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Summaries of Arkansas Cotton Research 2009

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University of Arkansas, Fayetteville

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DIVISION OF AGRICULTURE

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Edited by Derrick M. Oosterhuis

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SUMMARIES OF ARKANSAS COTTON RESEARCH 2009

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PREFACE

Cotton acres continued to decline in 2009 due to high commodity prices and lower production costs associated with soybean and corn. According to the Arkansas Agricultural Statistics Service, producers reduced cotton acres by another 22% from 640,000 acres in 2008 to 500,000 in 2009. Arkansas cotton lint yields in 2009 were reduced significantly due to record late-season rainfall. They picked an average of 797 lb of lint per acre, the lowest yield average per acre since the 2000 growing season. Arkansas cotton growers produced 830 thousand bales, the lowest cotton production in Arkansas since 1976, but third in the U.S. behind Texas and Georgia. Increased production costs associated with cotton seed, fuel, fertilizer, glyphosate-resistant weed management and insect pests have increased to the point where it is difficult for cotton producers to cover these costs under current cotton prices. Fortunately, the price of lint per pound has increased in the last few months

The 2009 production season was much like 2008 in that extended cool wet weather slowed cotton plantings down well below the five year average (Fig. 1). Relentless rainfall in the spring resulted in the majority of the 2009 cotton crop being planted past the optimum window for maximum yields. The result was delayed cotton planting and later maturity across much of the state. Extended periods of cool wet weather increased incidence of seedling disease and many acres were replanted as a result.

Pests continued to be problematic in 2009. Weed resistance, particularly glyphosate-resistant Palmer amaranth (pigweed) continues to be an emerging problem for many producers across Arkansas. In 2009 twenty counties were identified as having a population of resistant Palmer amaranth. The severity of this problem weed in cotton will encourage increased utilization of residual herbicides and new technologies for weed management in 2010. The increase in glyphosate resistance across the state may lead to the highest use of residuals since the development of glyphosate-tolerant varieties in 1997. Insect pests for 2009 were heavy in areas, especially where other crops were added in rotation to the farm mix. In future seasons, it will be important to look at pest management in a whole-farm approach as far as crop diversity and field selection to possibly reduce flushes of sucking bug pests around alternative crop borders.

Devastating results from record annual rainfall in September and October resulted in tremendous hard-lock and boll rot. Much of the lint never made it into the picker. This was the second year in a row for end of season storms to reduce cotton yields, more drastically so in Southeast Arkansas counties. Cotton losses from the 2009 weather were well over $100 million in lint, seed and fiber quality.

Tom Barber and Derrick Oosterhuis

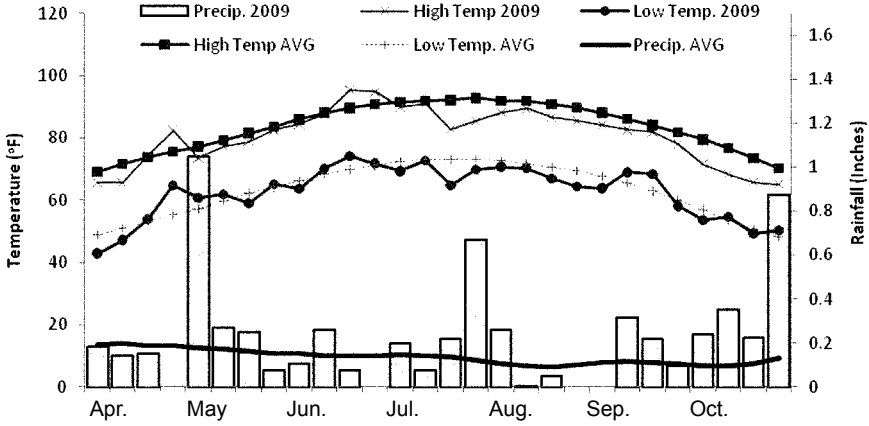

Fig. 1. Weekly maximum and minimum temperatures and rainfall for 2009 compared with the long-term 35-year averages in eastern Arkansas.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The *Summaries of Arkansas Cotton Research 2009* 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 Division of Agriculture, the Cotton Board, and Cotton Incorporated. Seven and one-half percent of the grower contributions to the total Cotton Incorporated budget are allocated to the State Support Committees of the cotton-producing states. The sum allocated to Arkansas is proportional to the states' contribution to the total U.S. production and value of cotton fiber over the past five years.

The Cotton Research and Promotion Act is a federal marketing law. The Cotton Board, based in Memphis, 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 2009.

Projects	Researcher	Short Title	$ Funding
02-291AR	Oosterhuis	Cotton Research In Progress	$5,000
07-973AR	Bourland	Cotton Breeding	$26,804
07-974AR	Barber	Irrigation Start & Stop	$23,780
07-975AR	Espinoza	Gypsum	$23,715
07-977AR	Oosterhuis	High Temperature Effects	$15,975
07-978AR	Barber	Verification Program	$31,073
07-979AR	Rothrock	Black Root Rot	$19,916
07-980AR	Smith	Glyphosate Resistant Pigweed	$19,661
07-981AR	Barber	15-inch Rows	$24,035
08-324AR	Barber	Defoliation Timing	$14,600
08-325AR	Burgos	Resistant Pigweeds - Genetics	$11,455
08-326AR	Kirkpatrick	Soils & Nematode Thresholds	$24,094
08-330AR	Norsworthy	Resistant Pigweeds - Prediction	$11,907
08-331AR	Sadaka	Fast Pyrolysis of Gin Waste	$30,872
08-332AR	Teague	Plant Bugs in Irrigated Cotton	$26,544
08-337AR	Windham	Soils & Cotton Populations	$28,500
09-486AR	Lorenz	Plant Bug Management - AR I	$5,513
09-632AR	Akin	Plant Bug Management - AR II	$5,513
09-633AR	Studebaker	Plant Bug Management - AR III	$5,512
TOTAL			**$354,469**

A C K N O W L E D G M E N T S

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
— 2009 —

University of Arkansas Cotton Breeding Program 2009 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 that will identify genotypes with favorable genes, combine those genes into adapted lines, then select and test derived lines.

BACKGROUND INFORMATION

Cotton breeding programs have existed at the University of Arkansas since the 1920s (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and possess good host-plant resistance traits. Bourland (2009) provided the most recent update of the current program.

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 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

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

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

A primary focus of conventional crosses in 2009 was to combine lines having specific morphological traits, enhanced yield components and improved fiber characteristics. In the conventional breeding effort, 24 new crosses, 24 F_2 populations 12 F_3 populations, 18 F_4 populations, 598 1st year progeny, and 168 advanced progeny were evaluated. Bolls were harvested from superior plants in F_2 and F_3 populations and bulked by population. Individual plants (910) were selected from the F_4 populations. After discarding individual plants for fiber traits, 578 progeny from the individual plant selections will be evaluated in 2010. Also, 168 superior F_5 progeny were advanced, and 72 F_6 advanced progeny were promoted to strain status.

Additionally, transgenic forms of Arkot lines crossed with lines possessing nectariless, frego-bract, high-glanding, or red-leaf traits were advanced in 2009. The transgenic effort included evaluation of 12 F_3 populations, 30 advanced progeny, and 8 strains. After discarding for field performance and fiber traits, 18 of the advanced progeny and strains will be evaluated in replicated strain tests in 2010. The strains include eight Round-up Ready Flex frego-bract lines. The frego-bract lines are being developed as part of an effort to evaluate them for use as a trap and/or monitoring of tarnished plant bugs.

Strain Evaluation

In 2009, 108 conventional lines were evaluated in replicated strain tests at multiple locations. Within each test, strains were compared to standard cultivars (DP 393 and SG 105). Based on their performance, 36 of the strains were selected and entered into 2010 New and Advanced Strain Tests. Superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality. The 2009 New and Advanced Strains were tested for host-plant resistance (tarnished plant bug, bacterial blight, fusarium wilt, and resistance to seed deterioration). Selected lines were evaluated in regional strain tests.

Germplasm Releases

Germplasm releases are a major function of most public breeding programs. In 2009, the Arkansas Agricultural Experiment Station released two cotton germplasm lines, Arkot 9811 and Arkot 9815, which were developed by this breeding program. Both lines have been best adapted to central and south Arkansas test environments. Over all test sites, lint yield, yield components and fiber quality of the two lines were equal to two check cultivars. Additionally, two advanced conventional lines performed very well in replicated strip tests. Both are being considered for variety release in 2010.

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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Screening for Temperature Tolerance in Cotton

D.M. Oosterhuis, J.L. Snider, D.A. Loka[1] and F.M. Bourland[2]

RESEARCH PROBLEM

Cotton originates from hot climates, but does not necessarily yield best at excessively high temperatures. Recent research has indicated that high temperature is a major abiotic factor adversely affecting cotton yields (Oosterhuis 2002). The ideal temperature range for cotton is reported to be from 68 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 ºF, 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 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 are 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 and Oliver, 2004) and subsequent fertilization resulting in fewer seeds per boll (Snider et al., 2009).

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. In the first part of this study, we studied the most suitable physiological and biochemical methods to accurately and reliably detect plant

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response to high temperature (Bibi et al., 2008). We selected two measurements: 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 measuring plant response to high-temperature stress and recovery for screening for high-temperature tolerance (Oosterhuis et al., 2009). Plants were grown at 30 °C day temperature for four weeks, after which they were subjected to 45 °C constant temperature for 4 hours, and then the temperature was lowered back to 30 °C until the next day to let the plants recover. Membrane leakage and chlorophyll fluorescence were measured at each of these stages. This provided a measure of how genotypes respond to high-temperature and how they recover from a period of high-temperature (Oosterhuis et al., 2009). This system was used in 2006 to screen 54 lines, in 2007 to screen 76 genotypes, and in 2008 we screened 20 lines from the Advanced Strains Test in the controlled environment chambers. However, the results were variable, and clear differentiation between genotypic response to high-temperature stress was not evident. In light of new research on plant response to temperature (Snider et al., 2010), the technique was refined with the addition of pre-stress measurements of membrane leakage, fluorescence and the antioxidant enzyme glutathione reductase.

RESEARCH DESCRIPTION

In the current study, a combination of diverse germplasm was used including: 2 sensitive cultivars (DP393 and CG3020B2RF selected from our previous growth room screening), 2 cultivars showing moderate tolerance (PHY370WR and DYNA2520B2RF), and 2 cultivars with substantial tolerance (VH260 a Pakistan cultivar that grows at temperatures of 45 ºC and Arkot 9704 from the Arizona variety trials). Heat tolerance was determined using previously identified techniques (membrane leakage and fluorescence) and new methods including pre-stress glutathione reductase, fluorescence temperature response curves, and relative cell injury. Measurements were made on two-week old plants in a controlled environment in a randomized complete block design with 6 replications.

The plants were grown in a large walk-in growth chamber at the Altheimer Laboratory in Fayetteville, Arkansas at 30/20 °C day/night temperature until two weeks after planting. At which time pre-stress measurements were made of glutathione reductase, fluorescence temperature response curves (using a thermoelectric cooler/heater and portable fluorometer), and relative cell injury (a modified membrane leakage technique). Following pre-stress measurements, the temperature was elevated to 45 °C, and after 1 hour, measurements were made of fluorescence and membrane leakage. The temperature was maintained for 4 hours, measurements made again, and then the temperature was lowered to pre-stress level (30 °C) and fluorescence and membrane leakage were measured again the following day (24 hours later) to evaluate recovery. For glutathione reductase measurements, the first expanded true leaf was stored in ziploc bags at -80 °C until measurement.

RESULTS AND DISCUSSION

The pre-stress measurements utilized in this study did not reveal any appreciable differences in genotype thermal stability. Although the quantum yield response curves exhibited temperature dependence in all cultivars examined (Fig.1), the threshold temperatures for quantum efficiency were not significantly affected by cultivar. Glutathione reductase activity and relative membrane stability were highly variable and showed no significant differences between cultivars.

The post-stress measurements did not find any significant effect of heat stress on the membrane leakage of the sensitive, moderate and heat tolerant cultivars (data not shown). Measurements of fluorescence yield before the initiation of stress showed variable results as DP393 (heat sensitive) and Arkot (heat tolerant) had similar values of fluorescence while DYNA2520B2RF (moderate tolerance) had significantly lower fluorescence values. No matter the significant differences on the fluorescence yield of cultivars during the pre-stress period, fluorescence of all cultivars, regardless of their heat sensitivity/tolerance, remained unaffected after 1 h and 4 h under 45 °C. The same results were observed in the fluorescence yield 24 h after the relief of stress.

The lack of significant differences between cultivars was likely related to the plant stage at which these measurements were made being too early, i.e., the plant material was too young and underdeveloped to show a true, easily identifiable response to high temperature. These techniques have previously been successful with plants in later stages of development (Snider et al., 2010). We will repeat this study with plants in later, more mature stages of development.

PRACTICAL APPLICATION

This project has quantified the effects of high temperature on cotton growth and identified methods of measuring the effects of high-temperature stress on cotton. A technique has been formulated to screen cotton genotypes for temperature tolerance. The technique is being used to screen entries from the Arkansas Cotton Variety Tests and Advanced Breeding lines for temperature tolerance. A few lines have been identified with appreciable temperature tolerance, but the majority of the entries have not shown any temperature tolerance and have been susceptible to high-temperature stress. Current commercial cotton cultivars do not appear to have significant tolerance to high temperatures (Brown and Oosterhuis, 2000). This is an ongoing 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 that are often experienced in the U.S. Cotton Belt.

ACKNOWLEDGMENTS

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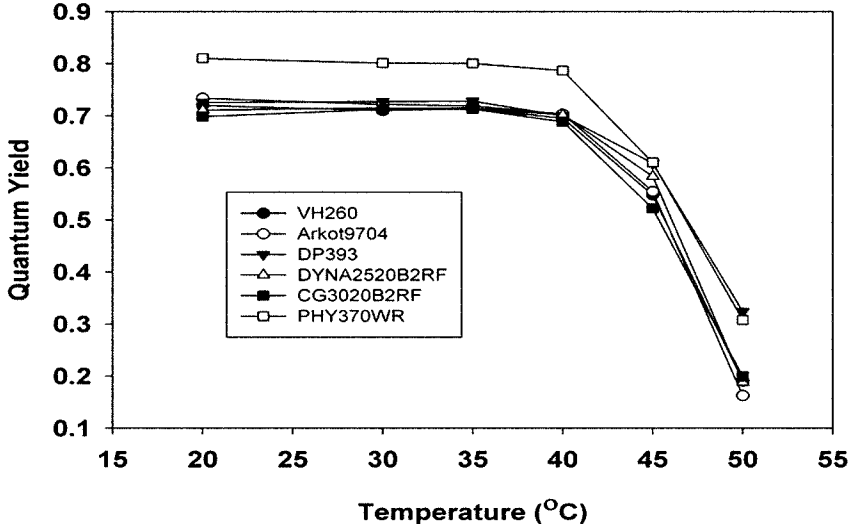

Fig. 1. Representative temperature response curve of quantum yield for six cultivars. Each data point represents the mean of six replications.

Genotypic Differences in Reproductive Thermotolerance are Associated With Elevated Pre-Stress Antioxidant Enzyme Protection in the Cotton Pistil

J.L. Snider, D.M. Oosterhuis, and E.M. Kawakami[1]

RESEARCH PROBLEM

Extreme year-to-year variability in yield is a major concern for Arkansas cotton farmers. This variability has been partially explained by year-to-year variation in average maximum temperature during flowering. For example, heat stress (average maximum temperatures near 95 °C) during flowering experienced by cotton plants during a typical growing season in the U.S. is a major cause of disappointingly low yields, with a correlation existing between low yields and high temperature (Oosterhuis, 2002).

