post application four (3DAT4), Transform (1.75 oz/acre ABCD), Mayhem (6 oz/acre ABCD) + Transform (1.5 oz/acre ABCD), Mayhem (6 oz/acre ABCD) + Transform (2.125 oz/acre ABCD), Mayhem (6 oz/acre ABCD) + Transform (2.75 oz/acre ABCD) and Mayhem 6 oz/acre (ABCD) + Alias 1.5 oz/acre (AC) + Acephate 0.75 lb ai/a (BD) all reduced plant bug populations below economic threshold. After 8 days post application (8DAT4), the only treatments that did not provide control were Mayhem (6 oz/acre ABCD), Mayhem (6 oz/acre AC) + Transform 1.5 oz/acre (BD) and Mayhem (6 oz/acre AC) + Acephate .75 lb ai/a (AC) + Transform 1.5 oz/acre (BD). Harvest totals across all treatments separated from the UTC giving at least a 58% yield increase above the UTC (Fig. 3).

ACKNOWLEDGMENTS

Appreciation is expressed to the Lon Mann Cotton Research Station and Arkansas cotton producers. Also we acknowledge Dow for their support.

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Table 1. Efficacy of Transform for control of tarnished plant bug. Mayhem Transform 2012.

	Mayhem Transform 2012 Average Plant Bugs/10 row feet							
Treatments	**7/20 3DAT1**	**7/23 6DAT1**	**7/27 4DAT2**	**7/30 7DAT2**	**8/6 7DAT3**	**8/9 3DAT4**	**8/14 8DAT4**	**Season Total**
Untreated control	23 a[†]	26.8 a	32.5 a	59 a	86.5a	93.5a	88.5a	409.8a
Novaluron 6oz/acre (ABCD)	10 bc	17.8 b	14.5 b	21 b	14bc	10.3b	6.8bc	95b
Sulfoxaflor 1.5oz/acre (ABCD)	8.3 bc	7.8 c	3 c	7.8 c	8.3bcd	5.3b	5.5bc	45.8cde
Sulfoxaflor 2.75oz/acre (ABCD)	9 bc	8.5 c	2.5 c	4.3 c	3.5cd	8b	3.5bc	32de
Novaluron 6oz + Sulfoxaflor 1.5 oz/acre (ABCD)	8.5 bc	5 c	3.5 c	5.5 c	5.5cd	3.5b	3.8bc	35.3de
Novaluron 6oz + Sulfoxaflor 2.125oz/acre (ABCD)	7.8 c	5.8 c	2.5 c	4.8 c	2d	3.3b	1.5c	27.5e
Novaluron 6oz + Sulfoxaflor 2.75oz/acre (ABCD)	11.3 bc	5.8 c	3 c	6.5 c	3.5cd	1.8b	2.5c	34.3de
Novaluron 6oz/acre (A,C), Sulfoxaflor 1.5oz/acre (B,D)	15 b	12.3bc	5.3 c	9.5 c	13.8bc	6.3b	8.8b	70.8bc
Novaluron 6oz (AC), Acephate .75lb ai/a (AC), Sulfoxaflor 1.5oz/acre (BD)	9.3 bc	9.5 c	4.8 c	10 c	10bcd	8b	8.3b	59.8cde
Novaluron 6oz/acre(ABCD), Alias 1.5oz/acre (AC), Acephate .75lb ai/a(BD)	11.3 bc	12 c	3.8 c	8.3 c	18.3b	4b	6bc	63.5bcd

[†]Treatments within columns with the same lertter are not significantly different (P = 0.05).

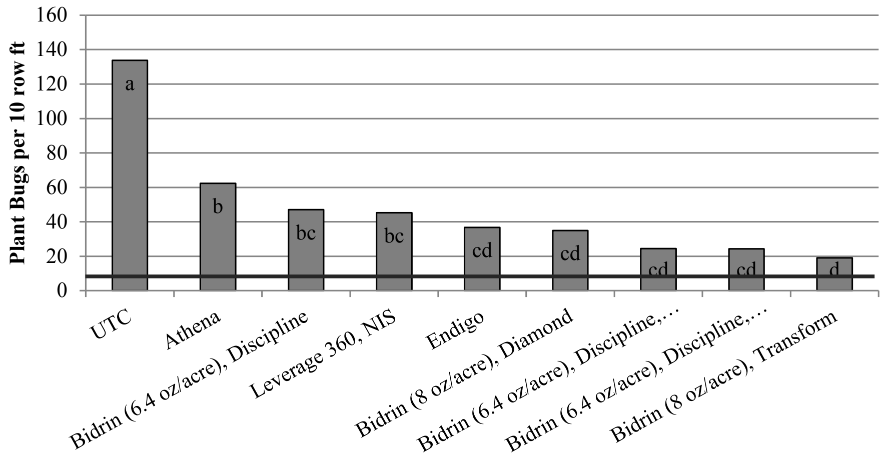

Fig. 1. Efficacy of Transform for control of tarnished plant bug 9 days after treatment (DAT) 2. Transform 1 Trial, 2012. Threshold of 6 plant bugs per 10 row feet is shown. UTC = untreated control.

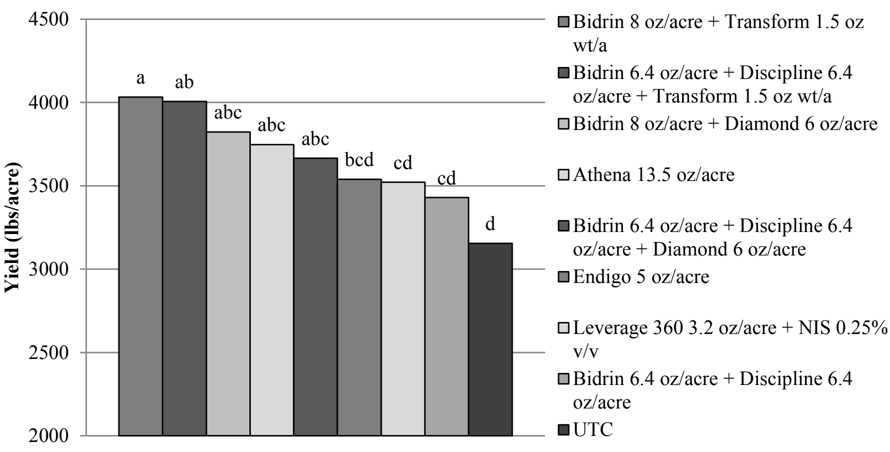

Fig. 2. Efficacy of Transform for control of tarnished plant bug. Transform 1 Trial, 2012 Harvest. UTC = untreated control.

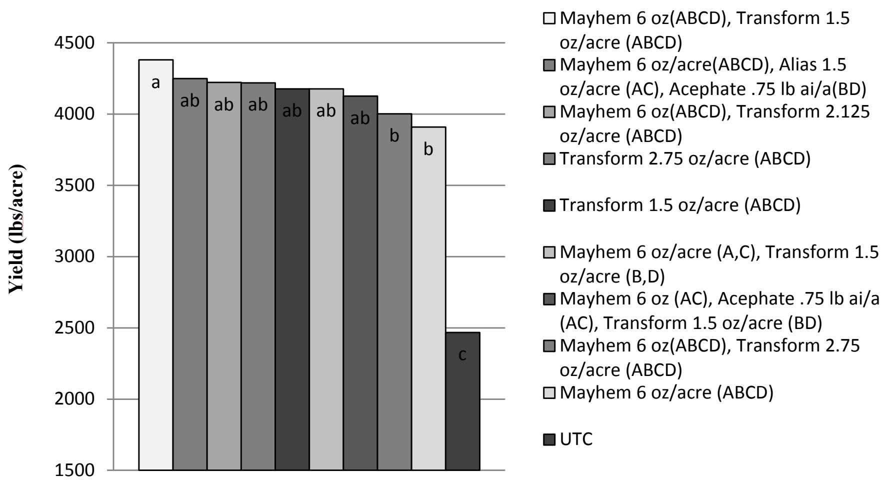

Fig. 3. Efficacy of Transform for control of tarnished plant bug. Mayhem-Transform, 2012 Harvest. UTC = untreated control.

Control of Tarnished Plant Bug with Tankmix and Premix Insecticides

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RESEARCH PROBLEM

The tarnished plant bug (TPB), *Lygus lineolaris,* is the most important insect pest of cotton in Arkansas. It is imperative for growers to have tools available to them to combat this pest and maintain the upper hand before increasing populations grow beyond their control. In order to inform growers of which tools are the most effective, it is crucial that trials are conducted to make that determination.

BACKGROUND INFORMATION

From 2003 to 2009 the tarnished plant bug caused more yield loss than any other pest averaging a loss of over 50,000 bales in Arkansas (Williams, 2009). Plant bug populations in the past several years 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 one application (Lorenz, et al., 2011). To make matters worse resistance to multiple insecticides has been found across the Midsouth U.S. (Snodgrass, 1996; Snodgrass et al., 2009). Use of insecticide premixes and tankmixes have been shown as an effective way to increase control (Thrash et al., 2012). A total of 33 trials from the 2009–2012 growing seasons were used to evaluate the control of insecticide mixes compared to single products.