BACKGROUND INFORMATION

Plants exposed to heat stress respond with increased antioxidant enzyme activity to prevent the accumulation of damaging reactive oxygen species (ROS) (Gong et al., 1998). Snider et al. (2009) recently showed that heat stress significantly decreased fertilization efficiency and carbohydrate content and caused an elevation in antioxidant enzyme protection in the pistils of a cotton cultivar widely utilized by Arkansas cotton growers (ST4554 B2RF). The objective of this study was to evaluate the effect of temperature and cultivar on fertilization efficiency and antioxidant enzyme activity in cotton pistils.

RESEARCH DESCRIPTION

Two consecutive experiments were conducted to evaluate the effects of heat stress on reproductive development and source leaf activity in *Gossypium hirsutum* L. Experiments were initiated in June 2008 and repeated in January 2009 using the cotton cultivars ST4554 B2RF (thermosensitive) and VH260 (thermotolerant)

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planted in two-liter pots and placed in two walk-in growth chambers (Model 36; Controlled Environments Limited, Winnipeg, Canada) at the Altheimer Laboratory, Arkansas Agricultural Research and Extension Center, Fayetteville Ark. under 30/20 °C day/night temperature regimes. Plants were grown under a 12 h photoperiod at a 500 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR) and were watered daily with half-strength Hoagland's solution.

At approximately one week prior to flowering, plants were randomly transferred from one growth chamber to the other, and the day temperature in one of the growth chambers was gradually increased at a rate of 2 °C day^{-1} until a 38/20 °C day/night temperature regime had been reached. Only flowers between main-stem nodes 5 and 10 in the first fruiting position along a sympodial branch were analyzed. Because there was no significant effect of experiment date on any of the parameters measured, data were pooled from the two consecutive experiments. Pistils used for fertilization efficiency analysis were collected 24 h after anthesis and stored in formalin-acetic acid-alcohol (FAA) for future microscopic evaluation. All other pistils were collected at midday (1200-1300 h) and stored at -80 °C for subsequent antioxidant enzyme analysis.

Pollen tubes were observed in ovules using UV microscopy, and fertilization efficiency was expressed as a percent and was calculated as follows: [(number of fertilized ovules per ovary) ÷ (total number of ovules in each ovary)] × 100. The activity of superoxide dismutase (SOD) was quantified spectrophotometrically by comparing the SOD-dependent inhibition of NBT reduction of known SOD standards with the inhibition of NBT reduction of the sample in a xanthine-xanthine oxidase coupled system at 560 nm. Glutathione reductase (GR) activity was quantified by monitoring the NADPH-dependent reduction of oxidized glutathione at 340 nm using a plate reader.

RESULTS

For fertilization efficiency, there was a significant two-way interaction between cultivar and temperature ($P = 0.0015$; Fig. 1b). Heat stress resulted in a 19.2% decline in fertilization efficiency for *G. hirsutum* cv. ST4554 from 78% under the 30/20 °C day/night temperature regime to 63% under the 38/20 °C day/night temperature regime (Fig. 1). In contrast with ST4554, fertilization efficiency was not significantly affected by day/night temperature regime in VH260 (the thermotolerant cultivar from Pakistan; Fig. 1).

For SOD (Fig. 2a) and GR (Fig. 2b) activity in the pistil, there was a significant two-way interaction between cultivar and temperature ($P = 0.0287$ and 0.0095, respectively). For example, under the optimal day/night temperature regime (30/20 °C) SOD activity was significantly higher (107% higher) for VH260 than for ST4554 (Fig. 2a). Under high day temperature conditions (38/20 °C), there was no significant difference in the SOD activity of the two cultivars (Fig. 2a). A similar trend was observed for GR activity, where the GR activity of VH260 was significantly higher (94.7% higher) than for ST4554 under the 30/20 °C day/night

temperature regime, but no difference in GR activity of the two cultivars was observed under the 38/20 °C day/night temperature regime (Fig. 2b).

DISCUSSION AND PRACTICAL APPLICATION

We conclude that reproductive thermotolerance (Fig. 1) in cotton is closely associated with elevated pre-stress antioxidant enzyme activity in the pistil (Fig. 2a-b) and that elevated pre-stress antioxidant enzyme activity in the pistil may be an important method by which thermotolerant cotton cultivars response to rapid temperature increases that are known to occur under field conditions (Wise et al. 2004). Additionally, the antioxidant enzyme status of the pistil may be an important criterion for selecting thermotolerant cotton cultivars and may help mitigate the detrimental effects on crop productivity projected to result from global climate change (Reddy et al., 2002).

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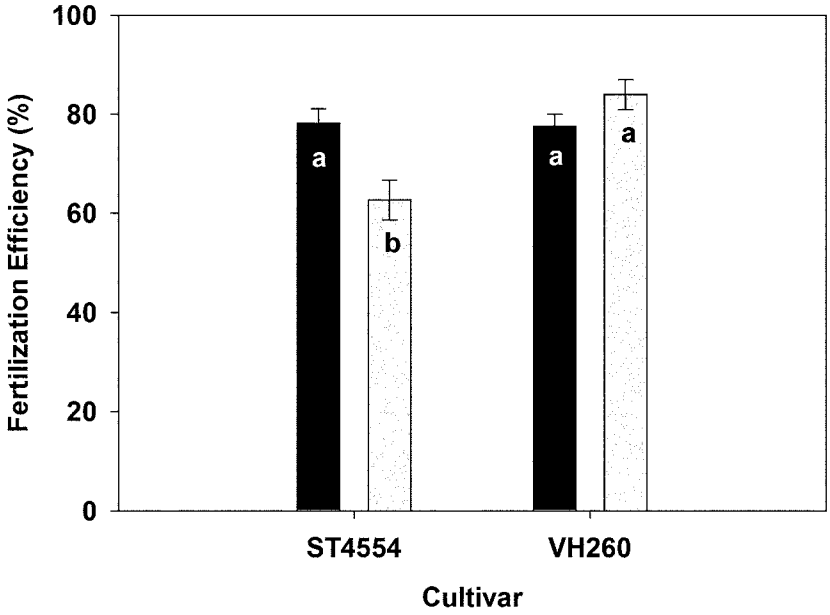

Fig. 1. Fertilization efficiencies for pistils of *Gossypium hirsutum* cv. ST4554 and VH260 under a 30/20 °C day/night temperature regime (black vertical bars; 30) and 38/20 °C day/night temperature regime (gray vertical bars; 38). All values are means ± standard error (n = 9), and values not sharing a common letter are significantly different (LSD; P < 0.05).

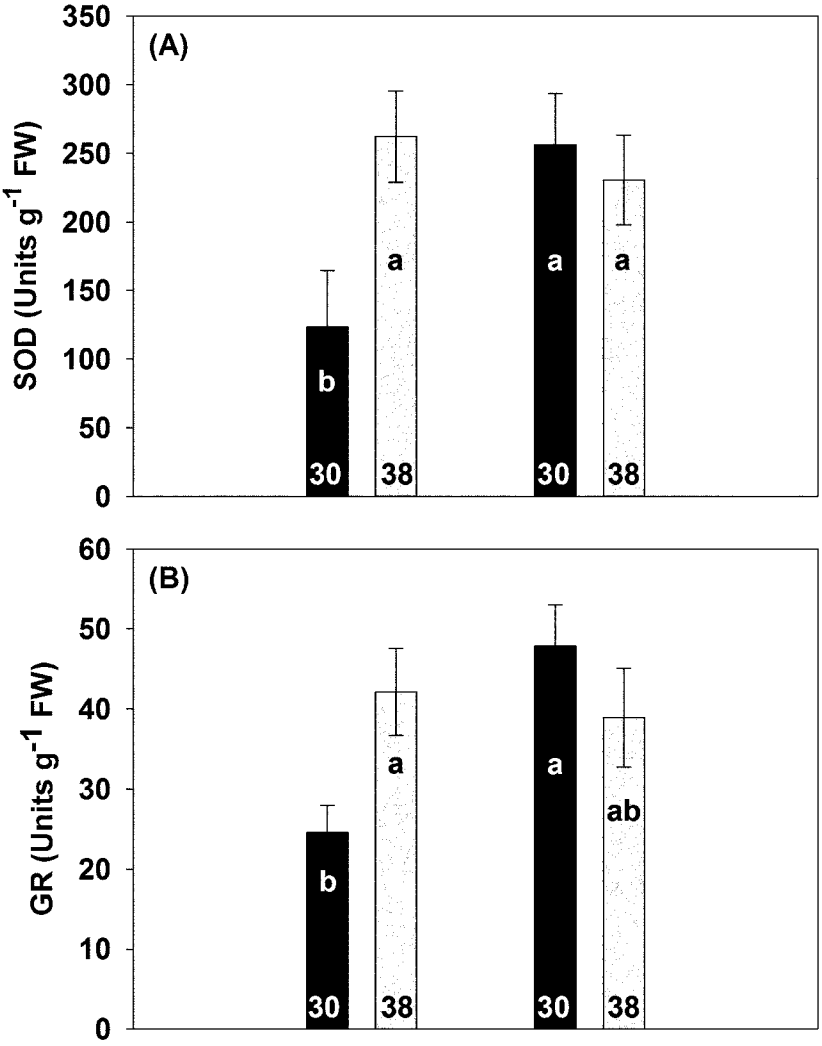

Fig. 2. Superoxide dismutase (SOD) activity (A) and glutathione reductase (GR) activity (B) in pistils of *Gossypium hirsutum* cv. VH260 and ST4554 under the 38/20°C day/night temperature regime (gray bars; 38) and the 30/20°C day/night temperature regime (black bars; 30). All values are means ± standard error (n = 10 for SOD and 16 for GR). Values not sharing a common letter are significantly different (LSD; P < 0.05).

Genotypic Differences in Thermotolerance are Dependent Upon Pre-Stress Capacity for Antioxidant Protection of the Photosynthetic Apparatus in Cotton

J.L. Snider, D.M. Oosterhuis, and E.M. Kawakami[1]

RESEARCH PROBLEM

Cotton is exceptionally sensitive to high temperature during reproductive development, with a negative correlation existing between high temperatures during flowering and yield (Oosterhuis, 2002). Furthermore, reproductive thermosensitivity in cotton is closely associated with the photosynthetic thermosensitivity of the subtending leaf (Snider et al., 2009). For example, high temperature is known to cause significant declines in fertilization efficiency (Snider et al., 2009) and carbohydrate content of the cotton pistil (Snider et al., 2009) along with declines in net carbon fixation of major source leaves (Bibi et al., 2008; Snider et al., 2009).

BACKGROUND INFORMATION

Plants exposed to heat stress respond with increased antioxidant enzyme activity to prevent the accumulation of damaging reactive oxygen species (ROS) (Gong et al., 1998). Although the importance of antioxidant enzymes in acquired thermotolerance following an acclimative response to high temperature has been shown previously for wheat (Almeselmani et al., 2006), information on the relationship between pre-stress antioxidant enzyme activity and innate photosynthetic thermotolerance is lacking. We recently obtained seeds for a cotton cultivar reported to have high fruit retention under maximum daily temperatures as high as 45 °C (VH260). The objective of this study was to quantify the relationship between PSII threshold temperature and pre-stress levels of antioxidant enzyme activity. We hypothesized that pre-stress antioxidant enzyme activity would be highest in a more thermotolerant cultivar and that the high temperature threshold for PSII efficiency will be dependent upon pre-stress antioxidant enzyme activity.

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RESEARCH DESCRIPTION

Two consecutive experiments were conducted to evaluate the effects of heat stress on reproductive development and source leaf activity in *Gossypium hirsutum* L. Experiments were conducted in January 2009 using the cotton cultivars cv. ST4554 B2RF (thermosensitive) and VH260 (thermotolerant) planted in two-liter pots and placed in two walk-in growth chambers (Model 36; Controlled Environments Limited, Winnipeg, Canada) at the Altheimer Laboratory, Arkansas Agricultural Research and Extension Center, Fayetteville Ark. under 30/20 °C day/night temperature regimes. Plants were grown under a 12 h photoperiod at a 500 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR) and were watered daily with half-strength Hoagland's solution.

To quantify *in situ* genotypic differences in actual quantum yield (Φ_{PSII}) temperature responses (measured using a pulse amplitude modulated fluorometer), first-position sympodial leaves subtending open flowers on the day of anthesis at the tenth main-stem node above the cotyledon nodes from both cultivars were selected. Leaves were continually illuminated at 500 μmol photons m^{-2} s^{-1} of growth chamber irradiance. Leaf temperature was increased in 5 °C increments up to 50 °C, and Φ_{PSII} was determined after 5 min of incubation at each temperature. Both the temperature at which Φ_{PSII} is maximal (T_{opt}) and the temperature at which Φ_{PSII} declines 15% from T_{opt} (T_{15PSII}), were determined from a best fit curve for both *G. hirsutum* cv. ST4554 (Fig. 1A) and VH260 (Fig. 1B) of Φ_{PSII} versus leaf temperature data. The threshold T_{15PSII} was used as an indication of heat stress and is comparable to the method of Froux et al. (2004), which is an acceptable method for quantifying high temperature thresholds. Temperature control was accomplished using a thermoelectric cooler/heater and leaf temperature was monitored using a type K fine-wire thermocouple and a digital thermometer.

Unheated sections of the leaves utilized for high temperature threshold determination were collected for pre-stress antioxidant enzyme quantification. The activity of superoxide dismutase (SOD) was quantified spectrophotometrically by comparing the SOD dependent inhibition of NBT reduction of known SOD standards with the inhibition of NBT reduction of the sample in a xanthine-xanthine oxidase coupled system at 560 nm. Glutathione reductase (GR) activity was quantified by monitoring the NADPH-dependent reduction of oxidized glutathione at 340 nm using a plate reader.

RESULTS

The optimal temperature (T_{opt}) and the high temperature threshold ($T_{15\Phi PSII}$) were both significantly affected by cultivar ($P < 0.0001$ and $P = 0.012$, respectively). For example, *G. hirsutum* cv. VH260 had a 7.5 °C and 5.5 °C lower mean T_{opt} (27.7 °C Fig. 1A) and $T_{15\Phi PSII}$ (38 °C; Fig. 1A), respectively, than ST4554 (Fig. 1B; 35.2 and 43.5 °C, respectively) when both were initially grown under control temperature conditions (30/20 °C). The average SOD activity was numerically

34.8% higher in VH260 than in ST4554, but there was no significant effect of cultivar on SOD activity (P = 0.154; Fig. 2A). However, GR activity of *G. hirsutum* grown under 30/20 °C day/night temperature regime was 225% higher in VH260 compared with ST4554 (P = 0.025; Fig. 2B). Figure 3 shows that the threshold temperature for efficiency of electron transport through photosystem II ($T_{15\Phi PSII}$) is nonlinearly dependent upon pre-stress levels of both GR (Fig. 3A; $r^2 = 0.532$) and SOD (Fig. 3B; $r^2 = 0.669$) activity. The initial effect of both GR and SOD antioxidant enzyme activity on T_{15PSII} is initially positive, followed by a gradual plateau above which additional antioxidant enzyme activity does not lead to a substantial increase in $T_{15\Phi PSII}$ (Fig. 3A-B).

DISCUSSION AND PRACTICAL APPLICATION

The results presented in Figs. 1-3 support our hypothesis that innate thermotolerance would be dependent upon pre-stress capacity for antioxidant defense in *G. hirsutum*. For example, Fig. 2B shows that VH260 has higher GR activity under control temperatures than ST4554 and likely contributes to the higher $T_{15\Phi PSII}$ observed for VH260 (Fig. 1), since antioxidant enzymes are an essential component of the heat stress response (Gong et al., 1998). We conclude that maintenance of sufficient levels of GR prior to heat stress is a genotypic mechanism for coping with rapid increases in leaf temperature under field conditions (Wise et al., 2004). These findings also suggest that pre-stress GR levels may be an important criterion for selecting heat tolerant cultivars without first exposing them to high temperature conditions as previously described (Almeselmani et al., 2006; Bibi et al., 2008).

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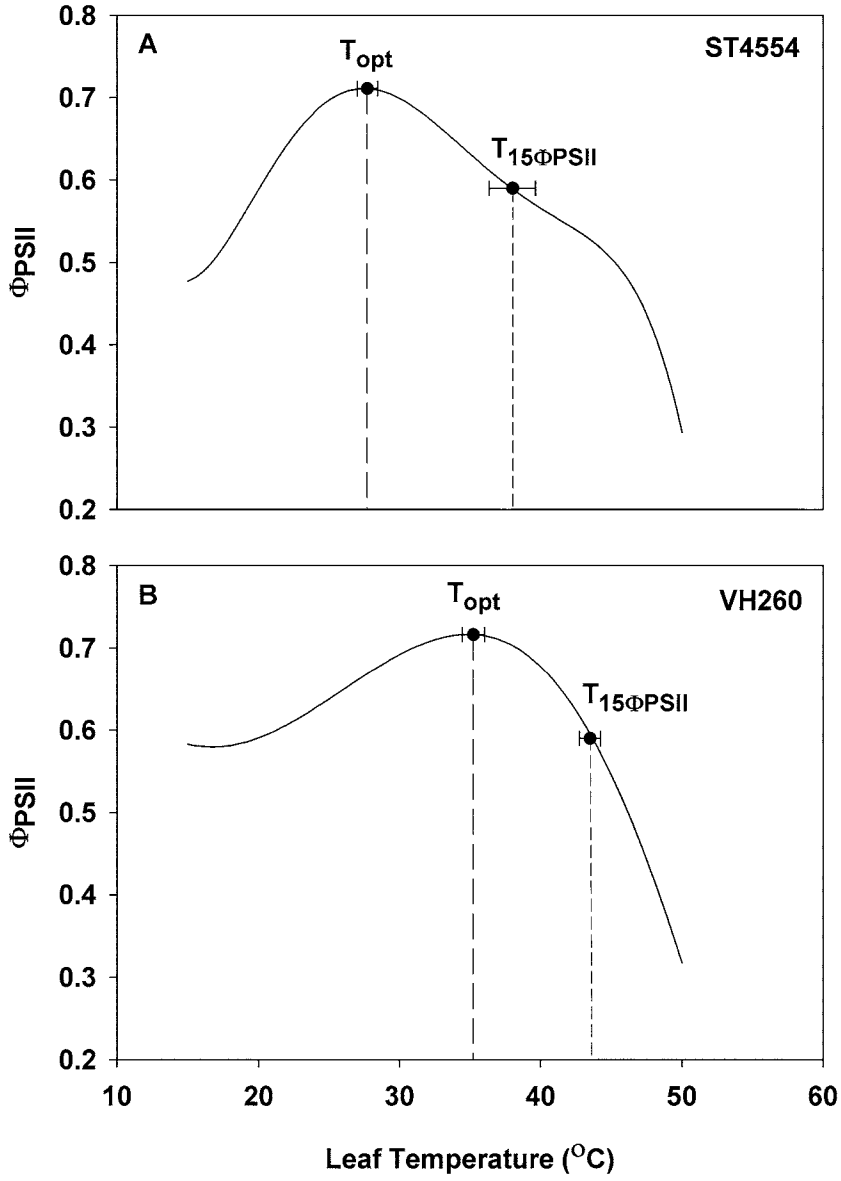

Fig. 1. The optimal temperature for Φ_{PSII} (T_{opt}) and the temperature resulting in a 15% decline in Φ_{PSII} from T_{opt} ($T15\Phi_{PSII}$) for thermosensitive (ST4554; A) and thermotolerant (VH260; B) *G. hirsutum* leaves illuminated with 500 µmol photons m^{-2} s^{-1}. Both cultivars were grown under optimal (30/20 °C) temperature conditions prior to chlorophyll fluorescence-determination of temperature responses. All values are means ± standard error (n = 6). Values not sharing a common letter are significantly different (Student's t-test; P < 0.05).

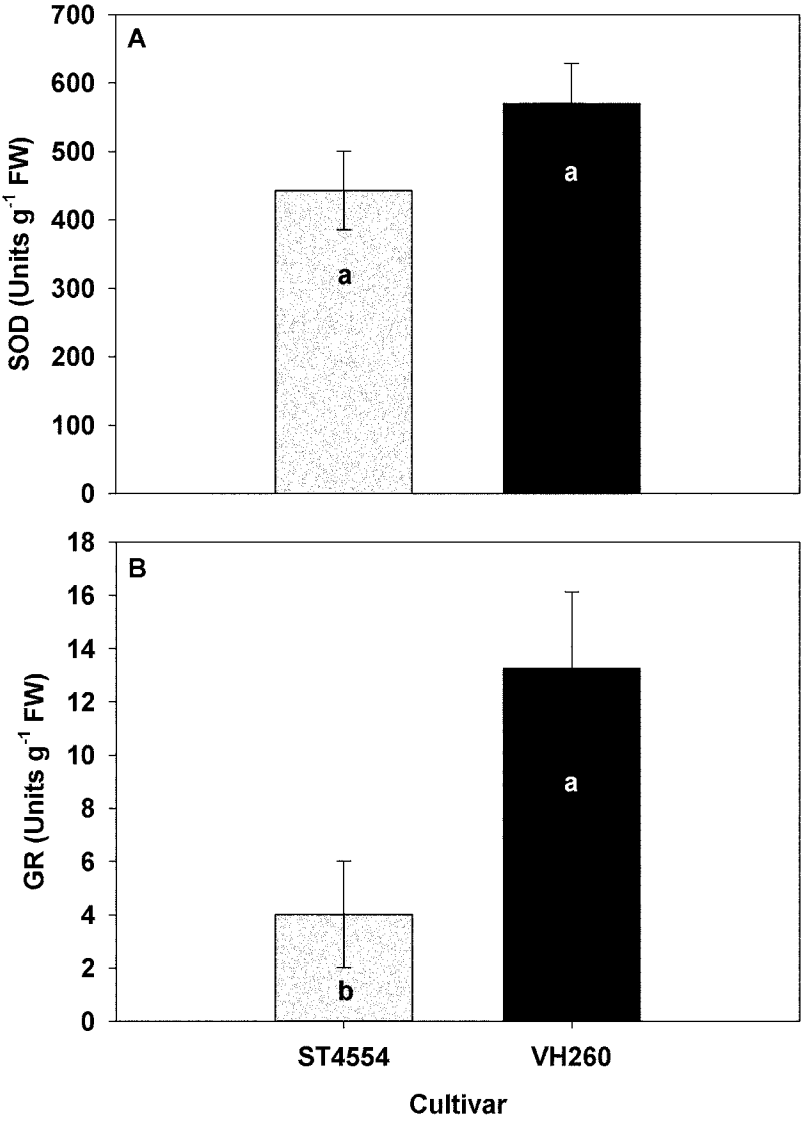

Fig. 2. Effect of cultivar on superoxide dismutase (SOD; A) and glutathione reductase (GR; B) activity of *G. hirsutum* grown under 30/20 °C day/night temperature regime. All values are means ± standard error (n = 6). Values not sharing a common letter are significantly different (Student's t-test; P < 0.05).

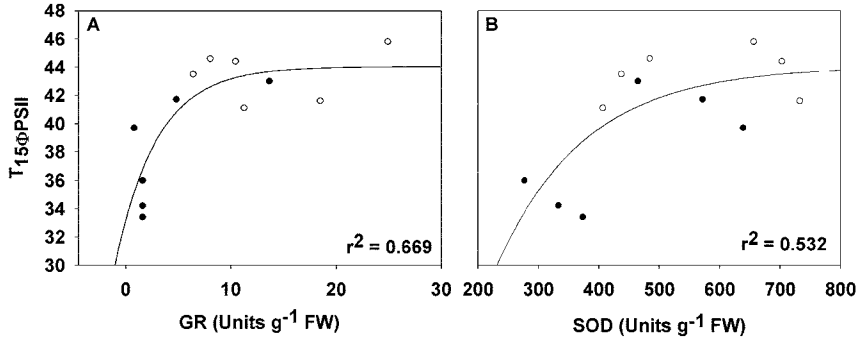

Fig. 3. The relationship between glutathione reductase (GR; A) and superoxide dismutase (SOD; B) activity and T_{15PSII} in *G. hirsutum* (solid circles = ST4554 and open circles = VH260) leaves grown initially under 30/20 °C day/night temperature regime prior to rapid leaf temperature increases.

Effect of Water-Deficit Stress on Reproductive Development in the Cotton Pistil

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

RESEARCH PROBLEM

Water-deficit is considered to be the main environmental factor responsible for plant growth compromise and severe yield loss. Even though cotton (*Gossypium hirsutum* L.) is considered to be relatively tolerant to drought since wild cotton lines inhabit regions of sparse precipitation (Lee, 1984), plant growth and yield reduction still occur when water supply is limited or interrupted. Investigations in other crops, such as maize, soybean and rice have suggested that carbohydrate metabolism of reproductive units is greatly affected by water stress treatments. In this study, it was hypothesized that water-deficit stress severely impairs cotton's gas exchange functions, which consequently results in a perturbation of carbohydrates and energy production metabolism of cotton's reproductive units.

BACKGROUND INFORMATION

For optimum growth and yield, an adequate supply of water is needed. Water stresses have been shown to have an effect on every aspect of plant growth, causing anatomical and morphological alterations as well as changes in physiological and biochemical processes and functions of the plants (Hsiao, 1973; Turner and Kramer, 1980). Cotton has some ability to tolerate water deficits by osmotic adjustment whereby cells accumulate solutes to maintain positive turgor at lower values of water potential (Oosterhuis and Wullschleger, 1987, 1991; Nepomuceno et al., 1998).

Cotton's flower buds themselves have been shown to be relatively insensitive to plant water deficits. Trollinder et al. (1993) and Van Iersel et al. (1996) observed that both cotton flowers and bolls exhibited a consistently higher water potential compared to that of the subtending leaves and bracts, during and after anthesis and under variable water stress conditions. Similarly, Guinn et al. (1988, 1990) showed that the hormonal metabolism of cotton flower buds remains unaffected by the imposition of water stress.

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However, to our knowledge the pathways of carbohydrate metabolism and subsequent energy production, as well as antioxidant metabolism of cotton flower buds under water stress have received little attention. Therefore, it is critical that more research be conducted in order to elucidate the physiological, metabolic and biochemical responses of cotton's reproductive units under conditions of water stress in order to facilitate methods of amelioration. Hence, the objectives of this study are to observe and quantify the physiological and biochemical changes that take place in cotton flower buds and their subtending leaves when they are subjected to limited water supply.

RESEARCH DESCRIPTION

Growth chamber studies were conducted in 2008-2009 in Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) ST 5288 B2F was planted into 2L pots containing a soilless horticultural media (Sun-Gro horticulture mix). The growth chambers were set for normal conditions of 30/20 °C (day/night), ±60% relative humidity, and 12/12h photoperiod, and half-strength Hoagland's nutrient solution was applied daily in order to maintain adequate nutrients and water. Plants were arranged in a randomized complete block design with 20 replications for each treatment.

Three water-deficit treatments were imposed and consisted of untreated control, early stress (water-deficit stress during squaring), and late-stress (water-deficit stress during flowering). Control plants received optimum quantity of water throughout the duration of the experiment, whereas early and late-stress plants had water withheld until desired stress levels were reached (i.e., leaf stomatal conductance $\leq$50 mmol/m²s). After induction of stress, plants received half the quantity of water needed and the stress was maintained for ten days.

Measurements of stomatal conductance, yield fluorescence and respiration were taken during 11:00 am-1:00 pm from the fourth main-stem leaf from the terminal from each plant using a leaf porometer (Decagon SC-1), a fluorometer (OS1-FL), and a gas-analyzer (LiCor 6200). Flowers for carbohydrate and antioxidants analysis and evaluation were collected when available from all three treatments. Total soluble carbohydrates and glutathione reductase levels were measured with a Multiscan Microplate Reader.

RESULTS AND DISCUSSION

A significant decrease in the fluorescence yield (Fig. 1) was observed in the plants that were deprived of water during the squaring phase (2-3 weeks after planting). We speculate that this decrease indicated a damage in the photosynthesis apparatus of the plants that was reflected in the carbohydrate levels of the pistils, since glucose levels (Fig. 2) of the water-stressed plants were significantly reduced compared to those of the control. Adversely, however, the levels of sucrose

(Fig. 3) of the water-deficit pistils were significantly higher compared to the control, indicating a perturbation in the carbohydrate metabolism and more specifically in the function of sucrose cleaving enzymes, sucrose synthase and acid invertase (Beasley and Ting, 1974).

Cotton plants deprived of water during the flowering period (late stress) responded by significantly increasing the antioxidant glutathione reductase levels of the pistils (Fig. 4). A significant decrease was also observed in the dark respiration rates of the water-deficient plants compared to the well-watered plants (Fig. 5). Consequently, total soluble carbohydrates (glucose, fructose and sucrose) levels were markedly lower in the pistils of water-deficient plants compared to the control (Figs. 2, 3, 6).

Both early (during squaring) and late (during flowering) water-deficit stresses had a detrimental impact on carbohydrate metabolism of cotton flower buds. Late-stress caused glucose, fructose and sucrose levels to significantly decrease, which resulted in a reduction in respiration rates. Early-stress caused a similar reduction to glucose levels, which was not accompanied by a similar reduction in respiration rates. Additionally fructose and sucrose levels of early-stressed flowers were significantly higher than those of late-stressed, indicating a perturbation in the breakdown and interconversion of carbohydrates in the flower. These responses would most likely result in a compromise of fertilization efficiency and seed set.

PRACTICAL APPLICATION

Water deficit is the major abiotic factor limiting plant growth and crop productivity around the world (Kramer, 1983). A better understanding of the physiological, metabolic and biochemical responses of cotton's reproductive units under conditions of water stress would provide important information for genotypic selection of drought tolerant cultivars as well as the formulation and application of exogenous plant growth regulators.

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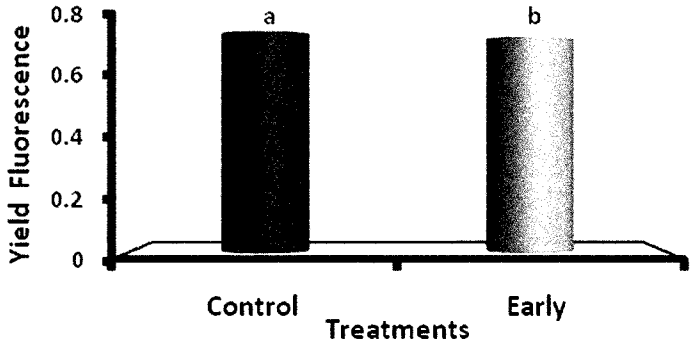

Fig. 1. Effect of water-deficit stress on yield fluorescence during squaring. Columns with the same letter are not significantly different (P = 0.05).