RESEARCH DESCRIPTION

Trials were conducted during the 2009–2012 growing season. Treatments were applied with a Mud Master fitted TXVS-6 hollow cone nozzle. Spray volume was 10 gallons per acre (GPA) at 40 psi. Plot sizes were 12.5 ft. (4 rows) by 50 ft. Insect numbers were determined by using a 2.5 ft. drop cloth and taking

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2 samples per plot for a total of 10 row feet per plot. Data were processed using Agriculture Research Manager V. 8 (Gylling Data Management, Inc., Brookings, S.D.), analysis of variance, and Duncan's New Multiple Range Test ($P = 0.10$) to separate means. Data was compared between tests by converting each treatment's season total plant bug numbers to their respective untreated checks season total to provide a percent control. The number of data sets used for each individual treatment's average is designated by n = #.

RESULTS AND DISCUSSION

Insecticide mixes usually increased TPB control when compared to individual compounds. All treatments showed an increase in efficacy when single products were mixed with bifenthrin (Fig. 1). An average efficacy increase of 14% was observed when selected insecticides were combined with bifenthrin. All selected insecticides showed an increase in efficacy when novaluron (6 oz/acre) was mixed with single products except Transform (Fig. 2). Tankmixes containing novaluron (6 oz/acre) showed an average increase of 15% when compared to single products. When selected insecticides were mixed with Transform, control was increased an average of only 2% (Fig. 3), which was not substantial enough to warrant the extra cost. Transform (2.5 oz/acre) provided the best control in the trial "Got Plant Bugs?", though no insecticide or mix provided significantly better control than any other (Fig. 4). Mixes that included Diamond regularly provided the best control of all treatments. Transform provided exceptional control when compared to all other single products. The results of these studies show insecticide mixes are an effective way to increase control of tarnished plant bug with existing products.

ACKNOWLEDGMENTS

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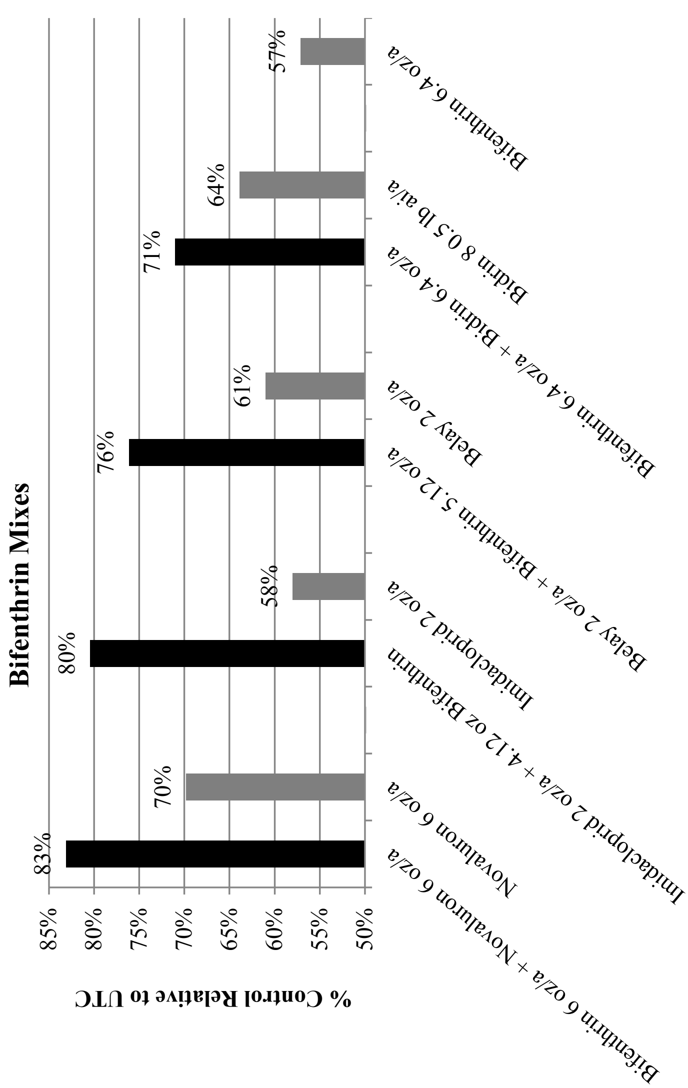

Fig. 1. Tarnished plant bug control with mixes of bifenthrin. UTC = untreated control.

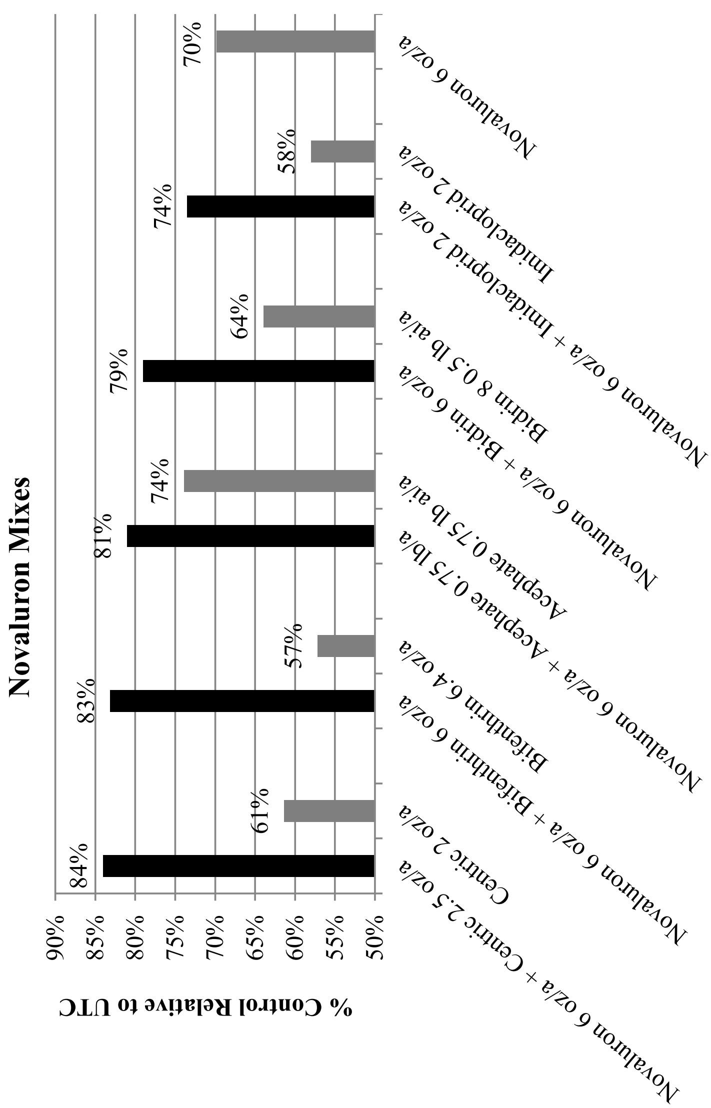

Fig. 2. Tarnished plant bug control with tankmixes and premixes of Mayhem. UTC = untreated control.

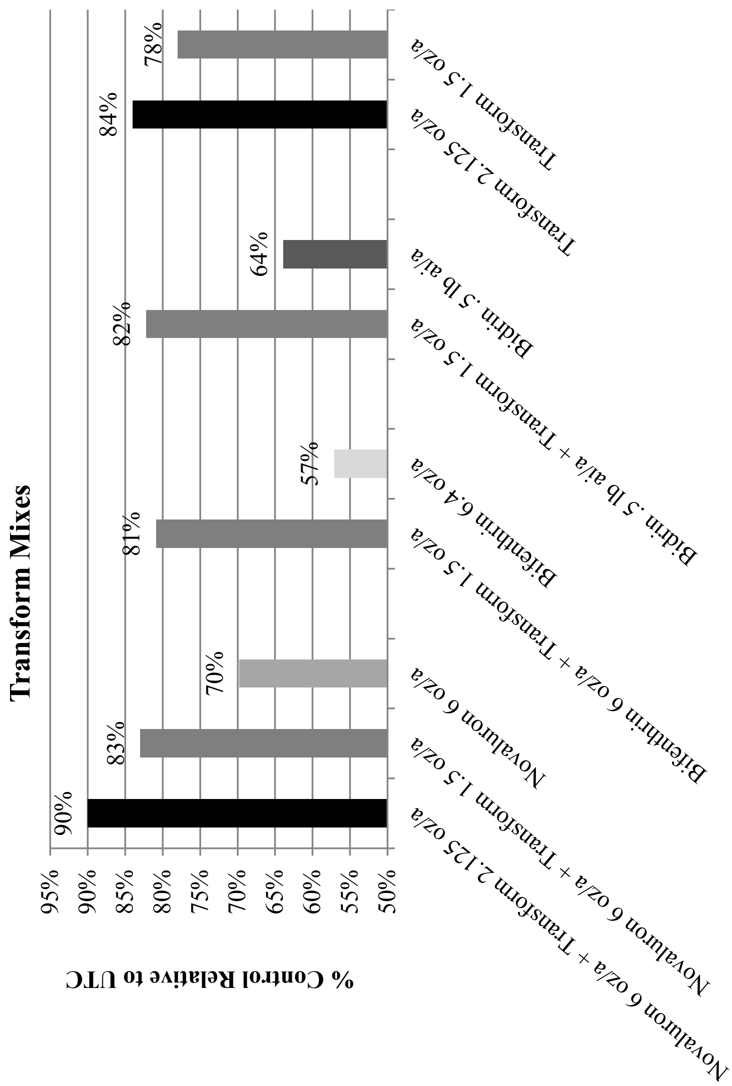

Fig. 3. Tarnished plant bug control with mixes of sulfoxaflor. UTC = untreated control.