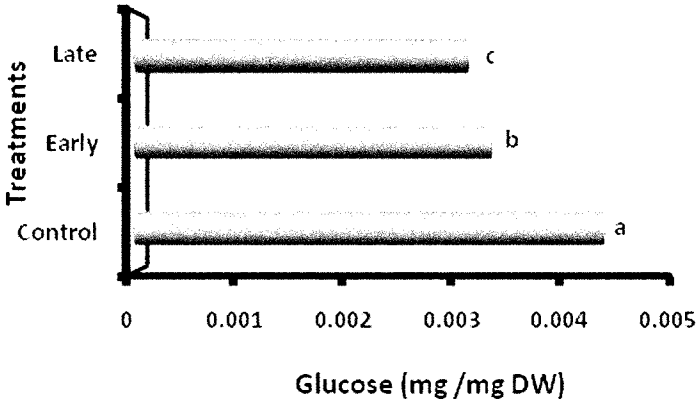

Fig. 2. Effect of water-deficit stress on glucose content in the pistil. Columns with the same letter are not significantly different (P = 0.05).

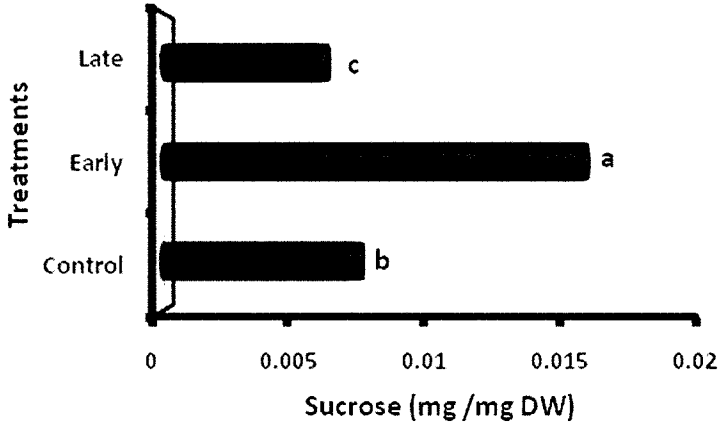

Fig. 3. Effect of water-deficit stress on sucrose content in the pistil. Columns with the same letter are not significantly different (P = 0.05).

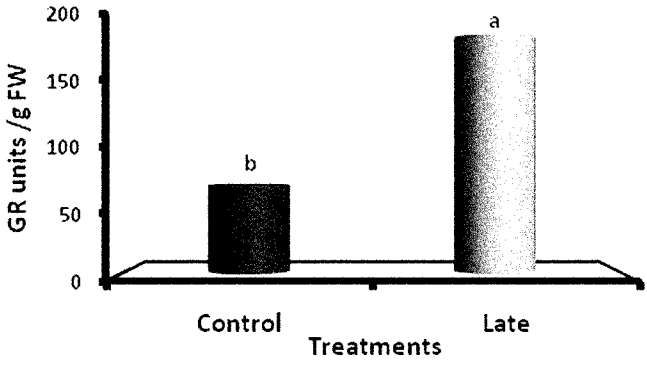

Fig. 4. Effect of water-deficit stress on glutathione reductase during flowering. Columns with the same letter are not significantly different (P = 0.05)

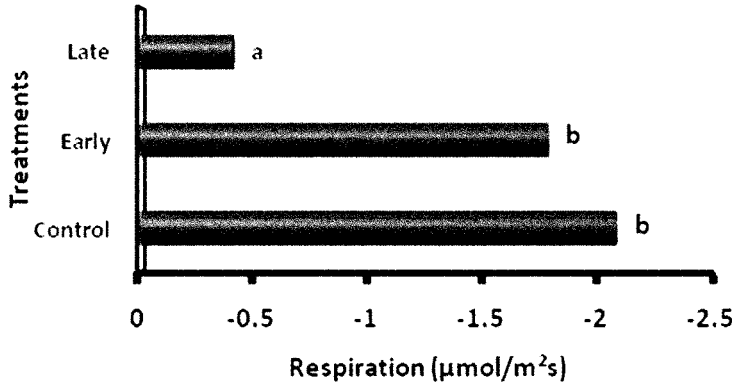

Fig. 5. Effect of water-deficit stress on dark respiration during flowering. Columns with the same letter are not significantly different (P = 0.05)

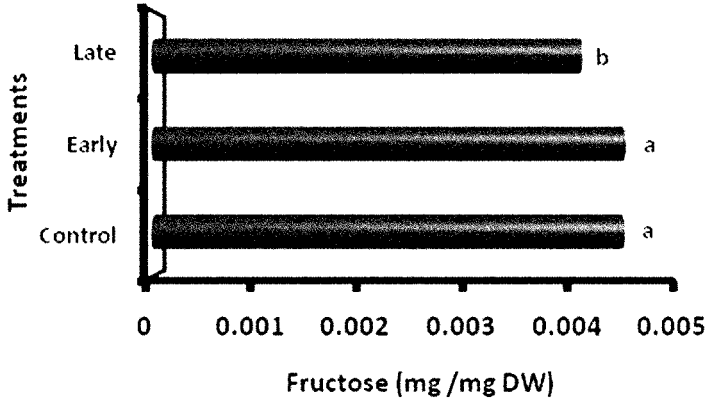

Fig. 6. Effect of water-deficit stress on fructose content in the pistil. Columns with the same letter are not significantly different (P = 0.05).

Effects of Temperature and Application of Urea with N-butyl Thiophosphoric Triamide and Dicyandiaminde on Cotton

E.M. Kawakami, D.M. Oosterhuis and J.L. Snider[1]

RESEARCH PROBLEM

Crops are usually known to have low N use efficiency, recovering only 30-35% of the N supplied (Constable and Rochester, 1988; Daberkow et al., 2000). Different practices have been recommended to increase crop N-use efficiency and much attention has been focused on the use of urease and/or nitrification inhibitors to decrease losses of N by volatilization and leaching. Cotton (*Gossypium hirsutum* L.) yields in the U.S. have been reported to be negatively affected by periods of extreme high temperatures during flowering and boll development (Oosterhuis, 2002).

Recently a number of studies have been conducted in the understanding of the physiological responses of cotton to heat stress (Snyder et al., 2009). Application of urease and nitrification inhibitors to crops has also been widely researched; however, there has been limited work on the effects of these inhibitors on the cotton growth and N assimilation physiology under high temperature conditions.

BACKGROUND INFORMATION

Nitrogen is a crucial nutrient in the production of crops for food, fiber, and energy for the world population. However, one of the biggest challenges in agriculture systems is to increase plant N-use efficiency. The world N consumption in 2000 reached 87 million MT, and due to the expanding food demand, N-use is expected to reach 249 million MT in 2050 (Tilman et al., 2001).

A practice commonly recommended to improve N fertilizer use efficiency is the addition of urease and/or nitrification inhibitors into urea fertilizers. Urease inhibitors (i.e., N-(n-butyl) thiophosphoric triamide - NBPT) delay hydrolyzes of urea fertilizer and thereby diminishes ammonia volatilization losses, and nitrification inhibitors (i.e., Dicyandiaminde - DCD) hinder the conversion of ammonium to nitrate lowering N-loss by leaching.).

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Cotton originated from warm temperature regions; but the cotton plant is known to respond negatively to high temperatures (Oosterhuis, 2002, Pettigrew, 2008). Optimum temperature for cotton growth is around 30 ^{o}C (Reddy et al., 1992); however in the U.S. Cotton Belt, temperatures commonly reach values higher than 35 ^{o}C (Reddy et al., 1991; Boykin et al., 1995 cited by Pettigrew, 2008). Oosterhuis (2002) suggested that high temperature during reproductive development is the main factor causing lower and variable cotton yields in the U.S. The effects of heat stress on cotton N assimilation with urease and nitrification inhibitor are not well documented. This research is designed to address these gaps in our knowledge and provide a better understanding of the N behavior in cotton plants under condition of heat stress.

RESEARCH DESCRIPTION

The experiment was conducted in the Altheimer laboratory, Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. Cotton (*Gossypium hirsutum* L.) cultivar ST4554 B2RF was planted in 2-liter pots filled with soil from a typical cotton growing area in Marianna, Ark. (Loring silt loam - fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs). The pots were arranged in two large walk-in growth chambers (Model PGW36, Conviron, Winnipeg, Canada) with day/night temperatures of 30/20 ^{o}C, 12 h photoperiods and a relative humidity of 70%. After 6 weeks, about one week prior to flowering, the day temperature of one growth chamber was increased in 2 ^{o}C increments every 2 days until the temperature reached 38 ^{o}C, while the temperature of the other chamber was maintained at 30 ^{o}C. The chambers were assumed to be identical in all variables (e.g., light and relative humidity) with differences only in day temperatures (30 ^{o}C and 38 ^{o}C).Plants were watered daily with deionized water only. The experiments were arranged in a randomized complete block design with two factors and 5 replications. The factors consisted of N treatment and temperature treatment.

The N treatments consisted of: (T1) untreated control, (T2) full recommended N rate with urea, (T3) 75% of the recommended N rate with urea, (T4) 75% of the recommended N rate with urea plus NBPT and, (T5) 75% of the recommended N rate with urea plus NBPT and DCD. The full recommended N rate consisted of 125 kg ha^{-1}, and correspondingly 94 kg ha^{-1} of N was used for 75% of the recommended N rate treatment. Treatments with urea plus NBPT, and urea plus NBPT and DCD, were applied using the commercial fertilizers Agrotain (Agrotain Int. LLC) and Super U (Agrotain Int. LLC), respectively. Nitrogen fertilization was split-applied at pre-plant and pinhead-square (PHS) stages. At pre-plant P_2O_5, K_2O and half of the N fertilizers were placed approximately 0.1 m below the seed. At PHS, the other half of the N rate was side-dress applied, incorporated 7 days later with ample water (12 mm). All nutrient fertilization was calculated for the area of one hectare with a 0.15 m furrow slice.

Flowers were collected at the first-flower stage (FF) and immediately stored in an ultra-freezer at -80 °C for subsequent protein and enzymes determination. At 4 weeks after FF, plants were harvested for growth analysis and N uptake determination.

RESULTS AND DISCUSSION

Statistical analysis of the data showed that there was no significant interaction effect between N treatment and temperature regime in any of the measurements collected. Significant N treatment effect was observed in the measurements of protein ($P = 0.0298$) glutathione reductase ($P < 0.0001$), N uptake ($P < 0.0001$), and dry matter ($P < 0.0001$). Temperature regime effect showed statistical significance on data of protein ($P = 0.0085$), N uptake ($P < 0.0001$), and dry matter ($P = 0.0035$). Cotton ovary protein analysis showed a 10% increase in protein content in the high temperature (38 °C) treatment (data not shown). Protein comparison between N treatments (Table 1) showed the lowest content in the ovaries collected from unfertilized control plots and no difference between fertilized treatments. Furthermore, enzyme data (Fig. 1) indicated that flowers from the unfertilized treatment had a two-fold increase in activity of glutathione reductase compared to fertilized treatments. Nitrogen measurements (Table 2) showed significantly higher N uptake in the treatment of urea at full recommended N compared to the Agrotain and Super U treatments. No difference in N uptake was observed between Agrotain and Super U treatments, however both had significantly higher uptake than urea application at 75% of the full recommended N rate. High temperature (38 °C) significantly increased N uptake (data not shown) and dry matter production (Fig. 2). Nitrogen treatment effect on cotton dry matter production (Fig. 3) was similar to N uptake data, with urea full rate having the highest dry matter values, followed by Agrotain and Super U treatments. Urea application at 75% of full N rate exhibited significantly lower dry matter than Agrotain and Super U treatments.

In summary, the results of this experiment indicated that high temperature increased N uptake, which resulted in higher protein and dry matter production. The performance of the sources of N in this experiment was not affected by high temperature, since no significant interaction was detected. As expected N deficiency decreased cotton protein content and increased glutathione reductase activity in cotton ovaries. The addition of NBPT to urea fertilization was effective in improving N uptake of cotton plants. On the other hand, no benefit of addition of DCD was observed in any of the measurements collected.

PRACTICAL APPLICATION

In conclusion, the N fertilization treatment of urea with NBPT increased N uptake and dry matter production of cotton compared to urea alone. High

temperature also had a positive effect on N uptake but it did not influence the performance of NBPT. In this research, the application of 75% of the full N rate with urea plus NBPT resulted in lower N uptake and dry matter production compared to the full N rate with urea alone. Thus, when using urea with NBPT, a higher rate than 75% of the full recommended N should be considered. However, in field experiments, application of urea with NBPT at 75% of the full recommended N had similar lint yields compared to urea application at the full N rate. An explanation for these conflicting results could be related to the fact that in this growth room, study cotton plants were grown in pots capable of holding only two liters of soil.

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Table 1. Effect of temperature and urea with and without NBPT and DCD on cotton ovary protein content. Rows with the same letter are not significantly different (P = 0.05).

N Treatment	Protein mg g^{-1} FW
Control	0.550 b
Full Urea (100%)	0.651 a
Urea 75%	0.644 ab
Agrotain 75%	0.729 a
Super U 75%	0.700 a

Table 2. Effect of temperature and urea with and without NBPT and DCD on cotton N uptake. Rows with the same letter are not significantly different (P = 0.05).

N Treatment	N Uptake (g)
N Uptake (g)	0.024 d
Full Urea (100%)	0.095 a
Urea 75%	0.069 c
Agrotain 75%	0.084 b
Super U 75%	0.085 b

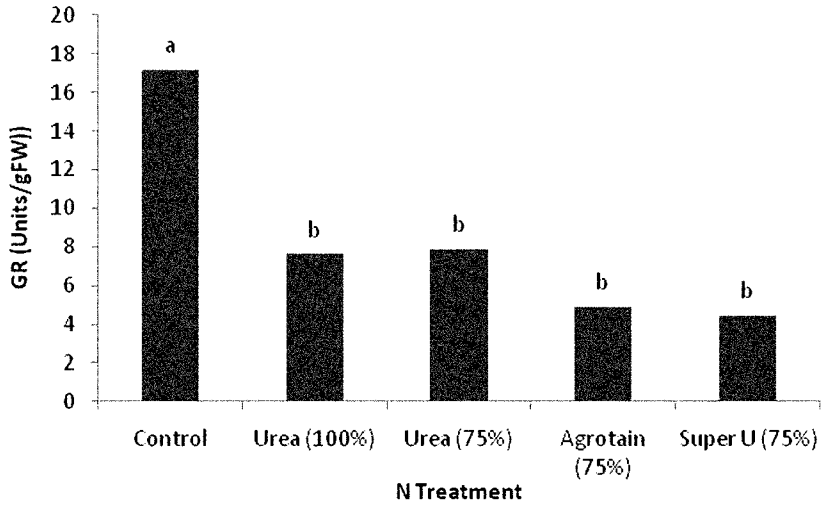

Fig. 1. Effect of urea with and without NBPT and DCD on GR activity. Columns with the same letter are not significantly different (P = 0.05).