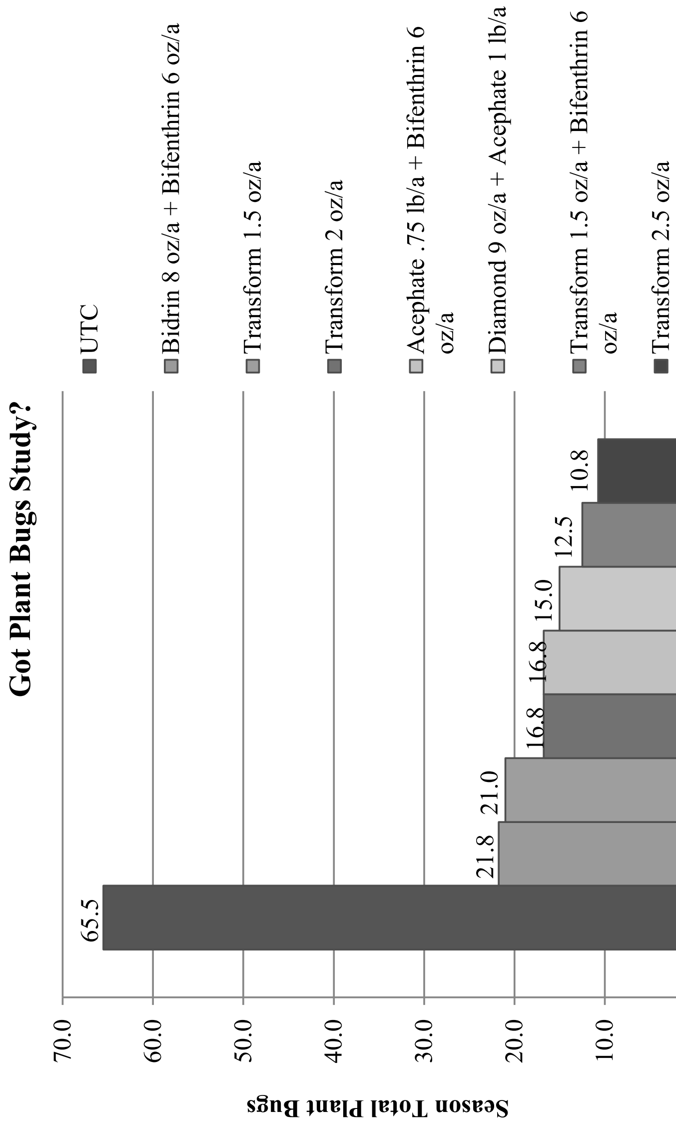

Fig. 4. Got Plant Bugs? Trial 2012. UTC = untreated control.

Effects of Early Infestations of Two-Spotted Spider Mites (*Tetranychus urticae*) on Cotton Growth and Yield

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RESEARCH PROBLEM

Spider mites are an occasional pest of cotton in Arkansas. Depending on the management of the crop and environmental conditions, spider mites have the potential to cause yield loss. In recent years cotton growers have seen an increase in spider mite infestations earlier in the cropping season. To better understand the effects of early-season infestation of spider mites on cotton development and yield, it is necessary to study the effects of spider mite infestation starting at different crop stages and the effects of spider mites at different infestation spans.

BACKGROUND INFORMATION

Historically spider mites have been considered a late-season pest of cotton in the Midsouth. Since 2005, infestations of spider mites have been reported in cotton as early as first and second main-stem nodes (Catchot et al., 2006). Insecticide (Temik 15G) applied during planting previously prevented early spider mite infestations. Currently, infestation of spider mites can occur in cotton with seed treatments or foliar applications (Gore et al., 2012). Infestations of spider mites can increase dramatically under dry weather and dusty conditions (Demirel and Cabuk, 2008). Cotton trials were established in late May of 2012 to evaluate the impact of early-season mite infestation on cotton growth and yield.

RESEARCH DESCRIPTION

Trials were established 25 May 2012 in Lee County, Ark. Cotton plants were infested during three plant growth stages, 4th true leaf, 6th true leaf and at early squaring. Within each plant stage, two-spotted spider mites (*Tetranychus urticae* Koch) were left on cotton for three different time durations, short (3–6 days), medium (9–10 days) and long (11–28 days). The combination of plant stage and du-

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ration of infestation resulted in 9 treatments. Plots had mites only for the duration of infestation, as miticides kept plants mite-free before and after infestation. Additionally, there was a control plot which was kept mite free for the duration of the experiment. The experiment had six replicates with plots of two 38-inch rows, 15 feet long. The cotton (*Gossypium hirsutum* L.) cultivar used was DP0912 B2RF. Mites were reared on green beans in a greenhouse. Cotton plants were infested by cutting bean plants at the base of the stem, and interweaving them through the entire length of the row. Mite counts were made using a standardized methodology to assure that plots were sufficiently infested. Leaf damage was assessed on a plot basis using a visual standard scale 0 = no damage 5 = total reddening (Gore et al., 2012). Leaf damage was assessed between 3 and 6 days after infestation, and then once a week thereafter. Plant heights were measured from the base of the plant to the terminal at squaring for five plants per plot. Cotton plots were harvested and seed cotton yield measured.

RESULTS AND DISCUSSION

Leaf damage ratings were between 0 and 3. Infestations started at the 4th true leaf had the highest leaf damage scores (Table 1). Leaf damage scores during 4th true leaf were ~ 2 for all the treatments, except for the first sampling date. Plant heights were measured at squaring, hence data for only the 4th true leaf and the 6th true leaf stages are reported (Table 2). There was a trend for reduction in plant heights when spider mites were present longer. However, only the treatments with the longer duration infested during the 4th true leaf (4-L) and the 6th true leaf (6-L) showed significant differences, when compared to the control. Plants of these two treatments were significantly smaller than the control. There was a tendency towards lower yield when mite duration increased (Table 3). Just as with plant heights, the 4th true leaf (4-L) and the 6th true leaf (6-L) infestations with long durations had significant reductions in yield.

PRACTICAL APPLICATION

These results indicate that cotton growth and yield are reduced when spider mites remain on plants for an extended time, even when damage may not be obvious.

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We thank the Lonoke Cooperative Extension Service summer crew for their help in collecting data and Lon Mann Cotton Research Station for their support in plot maintenance.

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Table 1. Mean scores for leaf damage during infestations at 4th true leaf (4) and short (S), medium (M) and long (L) infestation durations and control (CNTL)

	Leaf Damage Score			
Treatments	**26 DAP**	**31 DAP**	**41 DAP**	**45 DAP**
4-S	1.1	1.8	0.3	0.5
4-M	1.2	2.2	0.8	0.8
4-L	1.4	2.1	2.0	2.3
CNTL	0.4	0.6	0.4	0.6

DAP = days after planting.

Table 2. Mean plant heights at squaring for infestation treatments started at the 4th true leaf (4) and 6th true leaf (6), and short (S), medium (M) and long (L) durations.

Treatments	Plant Heights (in) (± SE)
4-S	18.9 (± 0.5) a
4-M	17.8 (± 0.4) abc
4-L	15.6 (± 0.4) d
6-S	17.4 (± 0.4) bc
6-L	16.7 (± 0.6) cd
CNTL[2]	18.2 (± 0.5) ab

[1]Means followed by same letter do not significantly differ (*P* = 0.05).
[2]Control treatment.

Table 3. Mean seed cotton yield for infestation treatments started at 4th true leaf (4), 6th true leaf (6) and squaring (SQ), and for short (S), medium (M) and long (L) durations.

Treatments	Yield (lb/acre) (± SE)
4-S	2712.59 (± 197.16) ab[1]
4-M	2811.93 (± 108.28) ab
4-L	2422.23 (± 128.82) b
6-S	3186.34 (±188.19) a
6-L	2406.95 (± 191.15) b
SQ-S	3018.24 (± 279.98) a
SQ-M	3048.80 (± 129.54) a
SQ-L	2735.52 (± 144.33) ab
CNTL[2]	2852.68 (± 85.37) a

[1]Means followed by same letter do not significantly differ (*P* = 0.05).
[2]Control treatment.

Impact of Foliar Insecticide Application on Dual Gene Cotton

G. Lorenz[1], G. Studebaker[2], S. D. Stewart[3], D. Kerns[4], A. Catchot[5], J. Gore[6], D. Cook[6]

RESEARCH PROBLEM

In 2012 several trials were conducted across Arkansas, Tennessee, Mississippi and Louisiana, to evaluate the efficacy of foliar insecticides for control of Heliothines, primarily cotton bollworm on conventional, Bollgard II, and WideStrike cultivars. In most of the trials, the foliar insecticide used was Prevathon (rynaxapyr or chlorantraniliprole). Some trials also included Belt (flubendiamide) or Tracer.