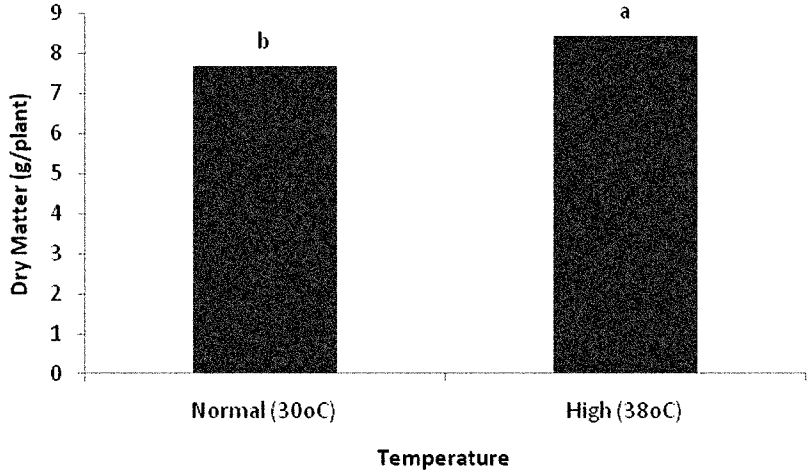

Fig. 2. Effect of temperature on cotton dry matter production. Columns with the same letter are not significantly different (P = 0.05).

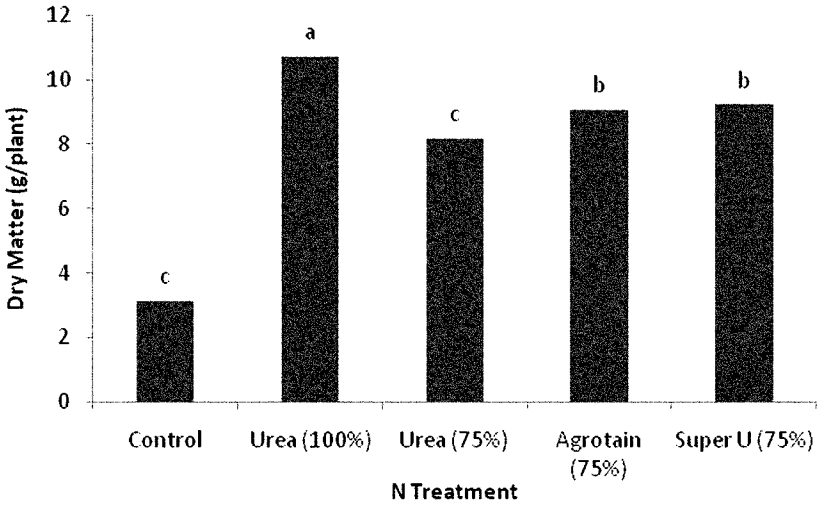

Fig. 3. Effect of urea with and without NBPT and DCD on cotton dry matter production. Columns with the same letter are not significantly different (P = 0.05).

Effect of 1-Methylcyclopropene on Growth and Biochemistry of Heat-Stressed Cotton Grown in a Controlled Environment

D.M. Oosterhuis, E.M. Kawakami, and D.K. Storch

RESEARCH PROBLEM

Extreme year-to-year variability in cotton yields is a major concern of cotton farmers and the cotton industry (Lewis et al., 2000). In addition, current cotton yields in the U.S. are less than half of the theoretical maximum (Baker and Hesketh, 1969). Low and variable cotton yields have been associated with environmental stress, of which temperature and drought appear to play the major role. When plants are stressed they produce the plant hormone ethylene, which is well known for its role in the regulation of fruit abscission, senescence and general plant responses to stress. The current project was designed to evaluate the possible use of a new and novel synthetic plant growth regulator 1-methylcyclopropene (1-MCP). This compound acts to suppress ethylene and thereby alleviate the adverse effect of environmental stresses on cotton. The cotton crop is particularly sensitive to stress during reproductive development, and alleviation with 1-MCP could reduce year-to-year yield variability and allow the cotton crop to yield closer to its potential.

BACKGROUND INFORMATION

Methylcyclopropene is a competitive inhibitor of the plant senescence hormone, ethylene (Sisler and Serek, 1999), and has been successfully and widely used post-harvest to prevent fruit ripening. More recently, 1-MCP has been shown to serve a beneficial role during fruiting in horticultural crops such as cherry tomatoes to prevent fruit shedding (Beno-Moualem et al., 2004). Our research with cotton, has shown that 1-MCP application results in a numerical yield increase in field-grown cotton (Kawakami et al., 2006), and that 1-MCP is able to ameliorate oxidative stress on cotton plants grown in the growth chamber (Kawakami et al., 2006; Storch, 2010). The current research was formulated to test the effectiveness of using 1-MCP to alleviate environmental stress during

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flowering and early boll development in field grown cotton. This is the fourth year of this study.

RESEARCH DESCRIPTION

The field study was planted in early May in 2006, 2007, 2008 and 2009 at the Lon Mann Cotton Branch Station in Marianna, Ark. The cotton (*Gossypium hirsutum* L.) cultivar ST4554B2RF was planted in a Loring silt loam (Oxyaquie Fragiudlafs) using a randomized complete block design with five replications. The plot size was three rows, 15 m in length. The trial was furrow irrigated as needed to maintain optimum moisture. The trial was fertilized according to recommended practices for cotton. Treatments consisted of: (T1) Untreated control; (T2) 1-MCP at 10g ai/ha applied at first flower (FF); (T3) 1-MCP at 10g ai/ha applied at first flower and again two weeks later. All 1-MCP treatments were sprayed with a backpack CO_2 sprayer calibrated to deliver 187 L/ha. The adjuvant AF-400 was added to the spraying solution at a rate of 0.375% v/v. After defoliation, the number of bolls acre and boll weight were determined by handpicking one meter lengths of row in each plot. The individual plots were machine picked.

RESULTS AND DISCUSSION

There was no significant effect of 1-MCP on yield, boll weight or boll number in 2009 (Table 1). This may have been related to the extreme adverse wet weather experienced during the month prior to harvest in 2009, which may have diluted any positive effect that 1-MCP may have had earlier during fruit development. There was, however, a significant positive effect on yield from 1-MCP when averaged over the four years (Fig. 1), with an increase of 113 kg/ha from the treatment where 1-MCP was applied at FF and FF+2, in contrast to the untreated control. No significant interaction between year and 1-MCP treatments was observed and the yearly yield data are shown in Fig. 2.

The effective flowering period for cotton is about 3-4 weeks, and during this time the boll load builds up steadily, the need for resources increases considerably (water, nutrients and carbohydrates), and at the same time summer temperatures reach a maximum. Therefore, “crop stress” increases dramatically after the start of flowering. 1-MCP has been shown to relieve temperature stress during flowering (Kawakami et al., 2009), and thus it would seem logical that the benefit from 1-MCP would be optimized during peak flowering and early boll development. This suggests that future research with 1-MCP should focus on applications made during the more stressful times of boll development, i.e., at and after the peak of flowering.

PRACTICAL APPLICATION

In conclusion, 1-MCP did not have a significant effect on the yield of field-grown cotton in 2009, due probably to the adverse weather in the latter part of the season. However, when averaged over the four years of the experiment, 1-MCP had a significant positive effect on yield from the FF and FF+2 treatment. The results to date suggest that 1-MCP should be applied later during the flowering period for maximum effect to counteract plant and environmental stress.

ACKNOWLEDGMENTS

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Table 1. Effect of 1-MCP on hand-picked lint yield, boll number, and boll weight in Marianna, Arkansas in 2009.

Treatment	Lint	Bolls	Boll Weight
	kg/ha	No./ha	g/boll
Untreated Control	1312	799479	4.02
1-MCP at FF	1256	802083	3.97
1-MCP at FF + 2 weeks	1386	865885	3.90
P-Value (α=0.05)	NS[1]	NS	NS

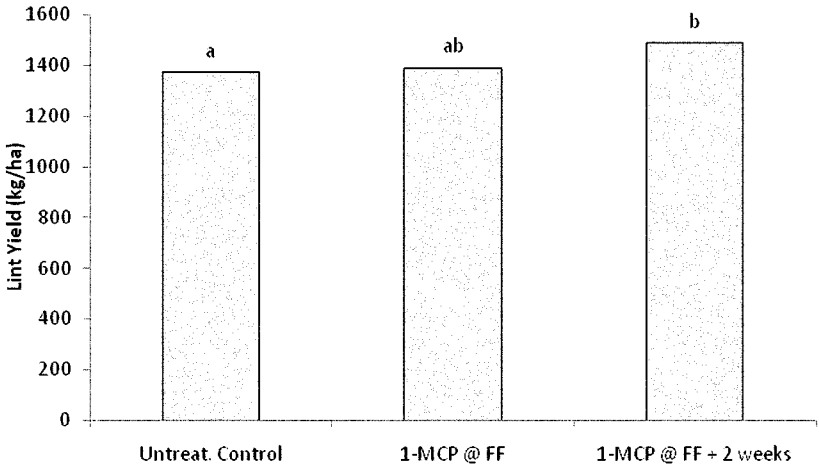

Fig. 1. Lint yield averaged over the four years of this experiment located in Marianna, eastern Arkansas. Columns with the same letters are not significantly different at the α = 0.05 level.

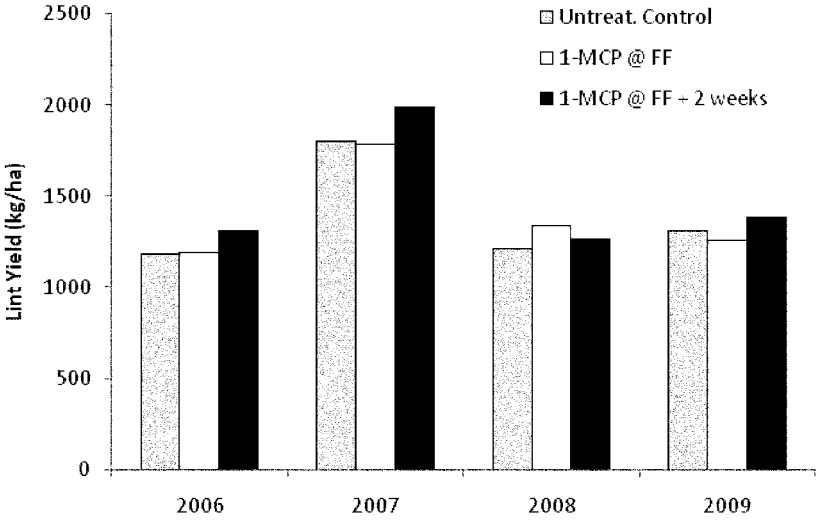

Fig. 2. Data of lint yield for the four years of this experiment that were averaged in Fig. 1.

Effects of Urea with NBPT and DCD on the Yield and Fiber Quality of Field Grown Cotton

E. M. Kawakami, D. M. Oosterhuis, and J. Snider[1]

RESEARCH PROBLEM

Nitrogen fertilization is one of the most expensive agricultural practices and crops are known to recover only 30-35% of the N fertilizer applied (Constable and Rochester, 1988; Daberkow et al., 2000). Recently, attention has been focused on studies to measure and maximize plant N-use efficiency. A practice commonly recommended to improve N fertilizer use efficiency is the addition of urease and/or nitrification inhibitors into N fertilizers. Urease inhibitors delay hydrolyzes of urea fertilizer diminishing ammonia volatilization losses. Nitrification inhibitors hinder the conversion of ammonium to nitrate lowering N loss by leaching. Numerous studies have been done with urease and nitrification inhibitors in different crops; however, there has been limited work done with cotton, particularly on the effects on plant growth parameters and N assimilation physiology.

BACKGROUND INFORMATION

Urea fertilization is known to be susceptible to NH_3 volatilization losses, and depending on fertilizer practices, soil type and environmental conditions this loss can reach values of 50% of the total N applied (Harisson and Webb, 2001; Cai et al., 2002). One approach for reducing potential losses of N in urea fertilization is to reduce urea hydrolyzes by inhibiting urease activity. Urease is an enzyme that catalyzes the hydrolysis of urea into carbon dioxide and ammonia. Inhibiting urease, the urea fertilizer could percolate or be incorporated into the soil before hydrolysis to NH_3 and be retained in the soil colloids thereby reducing losses of gaseous N. A well known urease inhibitor is NBPT (N-(n-butyl) thiophosphoric triamide). The main advantage of NBPT is the high efficiency in inhibiting urease at low concentration in a wide variety of soils (Vittori et al., 1996; Rawluk et al., 2001).

Utilization of nitrification inhibitors has the objective of reducing nitrate leaching losses by retaining the applied N in the ammoniacal form, which is

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retained in the Cation Exchange Capacity of the soil (Reidar and Michaud, 1980). Dicyandiaminde (DCD) is a well known nitrification inhibitor studied in a wide range of crops. The DCD inhibits *nitrosomonas* bacteria stopping the oxidation of NH_4^+ to NO_2^- (Ambergern, 1989). Inhibition of *nitrosomonas* is mediated by the reaction of the C-N group of DCD with sulfhydryl or heavy metal groups of the bacteria's respiratory enzymes (Ambergern, 1989). The objective of this research was to evaluate the effect of sidedress application of urea with NBPT and DCD at the pinhead-square stage of cotton, on the yield parameters: boll size, boll number, seedcotton yield and lint yield.

RESEARCH DESCRIPTION

The field study was conducted in 2009 at the University of Arkansas Cotton Branch Station at Marianna, in a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) soil. The cotton (*Gossypium hirsutum* L.*),* cultivar ST4554B2RF was planted on 20 May and harvested on 14 November. Except for N, the experiment was uniformly fertilized following preseason soil tests and state recommended rates; N was applied according to treatments. Weed and insect control was performed according to state recommendations. Mepiquat chloride was applied as needed to control vegetative growth.

Nitrogen treatments consisted of: (T1) untreated control, (T2) full recommended N rate with urea, (T3) 75% of the recommended N rate with urea, (T4) 75% of the recommended N rate with urea plus NBPT and, (T5) 75% of the recommended N rate with urea plus NBPT and DCD. Full recommended N rate consisted of 125 kg ha^{-1} and correspondingly 94 kg ha^{-1} of N was used for 75% of the recommended N rate treatment. Nitrogen treatment application was side-dressed split applied half at unfold cotyledons stage and half at pin-head-square stage. Treatments with urea plus NBPT and urea plus NBPT and DCD were applied using the commercial fertilizers Agrotain (Agrotain Int. LLC) and Super U (Agrotain Int. LLC), respectively. Nitrogen fertilization was split-applied at pre-plant and pin-head-square (PHS) stage. The plot size was 4 rows spaced by 0.96 m with a length of 15 m. A randomized complete block design with 5 replications was used to conduct the experiment. Statistical analysis was conducted using JMP software and treatments differences were detected using LSD ($\alpha = 0.05$) with probability lower than 0.1.

The yield parameters boll size, boll number, and gin-turnout were calculated from a one meter length of row, hand-picked cotton. Seedcotton yield was recorded from a machine harvested 2 middle rows of each plot and lint yield was estimated by multiplying seedcotton yield by gin-turnout data. Fiber quality was analyzed by Louisiana State University Cotton Fiber Testing Laboratory, AgCenter, Baton Rouge, La. The following parameters were analyzed: micronaire, length, strength, color, uniformity, short fiber index, and elongation.

RESULTS AND DISCUSSION

The results of the machine harvested plots indicated a significant treatment effect on seedcotton yield ($P < 0.0001$) and fiber yield ($P < 0.0001$). Nitrogen treatment effect was identical for seedcotton and lint parameters, the unfertilized control treatment exhibited the lowest yield followed by Urea (75%) (Figs. 1 and 2). The highest yield was observed by the Urea (100%), Agrotain and Super U treatments, all of which were significantly different than unfertilized control and Urea 75% treatments.

In the hand-picked cotton samples, significant treatment effect was observed on boll number ($P = 0.001$) and gin-turnout ($P = 0.005$). No treatment effect was detected on boll weight ($P = 0.335$). Boll number data indicated that all fertilized treatments had superior boll counts than the unfertilized control treatment (Fig. 3). Among the fertilized treatments, Super U application exhibited a significant increase in boll number compared with Urea (75%). In comparison to the treatment Urea (75%), application of Urea (100%) and Agrotain had only numerical increase in boll count. Gin-turnout measurement showed no differences between fertilized treatments; however significant increase in gin-turnout values was observed in the unfertilized control treatment (Fig. 5).

Fiber quality data indicated a statistical significant treatment effect on fiber elongation ($P = 0.03$), micronaire ($P = 0.005$), and maturity ($P = 0.01$) parameters. No treatment differences were observed on the measurements of fiber length ($P = 0.33$), uniformity ($P = 0.41$), short fiber index ($P = 0.58$), and strength ($P = 0.25$). Urea (100%) treatment exhibited the highest values of fiber elongation, significantly superior than Urea (75%) and unfertilized control treatment (Table 1). Agrotain and Super U application significantly decreased fiber micronaire in comparison to Urea (75%) and the unfertilized control treatments (Table 1). Fiber maturity data indicated that the unfertilized control and Urea (75%) treatments increased fiber maturity compared to Urea (100%) and Agrotain treatments (Table 1).

In summary, the results of this research indicated that addition of NBPT to urea had a significant effect on increasing cotton yields. On the other hand, addition of DCD did not have any significant effect on N fertilization, since no differences between Agrotain and Super U were observed. In this experiment, we did not observe differences between Urea (100%) and Agrotain treatments, therefore we are able to conclude that the addition of NBPT resulted in an increase of up to 25% in urea fertilizer efficiency. The fiber quality data indicated that application of nitrogen increased fiber elongation, decreased fiber micronaire and fiber maturity.

PRACTICAL APPLICATION

In conclusion, the N fertilization of urea with NBPT increased cotton yields compared to urea alone. In the case of a side-dress application of urea, the addition of NBPT should be considered to improve N fertilization efficiency. This research showed that use of urea with NBPT has great potential for decreasing the rate of urea application without compromising yield.

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Table 1. Effect of urea with and without NBPT and DCD on fiber quality of cotton.

Treatment	Length mm	Uniformity %	Short Fiber Index %	Strength g/tex	Elongation %	Microaire -	Maturity %
Untr. Control	1.01	80.72	10.08	27.78	13.46 b*	5.10 a	83.80 a
Urea (100%)	1.04	80.84	9.84	26.56	14.66 a	4.64 bc	81.80 b
Urea (75%)	1.05	81.30	8.42	28.74	13.40 b	4.98 ab	83.80 a
Agrotain (75%)	1.05	80.54	9.76	28.26	14.12 ab	4.42 c	81.80 b
Super U (75%)	1.06	81.08	8.48	28.12	13.88 ab	4.56 c	82.40 ab
P-value	0.33	0.41	0.58	0.25	0.03	0.005	0.01

*Numbers with the same letters are not significantly different (P = 0.05).

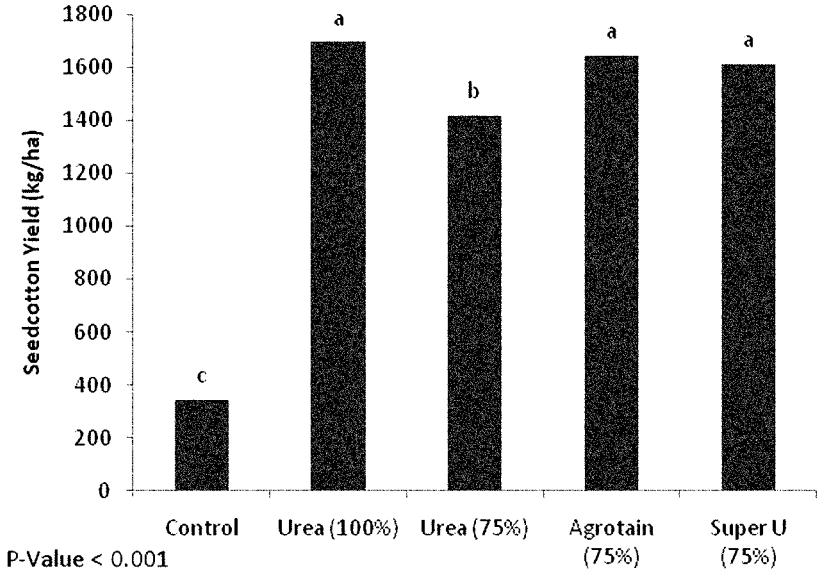

Fig. 1. Effect of urea with and without NBPT and DCD on seedcotton yield. Columns with the same letter are no significantly different (P = 0.05).

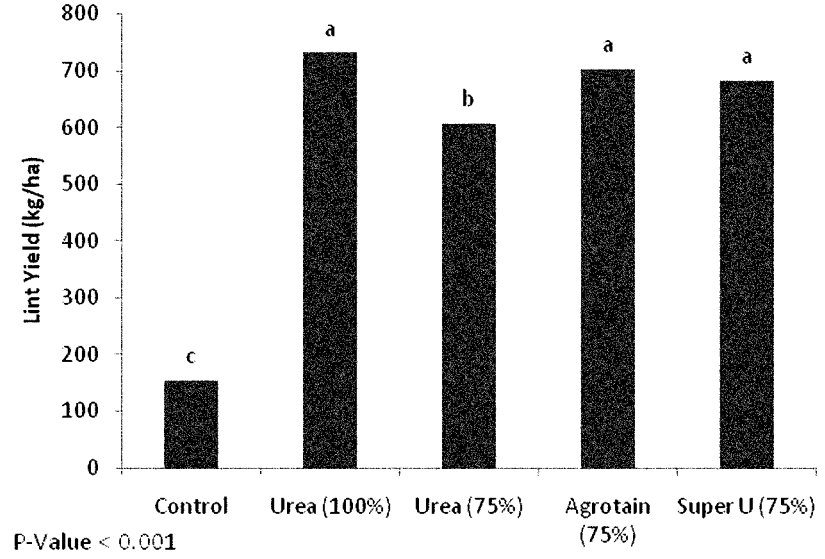

Fig. 2. Effect of urea with and without NBPT and DCD on cotton lint yield. Columns with the same letter are no significantly different (P = 0.05).

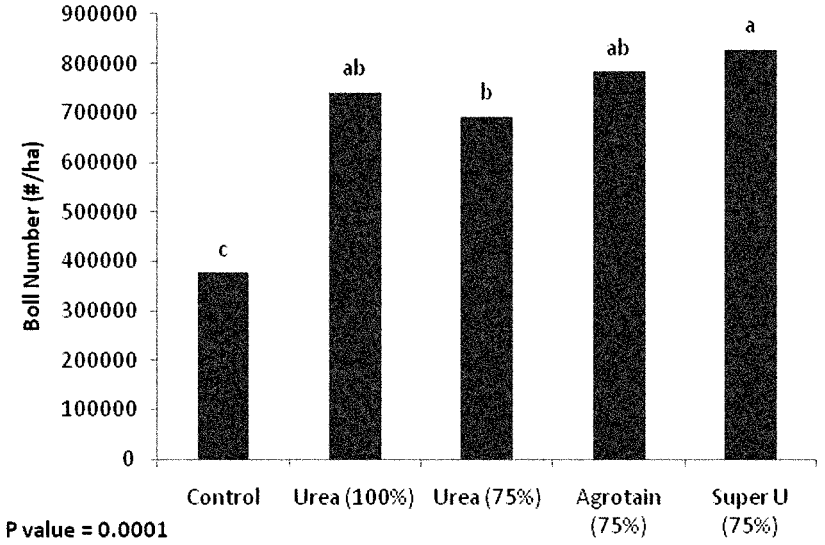

Fig. 3. Effect of urea with and without NBPT and DCD on number of cotton bolls. Columns with the same letter are no significantly different (P = 0.05).

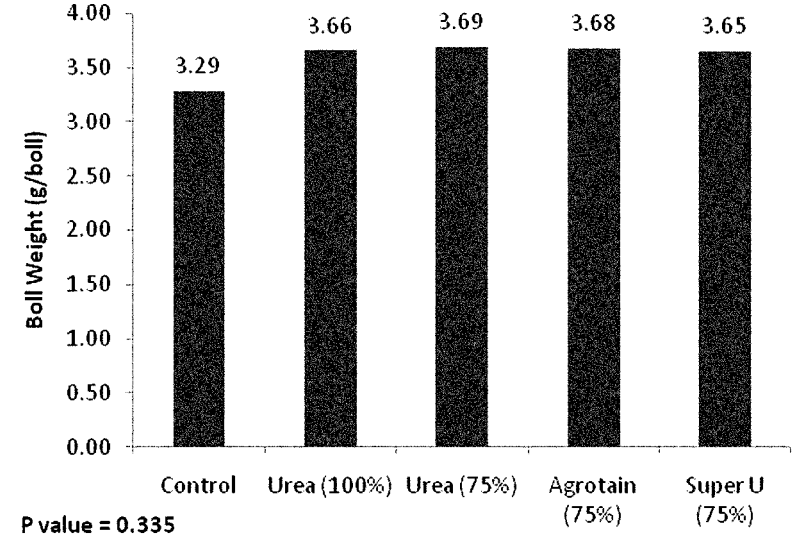

Fig. 4. Effect of urea with and without NBPT and DCD on cotton boll wetight. Columns with the same letter are no significantly different (P = 0.05).

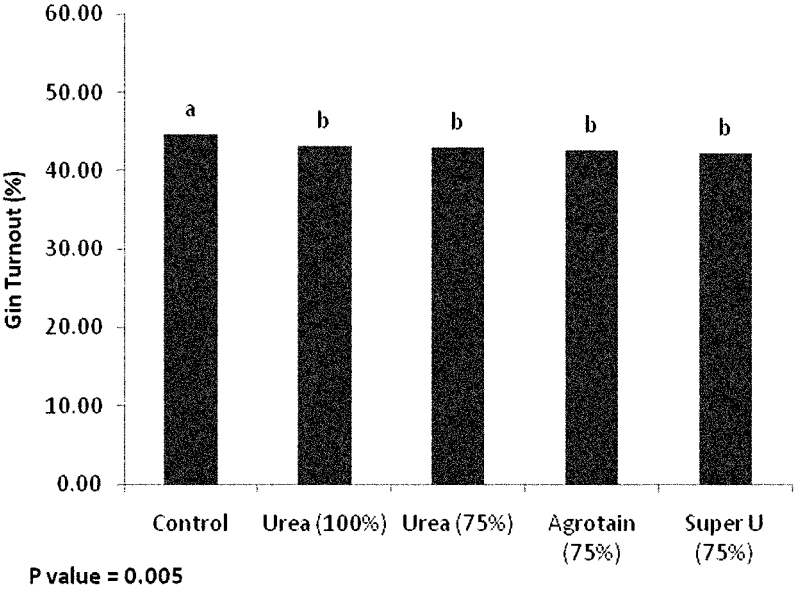

Fig 5. Effect of urea with and without NBPT and DCD on cotton gin turnout. Columns with the same letter are not significantly different (P = 0.05)

The Potential Use of Gypsum for Improved Cotton Productivity

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

RESEARCH PROBLEM

Irrigation initiation, frequency and termination have a significant impact on fruit retention and final cotton lint yield and lint quality. Poor soil and irrigation management may increase surface runoff and erosion, which are responsible for extensive losses of topsoil and agricultural productivity and increase environmental liability. Surface crusting is one of the most important factors that influence such processes. Subsoil acidity and associated aluminum solubility, which is common for many Alfisols in the Mississippi delta, restricts root growth and can significantly impact water and nutrient use efficiency. A three-year study was established in 2007 with the objective of assessing the potential benefits of gypsum applications on water infiltration, and subsoil acidity.

BACKGORUND INFORMATION

Gypsum ($CaSO_4$) is a well known anti-crusting agent. There is evidence that applications of this material improve infiltration rates on soils prone to surface crusting. Keren et al., (1983) reported a significant reduction in seal formation when gypsum was applied to a silt loam soil. Deep lime incorporation to correct subsoil acidity is impractical and uneconomical. Methods to ameliorate subsoil acidity—by reducing the solubility of aluminum—using surface applications of gypsum have been developed (Summer, et al., 1986, Black, et al., 1984). In all these studies, increased exchangeable Ca and reduced exchangeable Al in the subsoil were reported. Gypsum can be mined or produced through the flue gas desulfurization (FGD) process at electric power plants. The FGD gypsum is normally 98% pure, with mined gypsum being of considerably less purity

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RESEARCH DESCRIPTION

An 80 acres field mapped as a Henry Silt Loam and Calloway Silt Loam was selected to assess the effect of FGD gypsum applications on aluminum solubility, cotton root growth and water infiltration. Treatments consisted of FGD gypsum at rates of 0, 1, and 2 ton/acre, with treatments replicated 3 times. Gypsum was applied with a commercial spreader, and calibrated to deliver the desired treatment rates. It was originally intended to apply the material prior to planting, but due to weather and/or land preparation, the material was applied after planting. Plot dimensions were 24, 38-in wide beds, 500 ft long. Deep soil samples (0-6 in., on 6 in. increments) were collected prior to gypsum applications during 2009. Soil pH (2:1) and extractable aluminum (2 M KCl) concentration were measured.

Soil moisture, at 7 and 15 in. deep, was monitored through the season with ECH_2O probes (Decagon devices, Pullman, Wash.). They were attached to a data logger for continued measurement, with soil moisture readings obtained hourly during the season. Two soil moisture stations (one data logger with two soil moisture probes) were installed in each treatment replicate.

Root tip length was assessed after harvest by carefully removing the soil on 1 ft radius by 3 ft deep on 3 plants per plot. Root observations were made from the 0 (control) and the 2 T/acre treatments only.

RESULTS

Soil Moisture Patterns

During the first two years of the study (2007 and 2008), no significant infiltration or soil moisture trends were observed. However, during the 2009 season some trends were obvious. Figure 1 shows average soil moisture content, 7 inches deep, for the 0 and 2 T/acre treatments during the first irrigation event. Thirty six hours after irrigation initiation the soil had reached field capacity in plots that received gypsum at 2 T/acre, while the soil moisture in the control plots had barely changed. The decreasing trend in soil moisture content was corrected in the control plots, but there was no significant increase in water storage.

Figure 2 shows average soil moisture patterns during the second irrigation event. Significant differences in water infiltration between the control and 2 T/acre treatments were observed. Soil moisture levels at 15 inches deep were considerably higher for the 2 T/acre, when compared to the other treatments. Plots that did not receive gypsum showed the least amount of stored water in the soil profile.

Aluminum Concentration

Soil samples were analyzed for soil pH, and for levels of exchangeable aluminum with 2 M KCl. The significant stratification trend is obvious and it is typical of an Alfisol with a fragipan (Figure 3). The pH levels for the top soil are within the optimum range, but that is not the case for the subsoil. Soil pH levels

below 5.0 can limit root growth significantly as the concentration of aluminum increases exponentially with increased acidity. Applications of lime are not an effective option due to reduced lime solubility and movement in the variable charged soils typical of the Mississippi delta.