BACKGROUND INFORMATION

Since the introduction of Bollgard in 1996, economic evaluations have been conducted by a number of researchers which indicate that in Arkansas, the most economical cultivar is the one that is highest yielding, regardless of technology associated with the cultivar (Bryant et al., 1997). Most studies show the efficacy of control advantage to single and dual gene technology; but when compared economically, high yielding cultivars are the most economical in Arkansas (Bryant et al., 2004). Recently, DuPont has developed Coragen (Rynaxypyr) and Bayer Crop Sciences has developed Belt (flubendiamide), these new insecticides are very effective for control of caterpillar pests. They have a similar mode of action that cause disruption of the calcium balance within insect muscle cells, leading to a rapid cessation in feeding as well as paralysis of target pests (Bayer CropScience and DuPont technical fact sheet, 2009). Both new insecticides have broad spectrum caterpillar pest control and both have very good residual activity (Hardke et al., 2007). Cotton bollworm and tobacco budworms accounted for only 0.27% reduction in yield in 2009; however, with the high populations encountered in Arkansas during the 2010 growing season, damage levels rose to 2.67%. This equated to cost of control plus loss of yield of over $14 million (Williams, 2010 and 2011). 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

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for our producers. Many of the acres planted with dual gene *B.t.* cultivars in 2009 and 2010 required supplemental foliar applications for bollworms. Applications targeting bollworm/budworms have increased from 0.6 applications per acre in 2008 to 1.7 applications per acre in 2010 (Williams, 2009, 2010, 2011). A similar trend was seen with the single gene bollgard cultivars as well. Bollgard I raised from 0.5 applications per acre to 1.2 applications per acre before Dual gene cotton was forced into the marketplace in 2004 (Williams, 2005). The objective of this study was to evaluate supplemental foliar applications on Bollgard II, WideStrike and conventional cotton to ascertain the benefit of these products in each type of cotton.

MATERIALS AND METHODS

Each location in Arkansas, Louisiana, Tennessee and Mississippi, selected a conventional, Bollgard II, and WideStrike variety. Treatments included untreated control Prevathon at 14 and/or 20 oz/acre, Belt at 3 oz/acre and/or Tracer at 2.9 oz/acre. Regardless of infestation, an application was made the first week of full bloom. Subsequent treatments were made as needed depending on extension threshold. All trials were sprayed for other pests such as plant bugs, aphids, etc as needed. Scouting was accomplished pre-application and at 3, 7, 10, 14, and 21 d post application. Harvest data was taken at all locations.

RESULTS AND DISCUSSION

Seasonal total larval counts indicated significant differences only in the conventional variety, while both Bollgard II and WideStrike cultivars showed little difference and relatively low numbers (Tables 1-4). Damage totals for all four locations were similar to seasonal larvae differences with major differences occurring in the conventional cotton and very few differences in the dual gene cotton cultivars. The exception was the Louisiana location, for which results were hard to explain. Harvest totals indicated in Arkansas that conventional cotton had significant increases in yield with all foliar treatments compared to the control; both dual gene cultivars had more yield compared to conventional cotton; and, the foliar applications of Prevathon increased yield over the untreated control in Bollgard II and WideStrike cotton (Table 1). A similar trend was seen in Mississippi (Table 4). No differences in yield were observed in Louisiana (Table 2). In Tennessee, no differences in yield were observed between dual gene cultivars which had higher yields compared to the conventional (Table 3). This marked difference might indicate foliar applications were made late. However, the Prevathon application did have a higher yield compared to the other foliar treatments and the untreated control. Harvest totals indicated in Arkansas that conventional cotton had significant increase in yield with all foliar treatments compared to control; both dual gene cultivars had more yield compared to conventional cotton; and, the foliar applications of Prevathon increased yield over the untreated control in Bollgard II and WideStrike cotton. A similar trend was seen in Mississippi. No differences in yield were observed in Louisiana. In Tennessee no differences in yield were observed between dual gene cultivars which had higher yields compared to the conventional. This marked difference might indicate foliar applications were made late. However, the Prevathon application did have a higher yield compared to the other foliar treatments and the untreated control.

PRACTICAL APPLICATION

After the development of tolerance to single gene transgenics, we are now experiencing similar tolerance developing in dual gene transgenics. Supplemental foliar applications may become necessary to maximize yield potential, at least until new technology becomes available to the grower.

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Table 1. Season total larvae, season total % damage, and yield lb/acre from Arkansas trial.

ARKANSAS	Season Total Larvae		Season Total % Damage		Yield lb/ac	
Conventional DP179						
Untreated control	34.0	a†	38.92	a	1662.0	e
Prevathon 14 oz/acre	24.7	b	17.27	c	2025.2	d
Prevathon 20 oz/acre	21.3	b	14.73	c	2237.1	c
Belt 3 oz/acre	21.0	b	22.87	b	1604.5	e
BGII STV5288						
Untreated control	5.3	cd	5.33	ef	2361.5	bc
Prevathon 14 oz/acre	1.3	d	2.13	f	2560.3	ab
Prevathon 20 oz/acre	0.5	d	2.87	ef	2679.6	a
Belt 3 oz/acre	3.5	cd	3.20	ef	2744.6	a
PHY375 WS						
Untreated control	9.3	c	9.53	d	2162.3	cd
Prevathon 14 oz/acre	3.0	cd	4.67	ef	2697.8	a
Prevathon 20 oz/acre	3.0	cd	4.60	ef	2725.2	a
Belt 3 oz/acre	4.0	cd	6.53	de	2380.3	bc

†Treatments within a column with the same letter are not significantly different (*P* = 0.05).

Table 2. Season total % damage, and yield lb/70ft from Louisiana trial.

LOUISIANA	Season % Total Damage		Yield lbs/70ft	
DP174				
Untreated control	2.70	b†	1174.08	a
Prevathon 20 oz/acre	3.83	a	1160.08	a
Belt 3 oz/acre	1.56	cd	1017.69	a
Tracer 2.9 oz/acre	1.56	cd	1297.79	a
BGII DP 1133				
Untreated control	0.85	def	1176.41	a
Prevathon 20 oz/acre	0.14	f	1374.82	a
Belt 3 oz/acre	1.28	cd	1218.43	a
Tracer 2.9 oz/acre	0.28	ef	1248.77	a
PHY499 WS				
Untreated control	1.99	bc	1181.08	a
Prevathon 20 oz/acre	1.56	cd	1223.10	a
Belt 3 oz/acre	1.56	cd	1195.09	a
Tracer 2.9 oz/acre	1.13	cde	1111.06	a

†Treatments within a column with the same letter are not significantly different (*P* = 0.05).

Table 3. Season total % damage, and yield lb/acre from Louisiana trial.

TENNESSEE	Season Total Larvae		Yield lb/acre	
FM9250 LL/GlyTol				
Untreated control	82.0	a†	2262.12	d
Prevathon 20 oz/acre	6.8	c	3400.35	b
Belt 3 oz/acre	12.5	bc	2892.56	c
Tracer 2.9 oz/acre	24.3	b	2834.10	c
DP0912 BGII				
Untreated control	1.0	c	3933.36	a
Prevathon 20 oz/acre	2.0	c	4286.98	a
Belt 3 oz/acre	2.3	c	3997.55	a
Tracer 2.9 oz/acre	3.5	c	4089.82	a
PHY375 WRF				
Untreated control	7.3	c	3956.86	a
Prevathon 20 oz/acre	1.5	c	4060.02	a
Belt 3 oz/acre	1.8	c	4179.80	a
Tracer 2.9 oz/acre	5.0	c	3967.17	a

†Treatments within a column with the same letter are not significantly different (P = 0.05).

Table 4. Season total larvae, season total % damage, and yield lb/acre from Mississippi trial.

MISSISSIPPI	Season Total Larvae		Season %Total Damage		Yield lb/acre	
PHY315 RF						
Untreated control	11.5	a†	43.33	a	973.1	f
Prevathon	4.8	bc	18.67	b	2080.0	cd
Belt	8.8	ab	35.17	a	1587.0	e
Tracer	10.3	a	34.50	a	1871.1	de
DPL0912 B2RF						
Untreated control	2.5	c	8.00	bc	2393.5	bc
Prevathon	0.5	c	6.67	bc	2795.2	a
Belt	0.5	c	9.33	bc	2442.5	abc
Tracer	1.0	c	7.17	bc	2455.6	abc
PHY375 WRF						
Untreated control	0.5	c	4.67	c	2178.0	cd
Prevathon	1.5	c	8.67	bc	2671.1	ab
Belt	1.0	c	7.00	bc	2360.9	bc
Tracer	0.0	c	7.00	bc	2409.8	bc

†Treatments within a column with the same letter are not significantly different (P = 0.05).

Variability of Thrips Abundance Across Soil Electrical Conductivity-Based Management Zones in Cotton With and Without Wheat Cover Crop

E.J. Kelly[1], T.G. Teague[1], and D.K. Morris[2]

RESEARCH PROBLEM

Soils in eastern Arkansas cotton fields have a diverse mixture of textures associated with the depositional processes of the Mississippi River. In northeast Arkansas, producers also must contend with sand blows: areas where seismic activity has pushed liquefied sand up to the soil surface through cracks and fissures. These spatially variable, soil physiochemical properties influence cotton yield potential. Management challenges with in-field soil variability are exacerbated by land-leveling activities, which may expose subsoil textures to the soil surface.

It has become a common practice for northeast Arkansas producers to plant cereal winter cover crops to protect seedlings from abrasive, windblown sand. There is also producer interest in adoption of site-specific, zone management in spatially variable fields. With zone management, production and protection inputs are gauged to match yield potential. The objectives of this 2012 field study were to determine if cereal winter cover crops affect infestation risks from early-season thrips and to investigate whether thrips distribution patterns were associated with management zones based on different soil textures.

BACKGROUND INFORMATION

Management zones are as defined as sub-regions of a field that have homogeneous combinations of yield-limiting factors, which a specified amount crop input is applicable to improve efficiency of farm inputs (Doerge, 1999). Management zones can be created using a variety of characteristics. For this study, the emphasis was to use soil electrical conductivity (EC) to classify zones. Soil EC has been useful for establishing management zones because it has been shown to be a stable indirect measure of soil physiochemical properties that have prevailing influence on yield (Corwin and Lesch, 2005). Cover crops in northeast Arkansas cotton typically are planted to protect young seedlings from blowing sand. Ad-

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ditional positive benefits include reductions in soil erosion and improved runoff water quality as well as improved crop root health, and enhanced weed management (Dabney et al., 2010). Previous research has shown that cover crops have the potential to increase yield in conservation tillage systems (Bauer and Roof, 2004; Bauer and Busscher, 1996; Raper et al., 2000). In this research project, thrips infestations were monitored in commercial cotton fields grown with and without cereal cover crops. These fields were further divided into soil EC-based management zones. Assessments included in-season crop and insect monitoring as well as yield evaluations.

RESEARCH DESCRIPTION

Cooperating producers, David Wildy (Wildy Family Farms, Manila), Gordon Miller (Gordon Miller Farms, Leachville) and Danny Finch (FDA Farms, Caraway) selected the paired research fields on each of their farms in Fall 2011. Soils in project fields had been mapped as a Routon-Dundee-Crevasse Complex, ranging from coarse sand to fine sandy loam. Previous land leveling activities to facilitate furrow irrigation exposed subsoil and clay layers in portions of the fields.

Each field was classified into three to four management zones based on soil EC grouped from measurements using a dual depth Veris® 3150 Soil Surveyor (Veris Technologies, Salina, Kan.) made in Fall 2011. Swath width for the sensor varied between farms. In the Wildy field, the Veris cart surveyor was pulled through every row (38 inch row spacing). For the Miller and FDA farms, Veris intervals were at 10 to 12 rows. There were four management zones in the Wildy and FDA fields (coarse sand, sand, sandy loam and clay) and three zones in the Miller fields (sand, sandy loam and clay). For the Wildy fields, category ranges -4 to 0, 0 to 35, 35 to 70, 116 to 460 mS/M were defined for coarse sand, sand, sandy loam and clay management zones, respectively. Similar groupings and ranges were defined for the Miller and FDA fields.

Within management zones in each field, sample points were randomly selected. There were three to four sites per zone per field. All plant and insect monitoring activities through the season occurred within a 12 row (38 ft) radius of the sample point. Standard COTMAN, Squaremap and Bollman sampling protocols were followed for plants within each sample site (Oosterhuis and Bourland, 2008). Other pest insects including tarnished plant bugs were monitored through the season (data not shown). A 10 ft-long section was designated for each sample point for handpicking for yield determination. Yield monitor data were collected from cooperating producers following machine harvests; these data were analyzed by creation of 50 ft by 50 ft harvest shapefiles in ArcGIS (ESRI, Redlands, Calif.). The shapefiles were then centered over the sample sites and data collection occurred throughout the season. The number of sample points that fell inside the harvest shapefile were then adjusted to replicate the same number of passes in each of the shapefiles completed by the cotton picker through all three of the fields. Harvest dates as well as other production details are listed in Table 1.

Thrips abundance was estimated using a whole plant wash method. Ten plants were randomly collected at each site. Sample dates were 17 and 23 May, 20 and 26 days after planting (DAP) for Miller Farm, 16 and 22 DAP for FDA Farm and 7 and 13 DAP for Wildy Farm. Plants were cut at the soil level and immediately placed in sealed plastic bags, positioned in coolers on blue ice and taken back to the laboratory for evaluation. Plants were immersed and "washed vigorously" in a 70% alcohol solution in glass beakers. Special care was taken to thoroughly rinse each bag. The solution was poured through coffee filters to separate thrips from alcohol. Thrips adults and larvae on the filter paper were counted using a dissecting microscope. Variation in average number of larvae and adults was analyzed using analysis of variance between groups (ANOVA) separately for each date and among management zones, tillage treatments and farms.

RESULTS AND DISCUSSION

Infestations of tobacco thrips (*Frankliniella fusca* (Hinds)) and western flower thrips (*Frankliniella occidentalis* (Pergande)) were detected in the first three weeks following crop emergence. Population densities were at low levels in two of three fields and did not exceed the University of Arkansas Cooperative Extension Service action threshold (2-5 thrips/plant with damage present). There was no spatial component for thrips numbers among the soil EC-based management zones for any farm or field ($P > 0.25$). Highest thrips numbers were observed on Miller Farm, where there were significantly fewer thrips associated with cotton grown with the wheat cover crop compared to cotton without wheat ($P < 0.01$) (Fig. 1).

COTMAN crop growth curves for cover crop and conventional fields were similar; however, there were differences in developmental pace and number of main-stem sympodia in plants among management zones (Fig. 2). Overall, days to cutout were significantly different among zones in two of three farms, ranging from 71 to 83 days at the Wildy fields and 81 to 90 days at the Miller fields. Cutout dates ranged from 77 to 86 days after planting at the FDA fields. For handpicked yields, there were no significant differences among fields with and without cover crop ($P > 0.25$). Yields differed among farms ($P = 0.06$), but there were no significant interactions. Yield differences were significant among management zones ($P = 0.0001$) with lowest yields associated with coarse sand and clay management zones, and highest yields from sand and sandy loam zones. Similar findings were observed with machine harvests (Fig. 3).

PRACTICAL APPLICATION

Fewer thrips were observed in cotton with terminated wheat cover crops. This has been noted in our previous research (Teague, unpublished data) as well as from other production regions including the Texas High Plains and the Southeast U.S. (Olson et. al., 2006). Planting of cereal winter cover crops as opposed to a winter weed fallow is an effective integrated pest management (IPM) tactic resulting in reduced risks of crop damage from thrips induced injury (Toews et al., 2010). Infestations were similar across management zones. Different soil textures affected the rate of development and crop maturity measured as days to cutout.

ACKNOWLEDGMENTS

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Table 1. Cotton cultivar, dates of planting and harvest for cotton and details for cereal cover crops establishment and termination in six commercial fields[a] monitored in 2012 thrips study.

Farm	Cultivar	Date of Planting	Date of harvest		Cover crop, seeding method, dates of planting & burndown
			Hand	Machine	
FDA Farm	Stoneville 5458 B2RF	1 May	26 Sept	15 Oct	wheat broadcast – 3 Nov 2011; terminated April 2012
Gordon Miller Farm	Stoneville 5458 B2RF	27 April	25 Sept	16 Oct	wheat seeded in alternate row middles 1 Nov 2011- terminated May 2012
Wildy Family Farm	Deltapine 0912 B2RF	10 May	24 Sept	27 Sept	oats broadcast 10 Nov 2011; terminated 3 March 2012

[a]Fields were located in the Buffalo Island production region in northeast Arkansas in the Little River Ditches Watershed in Craighead and Mississippi Counties.

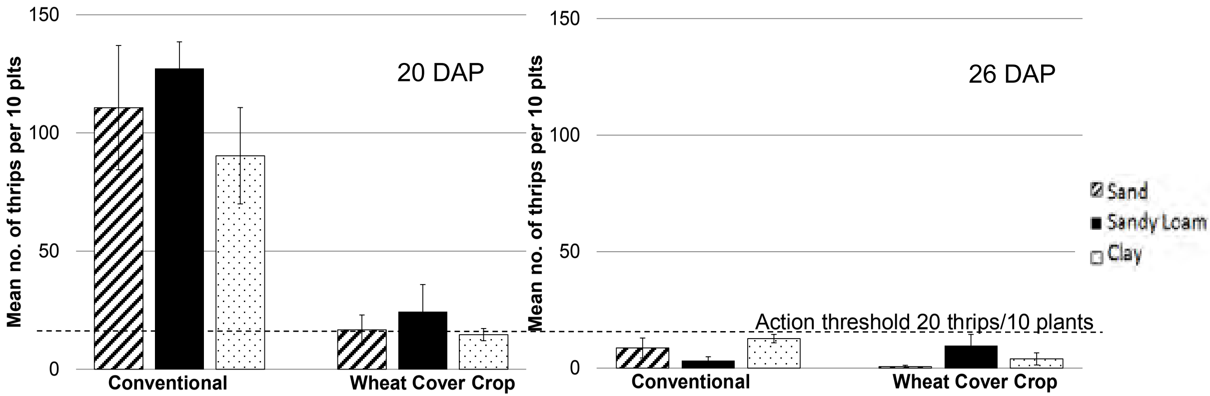

Fig. 1. Mean (±SEM) numbers of thrips per 10 plants observed on plants collected on cotton planted in conventional and with a wheat cover crop on 17 and 23 May (20 and 26 days after planting (DAP)). Spinetoram (Radiant @1.5 oz/ac) insecticide was applied by the cooperating grower to both fields following sample collection on 17 May.