Figure 4 shows average 2M KCl-extractable aluminum concentration for samples from each of the treatments. Extractable aluminum was 1 ppm in all the treatments in the first 6 inches of soil. However, average aluminum levels were 240 ppm for samples collected from the control plots, 12-18 inches deep. The effect of gypsum on aluminum concentrations is evident as the average aluminum concentration at the 6-12 inches for the 1 and 2 T/acre treatments was only 20% of that of the control plots. This effect was also evident at the 12-18 depth, where aluminum levels for the treated plots were 50-60% of the levels measured for the control plots. A standard threshold level for aluminum concentration in soil is 25 ppm (Hailing Zhan, personal communication).

Aluminum levels above 25 ppm appear to be toxic for roots. Limited root depth was evident in this field, with very little root mass observed beyond the first 10 inches of soil.

Average root tip length for samples collected from the check plots was 11 (± 4) inches, compared to 19 (± 3) inches for the 2 T/acre treatments.

PRACTICAL APPLICATIONS

Prior to the third year of the study, there was an indication that water infiltration was improved when gypsum was applied at a rate of 2 T/acre, compared to the control and 1 T/acre treatments. However, significant changes were observed prior to the third year of the study. Soil water storage appeared to be positively impacted by gypsum applications.

Soil pH showed significant stratification, with top soil samples (0-6 inches) averaging a 6.6 water pH, but samples down to 18 inches tested an average of 4.3 for water pH. This acidity level is directly correlated to excessive aluminum solubility, resulting in toxic levels for optimum root growth. Plants from the control and 2 T/acre treatments were studied for root tip length as related to treatment effect. Average root tips lengths from the control plots was 11 inches, compared to 19 inches for the 2 T/acre. Gypsum appears to be a feasible alternative to correct subsoil aluminum toxicity, as lime will not move down to such depths due to reduced $CaCO_3$ solubility.

The number of acres affected by acidic subsoil is not known at this time, but it is believed to be a common feature in several of the most common soil series where cotton is produced, including the Loring, Memphis, Calloway, Henry and Dubbs series.

ACKNOWLEDGMENTS

This study was funded by the State Cotton Support Committee, The National Network for Use of FGD Gypsum in Agriculture, and the Ag Spectrum Company.

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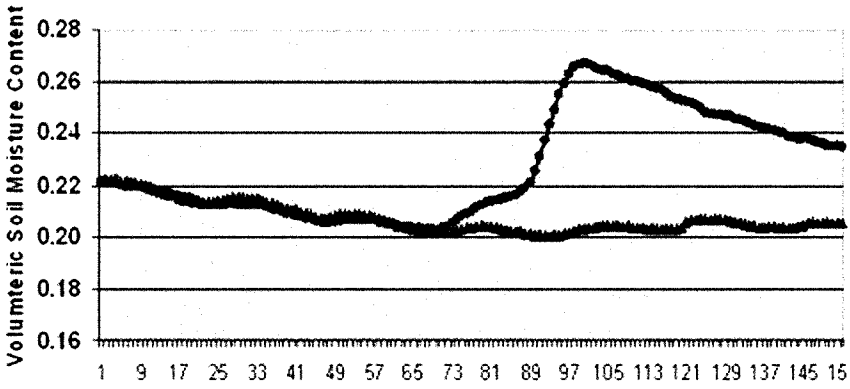

Fig. 1. Average volumetric soil moisture levels for the control and the 2 T/acre gypsum treatment after the first irrigation event at 7 inches during the 2009 season.

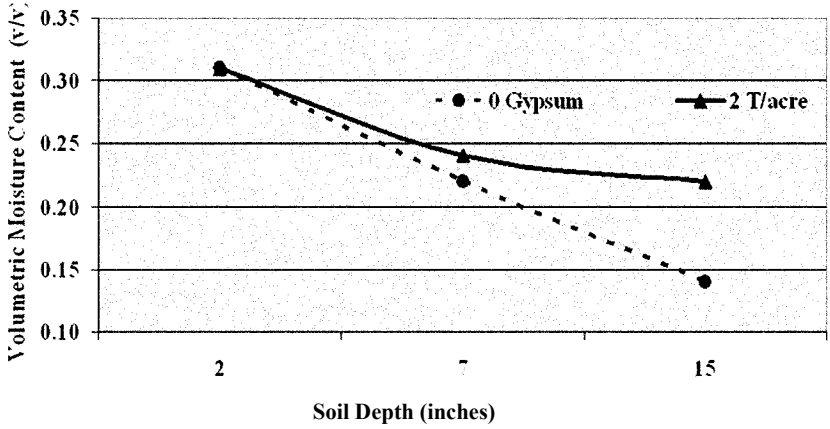

Fig. 2. Volumetric soil moisture content, for the different treatments, 4 days after a rainfall event.

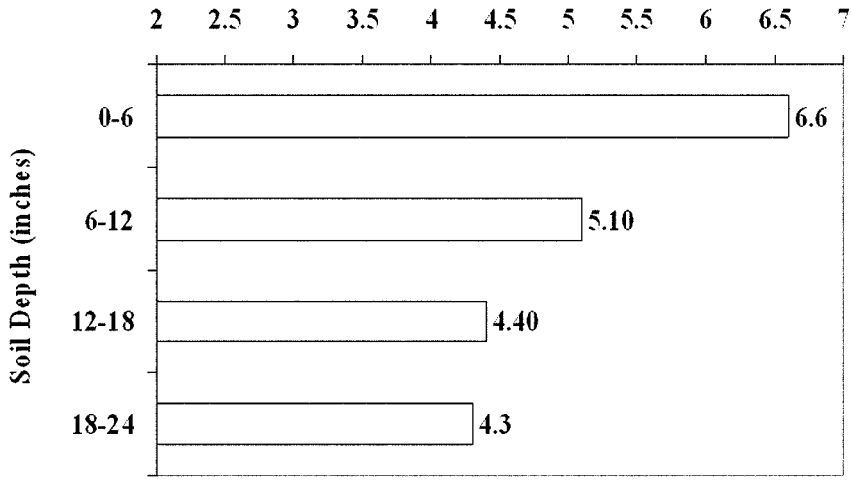

Fig. 3. Average water soil-pH for the control plots according to soil depth. Samples were collected in the spring of 2009.

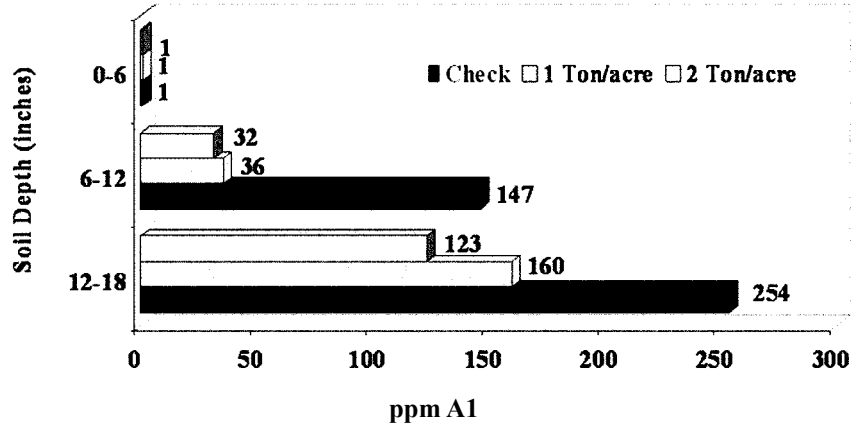

Fig. 4. Average extractable aluminum (2 M KCl), at three soil depths, according to gypsum treatment.

Effect of Potassium Fertilization on Seedcotton Yield in a Silt Loam

M. Mozaffari[1], N. A. Slaton[2], and C. Kennedy[3]

RESEARCH PROBLEM

Advances in plant breeding and pest management have resulted in commercial cotton (*Gossypium hirsutumn* L.) cultivars that mature faster and produce higher yields than the obsolete cultivars. Potassium (K) is one of the most important nutrients for growth and development of the cotton plant. Potassium is required for regulating the stomatal opening and closing, maintaining leaf turgor pressure and leaf photosynthesis (Bednarz and Oosterhuis, 1999). Therefore, K deficiency will seriously limit cotton yield potential and fiber quality.

BACKGROUND INFORMATION

Information on modern cotton cultivars response to K fertilization will aid in developing agronomically sound K-fertilizer recommendations. The objective of this experiment was to evaluate the effect of K application rate on seedcotton yield and Mehlich-3 extractable soil K for a modern cotton cultivar grown using production practices common to Arkansas.

RESEARCH DESCRIPTION

In 2006, a long-term replicated cotton K-fertility experiment was initiated on a Loring silt loam at the University of Arkansas Lon Mann Cotton Research Station in Marianna, Ark. The experimental design was a randomized complete block where the same K-rates (0, 30, 60, 90, 120 and 150 lb K_2O/acre applied as muriate of potash) have been applied to the same plots. The experiment was repeated in 2007 with the same K-rates applied to the same plots as 2006. In 2008, cotton was planted and harvested again, but no K fertilizer was applied. In 2009, the K rate experiment was resumed as implemented in 2006 and 2007. Each

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[3] Resident director, Lon Mann Cotton Research Station, Marianna.

individual plot was 40-ft long and 12.5-ft wide allowing for four rows of cotton with 38-inch wide row spacings.

Prior to application of any K fertilizer, six soil cores were collected from the 0-to 6-inch depth of each plot and composited. The same procedure was followed in the fall after cotton harvest. Soil samples from each plot were oven dried at 65 °C, crushed, and extracted with Mehlich-3 solution and the elemental concentrations were measured by inductively coupled plasma atomic emission spectroscopy. Soil pH was measured in a 1:2 (weight:volume) soil-water mixture. Soil particle size analysis was determined by the hydrometer method (Arshad et al., 1996). The 0-to 6-inch depth of soil contained 14% sand and 23% clay and would be classified as a silt loam. Averaged across all plots, the soil pH was 7.0 and mean values of selected Mehlich-3 extractable nutrients were 45 ppm P, 981 ppm Ca, 266 ppm Mg, and 4.5 ppm Zn.

In late May, 120 lb N/acre as urea (46% N) was surface applied to the entire research area and incorporated with tillage when existing cotton beds were being prepared for planting. Cotton ('Stoneville 4554B2RF') was seeded into a conventionally tilled seedbed on 1 June and emerged on 11 June. All K-fertilizer treatments were surface applied on 30 June. Standard pest management practices as recommended by the University of Arkansas Cooperative Extension Service were followed. Cotton was irrigated as needed using the University of Arkansas Cooperative Extension Service Irrigation Scheduler program. Cotton was harvested with a spindle-type mechanical picker on 7 November. Analysis of variance was performed to evaluate the effect of K application rate on seedcotton yield and soil-test K using the PROC GLM procedure of SAS. Significant treatment means were separated by the Waller-Duncan minimum significant difference (MSD) test when appropriate ($P < 0.10$).

RESULTS

Previous annual K-fertilizer application rates had significantly influenced preplant soil-test K producing mean soil-test K values ranging from 60 to 77 ppm (Table 1). In Arkansas, Mehlich-3 extractable K concentrations ≤ 90 ppm are interpreted as 'Low'. The average soil-test K in soil fertilized with ≥ 120 lb K_2O/acre was significantly ($P = 0.10$) greater than soil receiving no K. Soil samples collected postharvest also showed that soil-test K was significantly influenced by annual K-fertilizer rate with mean values ranging from 56 to 91 ppm (Table 1). Soil-test K in all K-fertilized plots was numerically higher in the samples collected postharvest compared to samples collected preplant despite K removal by the cotton crop.

Potassium fertilization significantly increased seedcotton yield in 2009 (Table 1). Potassium application rates ≥ 30 lb K_2O/acre significantly increased seedcotton yields compared to the no K control. The greatest yields were produced by cotton receiving 90 to 150 lb K_2O/acre.

PRACTICAL APPLICATION

Application of ≥ 30 lb/K_2O/acre significantly increased seedcotton yield which was maximized by application of 90 to 150 lb K_2O/acre on a soil having a 'Low' or 'Very Low' soil-test levels. Routine soil testing properly identified the need for K fertilization. Based on preplant soil samples and current recommendations, 95 to 140 lb K_2O/acre would have been recommended depending on annual K rate. For this particular soil, the current University of Arkansas K fertilizer recommendations accurately identified the need for K and recommended K rates that maximized seedcotton yield in this trial. Both short- and long-term fertilization research is needed to develop a robust database to support and verify soil-test based K-fertilizer recommendations for modern cotton production in Arkansas. The results of this study indicate that soil-test based K-fertilization is a critical component of nutrient management for cotton production in Arkansas.

ACKNOWLEDGMENTS

The authors thank the staff of the University of Arkansas Lon Mann Cotton Research Station and University of Arkansas Soil Testing and Research Laboratory for their assistance with field work and laboratory analysis. Research was funded by the University of Arkansas Division of Agriculture.

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Bednarz, C.W. and D.M. Oosterhuis. 1999. Physiological changes associated with potassium deficiency in cotton. J. Plant Nutr. 22:303-313.

Table 1. Mean Mehlich-3 soil-test K concentrations in spring (preplant) and fall (postharvest) 2009 and seedcotton yield as affected by annual K-fertilizer rate during the 4th year of a continuous-cotton, K-fertilization trial conducted on a Loring silt loam at the Lon Mann Cotton Research Station in Marianna, Ark.

	Mehlich-3 soil-test K		
K-fertilizer rate	**Preplant**	**Post-harvest**	**Seedcotton yield**
lb K_2O/acre	- - - - - - - ppm - - - - - - -		lb/acre
0	60	56	786
30	63	64	1269
60	66	70	1363
90	65	74	1426
120	69	87	1515
150	77	91	1553
MSD[1] 0.10	8	11	176
P value	0.0101	<0.0001	<0.0001

[1] MSD, Minimum significant difference as determined by Waller-Duncan Test.

Biosolids, Poultry Manure, and Urea Increase Seedcotton Yield in a Silt Loam

M. Mozaffari[1], N.A. Slaton[2], L.A. Fowler[3], and F.M. Bourland[4]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) growers in Arkansas have become interested in organic sources of N due to volatile synthetic fertilizer prices and the beneficial effects of increased soil organic matter. However, little is known about cotton responses to high organic fertilizer.

BACKGROUND INFORMATION

Fresh poultry litter (FPL), pelleted poultry litter (PPL), and a heat-dried pelleted biosolid marketed under the trade name of Top Choice Organic (TCO)[5], are three low-analysis, high organic matter fertilizers currently available in eastern Arkansas. Unfortunately, there is very little information on cotton response to these materials. The objectives of this field study were to evaluate effect of FPL, PPL, TCO, and urea-N fertilizer on seedcotton yield and leaf-blade N on a representative cotton soil in eastern Arkansas.

RESEARCH DESCRIPTION

A replicated field experiment was conducted in 2009 in a commercial field on a Dundee soil on Judd Hill Plantation in Poinsett County, Arkansas. A composite (10-12 cores) soil sample was collected from the 0-to 6-inch depth of each replication before application of any soil amendments. Soil samples were oven-dried, crushed, and particle size analysis was performed by the hydrometer method (Arshad et al., 1996). Soil nitrate was extracted with 0.025 M aluminum sulfate and measured with a specific ion electrode (Donahue, 1992). Soil pH was

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[2] Professor, Crop, Soil, and Environmental Sciences Department, Fayetteville.
[3]Farm foreman, Northeast Research and Extension Center, Keiser.
[4]Director/professor, Northeast Research and Extension Center, Keiser.
[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.

measured in a 1:2 (weight:volume) soil-water mixture. Other soil nutrients were extracted with Mehlich-3 solution and the concentration of selected elements in the extracts was measured by inductively coupled plasma atomic emission spectroscopy.