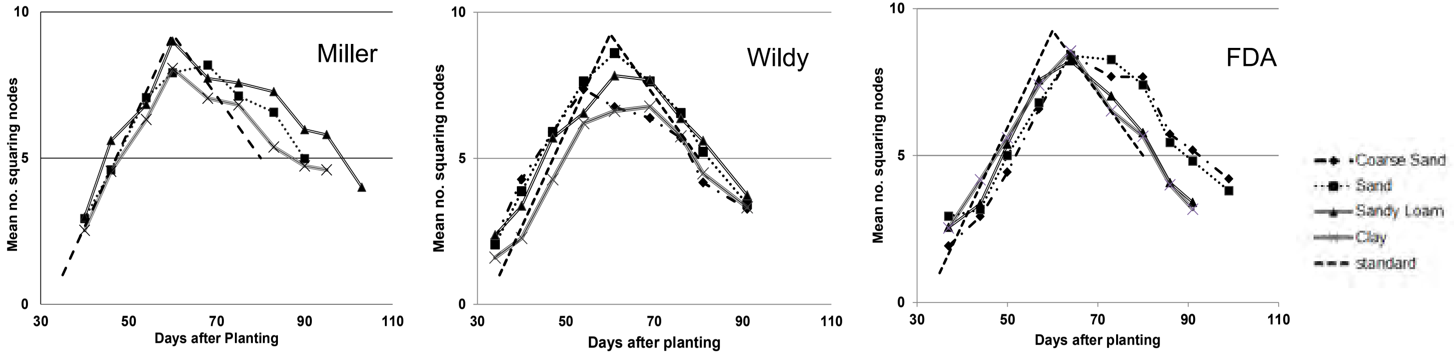

Fig. 2. COTMAN Growth curves for soil electrical conductivity (EC)-based management zones for each pair of conservation practice fields on the FDA, Wildy and Miller Farms in NE Arkansas 2012. Soil EC classifications ranged from low-EC coarse sand to high-EC clay soil.

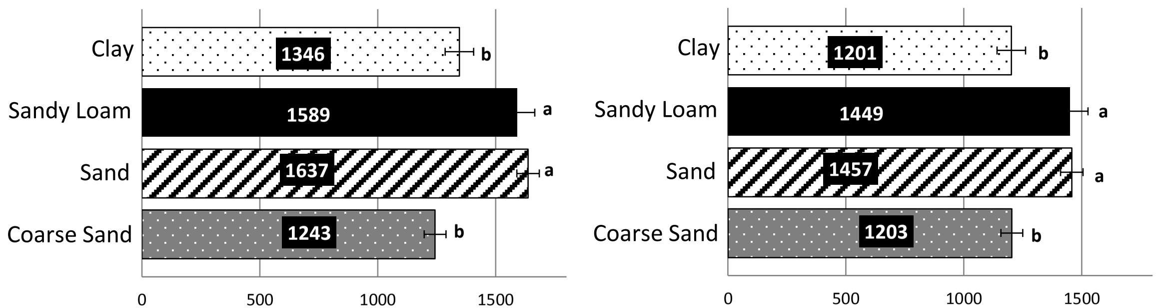

Fig. 3. Mean lint yields (±SEM) for management zones from handpicked samples (left) on the three farms, and from 50 × 50 ft area estimates derived from the Miller and Wildy yield monitors (right). Means followed by similar letters do not differ significantly (analysis of variance *P* = 0.05; least significant difference = 0.05).

Effect of Varietal Selection and Planting Date on Tarnished Plant Bug Levels in Cotton

G.E. Studebaker and F.M. Bourland[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, 2012). 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. Planting date can also have an effect on TPB populations in cotton. Typically, earlier planting dates tend to sustain less damage. Coupling resistance with an early planting date could be an effective tool in managing TPB in cotton.

BACKGROUND INFORMATION

Tarnished plant bug is one of the most important pests of cotton in Arkansas. From 2003 to 2012 it caused more yield losses than any other pest averaging a loss of over 50,000 bales in Arkansas (Williams, 2012). Recent data from small plot studies has indicated that some commercially grown cultivars may be less attractive or exhibit some level of resistance to TPB. A large block study was conducted in 2012 to evaluate the resistance of several early- and late-maturing cultivars that exhibited low damage from TPB in small plot studies in previous years.

RESEARCH DESCRIPTION

Trials were conducted at the Northeast Research and Extension Center, Keiser, Ark. Plots were 24-rows by 80-ft long arranged in a 3-factor factorial design with 4 replications. Early and late maturing cultivars showing low damage in small plots as well as early- and late-maturing cultivars showing high damage in small plots were used to conduct the study (Table 1). Each cultivar had two TPB treatment regimes: an untreated control and treated when TPB numbers reached 3/5 row-ft. Cultivars also had two planting dates: early and late. Plots were sampled weekly with a drop cloth. When TPB reached the treatment level of 3 bugs per

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5-row feet, treatments were applied with a high clearance sprayer calibrated to deliver 10 gal/acre-through two hollow cone nozzles per row. Acephate at 0.75 lb ai/acre was applied when threshold was reached. Plots did not reach treatment level until after the start of flowering. Yields were taken from the center 4 rows of each plot at the end of the season. All data were analyzed using ARM version 8 software (Gylling Data Management, Inc., Brookings, S.D.). Treatment means were separated at the $P = 0.05$ alpha level.

RESULTS AND DISSCUSSION

The two susceptible cultivars, University of Arkansas (UA) 48 and Phytogen (PHY) 375WRF, reached treatment threshold more often than the resistant cultivars regardless of planting date (Fig. 1). Planting date did have an effect on TPB treatments in three cultivars with the later planting date requiring more TPB applications (Fig. 1). Planting date did not have any effect on TPB treatments in PHY 375WRF (Fig. 1). The level of yield increase over the untreated control in each cultivar by planting date is reported in Fig. 2. Therefore, the bars shown in Fig. 2 represent the level of yield loss caused by TPB in each cultivar. Resistant cultivars suffered less yield loss from TPB than susceptible cultivars. Planting date also had little effect on yield in resistant cultivars. Cultivar UA48, a highly susceptible variety, had the highest overall yield loss from TPB. Planting date also had the greatest effect on this cultivar with the highest yield loss in the late planting date.

PRACTICAL APPLICATION

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

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

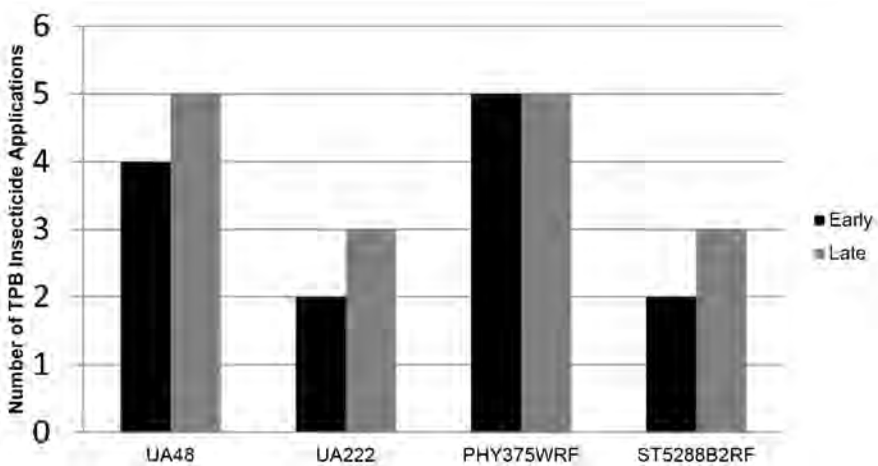

Fig. 1. Frequency of tarnished plant bug treatments in early and late planting dates in different cultivars in 2012.

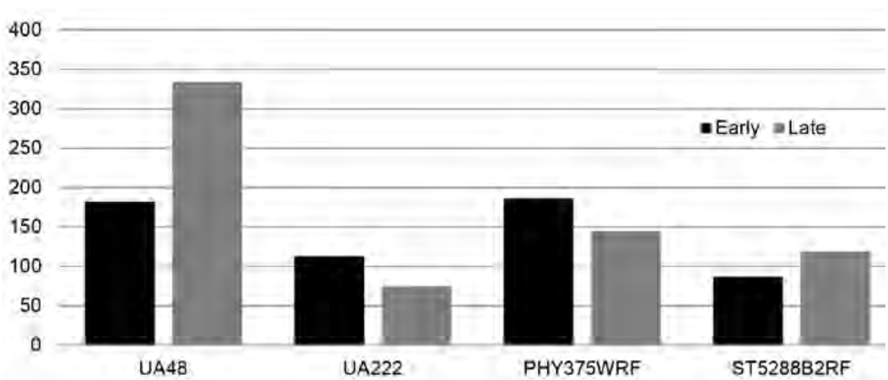

Fig. 2. Average lint yield increase (lb/acre) over untreated in early- and late-planting dates in 2012.

Cotton Acreage Response to Price Signals Due to Agricultural Policy and Market Conditions

A. Flanders[1]

RESEARCH PROBLEM

Commodity programs for agriculture have a dual challenge of addressing public policy objectives of farm income stability and maintaining desirable efficiencies that derive from market-based outcomes. Agricultural policy for cotton supports production revenue. Even with government programs, U.S. cotton acreage has shifted to other field crops. The objective of this research is to quantify the response of cotton acreage to market prices and loan deficiency payments (LDP) for cotton and competing crops.

BACKGROUND INFORMATION

Legislation in the 2002 Farm Bill provided for a common commodity policy of income support among field crops consisting of direct payments (DP), counter-cyclical payments (CCP), and marketing loans (USDA ERS, 2012b). Since 2002, a common agricultural policy for all field crops has included LDP, DP, and CCP. Income support payments from LDP achieve a price floor that approximates average U.S. variable costs of production. Other payments from DP and CCP are decoupled from current production and do not provide incentives for increasing production $(dDP/dY = dCCP/dY = 0)$.

RESEARCH DESCRIPTION

Data are for 17 states with Upland cotton production during 2002-2010 (USDA ERS, 2012a; USDA NASS, 2012). Panel data for a short time period leads to results that encompass a common program of agricultural commodity policy. The goal of the empirical model is to quantify response of cotton acreage to market prices and LDP for cotton and competing crops. A regression model in the form of Acreage = f (Cotton Price, Cotton Costs, Competing Crop Price, Competing Crop Costs, Production Technology) is estimated with fixed one-way panel data analysis. Corn represents prices and costs for competing crops. Prices

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and costs are lagged values for the year prior to planted cotton acreage. Technology is represented by a trend variable. All variables except technology are applied as logarithms.

RESULTS AND DISCUSSION

Price elasticities developed for short time periods lead to acreage response estimates that are due to a single agricultural policy. Regression results are presented in Table 1. A positive coefficient of 0.475 for cotton price indicates a positive relationship with prices and acreage. Conversely, there is a negative relationship for corn prices and cotton acreage with an elasticity of -0.855. The greater elasticity for corn prices are a consequence of market prices only, and the cross-prices elasticity is 80% greater than the own-price elasticity which is a response of market prices and cotton LDP. Coefficients for average costs have expected signs, but are not statistically significant. The trend coefficient of -0.026 indicates a negative relationship between technology and cotton acreage as cotton yields have increased during 2002-2010. As prices and costs in the model control for equilibrium economic conditions of cotton production, the technology variable coefficient is consistent with fewer cotton acres required to satisfy supply and demand. The intercept term represents Texas as the reference state. Dummy variables, not presented in Table 1, for all 16 other states are statistically significant with negative signs.

PRACTICAL APPLICATION

This research covers a comparatively shorter time period than previous studies and enables analysis with a uniform public policy. Price elasticities developed for short time periods lead to acreage response estimates that are due to a single policy for a common time period. Relatively high prices for competing crops have impacted cotton acreage. Results for cotton acreage allocations with own-price and cross-price elasticities demonstrate it is possible to alter markets without creating distortions that cause producers to ignore price signals.

LITERATURE CITED

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Table 1. Regression results for U.S. cotton acreage.

Variable	Coefficient	Std. Error	t Statistic	Prob. > |t|
Intercept	9.783	0.252	38.860	<0.0001
Cotton Price	0.475	0.231	2.060	0.0417
Corn Price	-0.855	0.131	-6.510	<0.0001
Cotton Average Costs	-0.147	0.103	-1.420	0.1579
Corn Average Costs	0.108	0.152	0.710	0.4770
Trend	-0.026	0.013	-2.060	0.0482
R-Square		0.9699		
F Statistic for No Fixed Effects		239.1500		
Prob. > F		0.0001		

2012 Cotton Research Verification Annual Summary

B.A. McClelland[1], L.T. Barber[2], and A. Flanders[1]

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 248 irrigated fields entered into the program. Producers are asked what they would like to improve in their current operation then a field is chosen that fits a standard model of the producers operation and requires the necessary recommendations to improve the farm.

All of the recommendations made to the producers in the program are based on proven research by University of Arkansas System Division of Agriculture researchers in their respective disciplines. The producer agrees to apply the necessary recommendations in a timely manner

RESEARCH DESCRIPTION

There were seven fields in the 2012 Cotton Research Verification Program. Locations were in Clay, Craighead, Jefferson, Lee, Mississippi, Phillips and St. Francis counties. All of the fields were furrow irrigated. Every week the producer, the agent, and the verification coordinator met, scouted the field, and discussed the recommendations. The average field size was 50 acres and the average yield was 1,110 lb/acre. This was 27 lb/acre higher than the projected state yield of 1083 lb/acre.

RESULTS AND DISCUSSION

The Clay County field is in the first year of the verification program. This field's producer asked the agent and verification coordinator to work on a problem field that yielded poorly the previous year and showed symptoms of severe potassium deficiency. Soil samples were taken and a fertility program was planned. Overall the field produced 1,054 lb/acre. Although the field produced less than the

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state average it did produce about 500 lb/acre more than the previous year.

The Craighead County field is in the second year of the verification program. The producer had a desire to continue to improve his irrigation management practices to achieve high yields and lower costs. He also wanted to learn how to manage two new cultivars that he wanted to plant on his farm. The PHAUCET program (USDA, NRCS) was used to determine the correct hole size for proper irrigation efficiency. He was very pleased with the way that the field watered evenly and he was able to reduce the amount of time he had to pump in order to water the whole field. He estimated that he saved enough time to equal one irrigation. The new varieties that were planted were Americot 1511 B2RF and Fibermax 1944 GLB2. The varieties were managed according to University of Arkansas Cooperative Extension Service (CES) recommendations and yielded very well. The field yielded 1,401 lb/acre.

The producer of the Jefferson County Verification was incorporating the CES recommendations into his farming operation. Each week the producer listened to the recommendations and applied them in a timely manner. The field yielded 913 pounds/A. The producer was pleased with the yield and the efficient use of inputs this year. The producer agreed to work with the CRVP one more year to give a new county agent experience in cotton production.

The Lee County field's producer indicated that the field was infested with glyphosate-resistant pigweed. A Liberty Link cultivar (Stoneville 5445LLB2) was used to incorporate a new herbicide technology. Control was achieved by using a combination of Liberty herbicide and residual herbicides. The field yielded 1100 lb/acre.

The Mississippi County field is in the first year of the verification program. The producer indicated in the preseason interview that he would like to work on irrigation efficiency and gain a better understanding of insecticide and irrigation termination timings. The PHAUCET program was used to determine the correct hole size for the greatest irrigation efficiency. An atmometer was placed at the field to indicate when irrigation should be initiated. The COTMAN crop monitoring program (Oosterhuis and Bourland, 2008) was used to determine termination dates for irrigation and insecticides. It yielded well with an average yield of 1,317 lb lint /acre.

The Phillips County cotton verification field was in the second year of the program. Root-knot nematode levels were at the economic threshold. A root-knot nematode-tolerant cultivar (Stoneville 5458B2RF) was selected to be planted. Prowl was applied to the field to give residual control for palmer pigweed. The herbicide was taken up by the seedling cotton and caused herbicide damage to the plants. The crop was delayed by the injury. Although the yield was lower than the state average at 725 lb/acre, it was an increase from the year before which yielded 543 lb/acre.

The St. Francis County field is in the first year of the program. The producer was interested in becoming familiar with CES recommendations to compare with his current practices. Each recommendation was explained so the producer could compare them to decisions he was making in similar situations. The PHAUCET program was used to ensure irrigation efficiency. The COTMAN program was used to determine irrigation and insecticide termination. The field yielded 1215 lb/acre.

PRACTICAL APPLICATION

Overall the 2012 production season in the CRVP was successful. Yields were increased in certain problem fields. Producers became aware of CES recommendations and they also became aware of how programs such as PHAUCET and COTMAN could assist them in making management decisions.

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2012 Cotton On-Farm County Variety Trials Performance Summary

B.A. McClelland[1] and L.T. Barber[2]

RESEARCH PROBLEM

Variety selection can be the most difficult, yet most important decision a cotton producer will make year in and year out. Because of new technologies becoming available, producers have experienced rapid turnover in the number of varieties that are available to plant each year with limited performance data. In order to be prepared and provide as much information as possible on cotton varieties, a standardized on-farm cotton variety testing program was developed in cotton-producing counties.

BACKGROUND INFORMATION

Each year the University of Arkansas System Division of Agriculture conducts several replicated on-farm demonstration trials to evaluate performance of a number of new cotton varieties (McClelland and Barber, 2012). These trials are not meant to replace University OVTs (Official Variety Trials); however they provide another source or supplement to the OVT data on which to base cotton variety selection. These standardized on-farm trials are helpful because they evaluate similar varieties over a wide range of soil types and management practices throughout the state of Arkansas. Additionally, on-farm trials are managed by cotton producers and should reflect the performance of varieties in a commercial production system. Producers are encouraged to spread risk by selecting at least four varieties with proven performance from multiple sources. New release varieties should be planted on only five percent or less of total acreage.

RESEARCH DESCRIPTION

County agents with the University of Arkansas System Division of Agriculture selected a producer within their respective counties to conduct the standardized variety trials. The 2012 locations were (from north to south): Clay, Craighead, Mississippi, Poinsett, Crittenden, Woodruff, Lonoke, St. Francis, Lee, Phillips,

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[2]Assistant professor, Department of Crop, Soil, and Environmental Sciences, Little Rock.

Lincoln, Desha, Drew, Ashley, Chicot, and Lafayette. Each location was managed by the producers or cooperators and all varieties were planted according to the equipment setup provided by the cooperator. Ten varieties were entered into the trial in 2012 and can be found in Table 1. Trials were harvested by the producers and weighed by the County Agents utilizing boll buggies with load cells. Large grab samples (10 lbs) were taken from each replication and ginned through a micro-gin courtesy of the University of Tennessee Extension Service in Jackson, Tenn. which included drying, pre-cleaning and lint cleaning allowing for accurate lint turnout. Fiber samples were then sent to the USDA Cotton Classing Office located at Memphis, Tenn. and physical fiber quality properties were measured.

RESULTS AND DISCUSSION

The following tables show the results of the Standardized On-Farm Cotton Trials. Due to the large space required for the whole publication, only the Overall Locations, North of I-40, South of I-40 and By Soil Type will be shown. The report can be viewed in its entirety at www.uaex.edu.

LITERATURE CITED

McClelland, B. and T. Barber. 2012. 2012 On-Farm Cotton Variety Performance Summary. MP 480. University of Arkansas System Division of Agriculture Research and Extension Services.

Table 1. Varieties selected for 2012 Standardized Cotton Performance Trials.

	2012 Cotton Trial Varieties	
Slot #	**Slot Criteria**	**Entry**
1	Top ranked Flex variety in 2011 according to USDA survey	DPL 0912 B2RF
2	Americot Brand	NG 1511 B2RF
3	Deltapine Brand	DPL 1133 B2RF
4	Deltapine Brand	DPL 1219 B2RF
5	Dyna-Gro Brand	DG 2570 B2RF
6	Fibermax Brand	FM 1944 GLB2
7	Phytogen Brand	PHY 375 WRF
8	Phytogen Brand	PHY 499 WRF
9	Stoneville Brand	ST 5458B2RF
10	Stoneville Brand	ST 5288 B2F

Table 2. Yield and fiber quality for 2012 Core Varieties at all locations.

Variety	Lint Yield	Lint Percent	Mic	Staple	Strength	Uniformity
Phytogen 499 WRF	1285.95	38.20	4.66	37.00	32.03	83.46
Americot 1511 B2RF*	1267.04	38.55	4.91	36.46	31.11	82.88
Stoneville 5458 B2RF*	1233.07	35.61	4.8	37.07	31.71	81.67
Deltapine 0912 B2RF*	1231.48	35.53	4.97	36.21	30.23	82.64
Phytogen 375 WRF*	1230.09	37.39	4.61	36.36	29.63	81.86
Stoneville 5288 B2F*	1228.38	35.75	4.84	36.36	29.15	81.39
Dyna-Gro 2570 B2RF*	1213.3	36.55	4.87	36.29	30.41	82.54
FiberMax 1944 GLB2	1180.76	35.58	4.66	38.21	32.71	82.17
Deltapine 1133 B2RF	1170.51	37.69	4.79	37.43	31.59	83.19
Deltapine 1219 B2RF	1092.81	36.10	4.51	37.36	33.35	81.91
LSD†	**93.05**	**0.60**	**0.28**	**0.63**	**0.83**	**0.65**
CV	**15.07**	**3.24**	**7.78**	**2.28**	**3.56**	**0.97**
Grand Mean	**1213.15**	**36.69**	**4.76**	**36.88**	**31.19**	**82.37**

*Not significantly different from the highest yielding variety in the trial.
†LSD = least significant difference; CV = coefficient of variation.

Table 3. Yield and fiber quality for 2012 Core Varieties north of I-40.

Variety	Lint Yield	Lint Percent	Mic	Staple	Strength	Uniformity
Phytogen 499 WRF	1289.53	38.53	4.75	37.25	31.9	83.46
NexGen 1511 B2RF*	1274.47	39.29	4.95	36.38	30.79	83.00
Phytogen 375 WRF*	123866	37.73	4.70	36.50	29.65	81.75
Deltapine 0912 B2RF*	1229.74	35.86	5.04	36.13	29.79	82.76
Stoneville 5288 B2F*	1227.41	36.16	4.98	36.38	28.64	81.46
Dyna-Gro 2570 B2RF*	1193.94	36.96	4.89	36.63	30.40	82.91
Stoneville 5458 B2RF*	1183.32	35.75	4.93	37.13	31.58	81.80
FiberMax 1944 GLB2	1174.52	35.93	4.71	38.25	32.69	82.18
Deltapine 1133 B2RF	1148.23	38.25	4.81	37.63	31.29	83.05
Deltapine 1219 B2RF	1090.4	36.62	4.59	37.63	33.75	82.03
LSD†	**111.39**	**0.75**	**0.32**	**0.92**	**1.04**	**0.81**
CV	**13.65**	**3**	**6.53**	**2.51**	**3.34**	**0.99**
Grand Mean	**1205**	**37.11**	**4.83**	**36.99**	**31.05**	**82.44**

*Not significantly different from the highest yielding variety in the trial.
†LSD = least significant difference; CV = coefficient of variation.

Table 4. Yield and fiber quality for 2012 Core Varieties south of I-40.

Variety	Lint Yield	Lint Percent	Mic	Staple	Strength	Uniformity
Stoneville 5458 B2RF	1298.13	35.43	4.59	36.75	31.58	81.44
Phytogen 499 WRF*	1281.28	37.78	4.65	36.25	31.76	82.85
Americot 1511 B2RF*	1256.53	37.5	4.81	36.25	30.96	82.11
Dyna-Gro 2570 B2RF*	1238.61	35.99	4.89	35.88	30.43	82.09
Deltapine 0912 B2RF*	1233.75	35.09	4.95	36.00	30.21	82.13
Stoneville 5288 B2F*	1229.92	35.21	4.65	36.25	29.68	81.5
Phytogen 375 WRF*	1218.87	36.95	4.59	36.13	29.44	81.65
Deltapine 1133 B2RF*	1199.65	36.97	4.85	37.13	31.83	82.98
FiberMax 1944 GLB2*	1188.91	35.12	4.5	37.88	32.44	81.9
Deltapine 1219 B2RF	1095.96	35.41	4.54	36.88	32.24	81.6
LSD†	**163.59**	**0.86**	**0.44**	**0.89**	**1.41**	**1.01**
CV	**17.13**	**3.06**	**9.28**	**2.41**	**4.57**	**1.23**
Grand Mean	**1223.91**	**36.13**	**4.7**	**36.54**	**31.06**	**82.02**

*Not significantly different from the highest yielding variety in the trial.
†LSD = least significant difference; CV = coefficient of variation.

Table 5. Yield for 2012 Core Varieties by Soil Type.

Variety	Sandy Loam	Silt Loam	Overall Mean
	lbs/ac (rank)	**lbs/ac (rank)**	**lbs/ac**
Phytogen 499 WRF	1277.30 (1)	1240.67 (1)	1285.95
Americot 1511 B2RF	1231.39 (5)	1211.46 (2)	1267.04
Phytogen 375 WRF	1272.42 (2)	1167.21 (6)	1233.07
Deltapine 0912 B2RF	1207.18 (7)	1180.12 (4)	1231.48
Stoneville 5288 B2F	1205.72 (8)	1180.13 (3)	1230.09
Stoneville 5458 B2RF	1237.69 (3)	1168.68 (5)	1228.38
Dyna-Gro 2570 B2RF	1214.17 (6)	1162.21 (7)	1213.30
FiberMax 1944 GLB2	1191.77 (9)	1121.93 (8)	1180.76
Deltapine 1133 B2RF	1234.30 (4)	1097.66 (9)	1170.51
Deltapine 1219 B2RF	1103.87 (10)	1034.85 (10)	1092.81
LSD†	**168.29**	**133.43**	**93.05**
CV	**13.85**	**20.72**	**15.07**
Grand Mean	**1217.58**	**1156.55**	**1213.15**
Number of Locations	**4**	**12**	**16**

†LSD = least significant difference; CV = coefficient of variation.

APPENDIX I

STUDENT THESES AND DISSERTATIONS RELATED TO COTTON RESEARCH IN PROGRESS IN 2012

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, remote sensing, and amelioration. (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)

Griffith, Griff. Glyphosate-resistant Palmer amaranth in Arkansas: Resistance mechanisms and management strategies. (Ph.D., advisor: Norsworthy)

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

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., advisor: Reba/Teague)

Loka, Dimitra. Effect of high night temperature on cotton gas exchange and carbohydrates. (Ph.D., advisor: Oosterhuis)

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)

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)

Phillips, Justin. Effects of 1-Methylcyclopene on cotton reproductive development under heat stress. (M.S., advisor: Oosterhuis)

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

Pretorius, Mathilda. High temperature tolerance 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)

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., advisor: Stewart and Srivastava)

APPENDIX II

RESEARCH AND EXTENSION 2012 COTTON PUBLICATIONS

BOOKS

Oosterhuis, D.M. and J.T. Cothren. (eds.) 2012. Flowering and Fruiting in Cotton. The Cotton Foundation, Cordova, Tenn. ISBN 978-0-939809-08-0

Oosterhuis, D.M. (ed.) 2012. Summaries of Arkansas Cotton Research 2011. Agricultural Experiment Station Research Series 602, Fayetteville, Ark.

CHAPTERS

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