The experimental design was a randomized complete block with a factorial arrangement of four N-fertilizer sources (FPL, PPL, TCO, and urea) where each source was applied at five N rates (30, 60, 90, 120, and 150 lb total N/acre) and compared to a no N control. Each treatment was replicated four times. Each organic N source was applied based on the total N analysis at rates listed in Table 1. Sub-samples of each organic-N source were analyzed for total nutrient content as described by Peters et al., 2003 (Table 2). Nitrogen treatments were broadcasted by hand to the soil surface on 13 May and incorporated with a Do-All on the same day. Potassium (48 lb K_2O/acre) and P (36 lb P_2O_5/acre) fertilizers were broadcasted to the research area and incorporated before planting by the cooperating grower. Each plot was 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch wide row spacings.

Cotton ('Stoneville 5458B2RF') was planted on 20 May on conventionally prepared beds. The center two rows of cotton in each plot were harvested with a spindle-type picker on 12 November. Analysis of variance was performed using the GLM procedure of SAS. Significant ($P \leq 0.10$) means were separated by the minimum significant difference (MSD) method.

RESULTS

Analysis of soil samples taken before application of treatments, indicated that the soil texture was a loam (53% sand, 30% silt, and 17% clay), soil pH was 7.0, and soil NO_3-N in the top 6 inches of soil was 7 ppm. These properties are typical for some of the cotton producing soils in eastern Arkansas. The chemical properties differed among the three organic amendments. Total N content of organic N sources, on as-is basis, ranged from 2.96% for FPL to 4.98% for TCO and organic N was the predominant form of N (Table 2). The TCO had the lowest moisture and K contents, but had highest total P, Ca, and C content.

The N source × N rate interaction did not influence seedcotton yield (Table 3). Averaged across N sources, N fertilization significantly increased seedcotton yield, which ranged from 2020 to 2570 lb/acre. Application of 120 lb N/acre produced the highest yield, which was 26% greater than the yield of cotton receiving no N. Although the interaction was not significant, the data suggest that 120 lb urea-N/acre produced the numerically highest seedcotton yield of 2775 lb/acre. Averaged across all N sources, there was no significant difference between the cotton fertilized with 150 and 90 lb of total N/acre thus highlighting the importance of applying the optimum rate of N fertilizer. The yield of cotton fertilized with 120 lb total-N/acre from FPL, PPL, and TCO ranged from 2445 to 2588 lb/acre.

Nitrogen source also significantly affected seedcotton yield (Table 3). Averaged across N rates, yield of cotton fertilized with all N sources ranged from 2215 to

2397 lb/acre and was significantly higher than the yield of cotton receiving no N. Seedcotton yield of urea fertilized plants was significantly higher than cotton treated with FPL and numerically higher than cotton fertilized with PPL or TCO. There was no significant difference in seedcotton yield of plants fertilized with TCO and PPL. Yield potential at this site was limited by unfavorable weather conditions as suggested by significant boll shedding during the cloudy days of August and excess soil moisture from above normal rainfall.

PRACTICAL APPLICATION

The results of this one-year study suggest that FPL, PPL, and TCO are potential N sources for cotton production in Arkansas. Although each organic N source tended to produce maximal or near maximal seedcotton yields that were comparable to preplant applied urea, the yield increase from N fertilization was relatively low (26%) in this trial. The yield data suggest that growers should not use these organic N sources as the sole source of N. The FPL, PPL, and TCO should be used to provide some proportion of the cotton crop's total N requirement with the total application rates being determined by the amount of P recommended (by soil test) to ensure the production of maximum cotton yields or to maintain an optimal soil-test P level to avoid building soil-test P to a high level. Thus, additional research is needed to determine the plant-available N content of each organic N source relative to commercial N fertilizer (e.g., urea) for cotton production in eastern Arkansas.

ACKNOWLEDGMENTS

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Table 1. Total N and product application rates for urea, fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic (TCO) biosolids used in a cotton N fertilization experiment at the Judd Hill Plantation in Poinsett County, Ark. in 2009.

	Amendment rate			
N rate	**Urea**	**FPL**	**PPL**	**TCO**
lb N/acre	----------lb of material applied/acre----------			
30	65	1014	822	602
60	130	2028	1644	1204
90	196	3042	2466	1806
120	261	4056	3288	2410
150	326	5068	4110	3012

Table 2. Selected chemical property means (n = 2-3) for the fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic (TCO) biosolids used in a N-fertilization trial conducted on a Dundee soil at Judd Hill Plantation in 2009.

				Total nutrient content (as is)					Inorganic N content	
N source	**n**	***pH**	**Moisture**	**C**	**N**	**P[1]**	**K[2]**	**Ca**	**NO_3-N**	**NH_4-N**
			---------- %----------						----------ppm----------	
FPL	2	7.7	41	19.3	2.96	1.43	2.35	2.31	18	5143
PPL	3	7.4	12	28.1	3.65	1.16	2.74	2.30	1626	2751
TCO	3	7.1	7.4	32.4	4.98	2.24	0.33	2.63	22	2256

[1] lb P_2O_5/ton = %Total P on “as is” basis multiplied by 20 x 2.29

[2] lb K_2O/ton = %Total K on “as-is” basis multiplied by 20 x 1.2

Table 3. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), Top Choice Organic (TCO) biosolids, and urea each applied at five total-N rates on seedcotton yield in a Dundee loam at Judd Hill Plantation in Poinsett County, Ark. in 2009.

N rate means	N source				N source means	N source	Seedcotton yield
	FPL	PPL	TCO	Urea			
lbs N/acre	-------- Seedcotton yield (lb/acre) ---------						(lb/acre)
0			2020			None	2020
30	2009	2013	2109	2015	2036	FPL	2215
60	2061	2324	2183	2321	2222	PPL	2380
90	2315	2428	2438	2349	2379	TCO	2314
120	2445	2588	2522	2775	2570	Urea	2397
150	2247	2545	2350	2619	2440		
MSD (0.10)[1]	interaction was NS[2]				129		142
P value	interaction =0.5965				<0.0001		0.0098

[1] Minimum Significant Difference (MSD) as determined by Waller-Duncan Test at P = 0.10.
[2] NS = not significant at P = 0.10.

Cotton Response to Poultry Manure and Biosolids in Leveled Soils

M. Mozaffari and C. Kennedy[1]

RESEARCH PROBLEM

Row-crop farmers in eastern Arkansas and other regions level land to create a gentle and uniform slope across a field to increase irrigation water-use efficiency. After land leveling, soil productivity may be reduced by the extensive soil manipulation, which often requires that organic amendments be applied to aid in restoring soil productivity (Brye et al., 2004).

BACKGROUND INFORMATION

Growers in eastern Arkansas have traditionally used fresh poultry litter (FPL) to restore soil productivity after land leveling, but FPL is not always readily available or the existing equipment may not be suitable for its application. Municipal biosolids have high organic matter content, contain N and other plant nutrients, and have been successfully used for mine land reclamation (Sopper, 1992). A type of pelleted biosolids has recently become available in eastern Arkansas and is being marketed under the trade name of Top Choice Organic® (TCO)[2]. Information on the potential effectiveness of TCO for restoring the productivity of precision leveled fields will be beneficial for Arkansas growers who may be interested in alternatives to FPL. Therefore, the objective of this research was to evaluate cotton (*Gossypium hirsutum* L.) response to FPL, pelleted poultry litter (PPL), and TCO in combination with synthetic fertilizers on a leveled soils in eastern Arkansas.

RESEARCH DESCRIPTION

A field experiment was conducted on a Loring silt loam at the Lon Mann Cotton Research Station in Marianna, Arkansas during 2008. This field had been precision leveled by removing the top 3 to 8 inches of soil from areas of

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[2] We do not endorse or recommend any commercial products.

higher elevation and depositing it in areas of lower elevation. A composite soil sample was collected from the 0-to 6-inch depth of each replication (n = 4) before applying any soil amendments. Soil samples were dried, crushed, and soil NO_3-N was extracted with 0.025 *M* aluminum sulfate and measured with a specific ion electrode (Donahue, 1992). Other soil nutrients were measured by extraction with Mehlich-3 solution. Soil particle size analysis was performed by the hydrometer method (Arshad et al., 1996). Sub-samples of FPL, PPL, and TCO were analyzed as prescribed by Peters et al. (2003). The experimental design was a factorial arrangement of FPL, PPL, and TCO each applied at two rates (1,000 and 2,000 lb/acre) plus 50 lb N/acre as urea (urea-N); a treatment consisting of 50 lb N/acre as urea; and a control that received no fertilizer or organic amendment. All cotton plots except the control were fertilized with muriate of potash and triple superphosphate to supply 90 lb K_2O and 90 lb P_2O_5/acre, respectively. All soil amendments were hand-applied and incorporated on 23 May. Each plot was 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch wide row spacings. Stoneville 4554B2RF cotton was planted on 27 May. The two center rows of cotton were harvested with a spindle-type picker on 6 October. Analysis of variance was performed using the GLM procedure of SAS to evaluate the effect of FPL, PPL, TCO and urea-N on seedcotton yield. When appropriate ($P \leq 0.1$), means were separated by the minimum significant difference (MSD) method.

RESULTS

Properties of Soils and Organic Amendments

In the 0- to 6-inch depth, soil texture was silt loam, organic matter was relatively low, soil P availability was medium and soil K availability was low (Table 1). The chemical properties differed among the three organic amendments and may have influenced the outcome of the research since the amendments were applied at uniform rates of material resulting in different nutrient addition rates. The FPL and PPL contained similar amounts of K, but the PPL had a lower moisture content and a higher N content than FPL resulting in slightly more N being applied in each rate increment. Likewise, the TCO had a lower moisture and higher N content than PPL and had the greatest N addition in each application rate increment. The amounts of N added in each rate are listed in Table 3.

Seedcotton Yield

Organic amendment and urea application significantly ($P < 0.0001$) increased seedcotton yield as compared to cotton receiving no N or soil amendment (Table 3). The average seedcotton yield in the control was 829 lb/acre compared to 2668 to 3829 lb/acre for cotton receiving urea-N only or urea-N plus an organic amendment. Among the amended treatments, urea plus 2000 lb TCO/acre produced the highest yield. Seedcotton yield of cotton fertilized with 2000 lb TCO/acre plus urea-N was significantly higher than cotton fertilized with the same rates of FPL or PPL plus urea-N. This is a reflection of higher total N content of TCO biosolids

(Table 3). Application of 2000 lb/acre of FPL plus 50 lb of urea-N/acre supplied 110 lb of total N/acre, and application of 1000 lb/acre of TCO plus 50 lb urea-N/acre supplied 112 lb of total N/acre. Seedcotton yield of cotton fertilized with a total of 110 lb of total N/acre from FPL and urea was not significantly different from the yield of plants fertilized with 112 lb of total N/acre from TCO and urea. The yield difference among treatments amended with 2000 lb FPL, PPL, TCO can be attributed to the higher N content of the TCO. Application of 2000 lb TCO/acre plus urea supplied 174 lb total N/acre, whereas 2000 lb FPL or PPL/acre plus urea supplied 110 and 122 lb total N/acre, respectively.

PRACTICAL APPLICATION

Fresh or pelleted poultry litter and TCO in combination with urea increased seedcotton yields in a precision-leveled soil. Cotton response to application of 2000 lb/acre of TCO plus 50 lb urea-N/acre was more pronounced than the same amount of either FPL or PPL plus urea. Seed cotton yield of plants fertilized with a comparable amount of total N from FPL plus urea or TCO plus urea was not significantly different. Nitrogen contribution and maybe some other constituents of these organic amendments improved cotton yields. Additional work is needed to ascertain the consistency of these results across a diverse group of soils and cropping systems.

ACKNOWLEDGMENTS

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Table 1. Selected soil chemical property means (0-to 6-inch depth) of samples taken before applying soil amendments on two recently leveled soils at University of Arkansas Lon Mann Cotton Research Station in Marianna in 2008.

Soil	Soil	Mehlich-3-extractable nutrients							Soil physical properties			
pH[1]a	NO_3- N [2]	P	K	Ca	Mg	Cu	Zn	SOM [3]	Sand	Silt	Clay	Texture
	---------- (ppm) ----------							---------- (%) ----------				
5.9	10	54	79	1493	315	1.3	1.9	1.10	5	71	24	silt loam

[1] Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[2] NO_3-N measured by ion-specific electrode.
[3] SOM, soil organic matter determined by Weight Loss on Ignition.

Table 2. Selected chemical properties of fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic (TCO) pelleted biosolids on 'as is' basis.

N source	n[1]	pH	H_2O	Total C	Total N	Total P^2	Total K^3	Total Ca	NO_3-N	NH_4-N
			---------- % ----------						------- ppm -------	
FPL	5	8.1	34	22.3	2.95	1.85	3.09	2.55	92	5346
PPL	6	7.4	14	28.1	3.57	1.33	3.04	2.18	1530	2632
TCO	8	5.9	7	36.7	6.28	2.23	0.38	2.24	259	2075

[1] number of samples analyzed.
[2] lbs/ton P_2O_5 = %Total P on "as is" basis multiplied by 20 x 2.29.
[3] lbs/ton K_2O = %Total K on "as-is" basis multiplied by 20 x 1.2.

Table 3. Effect of fresh poultry litter (FPL), pelleted poultry litter (PPL), and Top Choice Organic pelleted biosolids (TCO) on seedcotton yield in a recently leveled Loring silt loam at University of Arkansas Lon Mann Cotton Research Station in Marianna in 2008.

Organic amendment		Nitrogen applied			Seedcotton yield
Type	Rate	Organic N[1]	Urea-N	Total N[2]	
	---------- N lb/acre ----------				--- lb/acre ---
None (control)	0	0	0	0	829
None	0	0	50	50	2668
PPL	1000	36	50	86	2782
PPL	2000	72	50	122	3205
FPL	1000	30	50	80	2532
FPL	2000	60	50	110	2895
TCO	1000	62	50	112	2992
TCO	2000	124	50	174	3829
P value					<0.0001
MSD at 0.10[3]					377

[1] calculated from total N content of the organic amendment on 'as is' basis in Table 2.
[2] calculated as the sum of organic N and urea-N.
[3] Minimum Significant Difference (MSD) as determined by Waller-Duncan Test at P = 0.10.

Effect of Herbicide Program on Seed Rain in Liberty Link® and Roundup Ready Flex® Cotton

G.M. Griffith and J.K. Norsworthy[1]

RESEARCH PROBLEM

Managing herbicide resistance has become a focal point of many weed scientists around the world. Large-scale adoption of glyphosate-resistant crops since the mid-1990s increased the reliance on glyphosate as the major herbicide for broad-spectrum weed control in crops such as cotton, soybean, and corn. Over-reliance on a single mode of action (MOA) has led to multiple glyphosate-resistant weed species in Arkansas such as horseweed [*Conyza canadensis* (L.) Cronquist], Palmer amaranth [*Amaranthus palmeri* (S.) Wats], and johnsongrass (*Sorghum halepense*), among others. The objective of this study was to evaluate weed species presence in different cotton production systems under various resistance management weed control programs.

BACKGROUND INFORMATION

Historically, cotton has been produced in monoculture under intensive tillage, which is one reason that cotton was considered one of the most erosive row crops in the Southern United States (Bloodworth and Johnson, 1995). A shift to conservation tillage systems in the mid-South in the mid-1990s was facilitated by the introduction of glyphosate-resistant crops and the ability to use a total postemergence (POST) herbicide program consisting of glyphosate applied alone (Givens et al., 2009). Reduced tillage practices and use of a single MOA can lead to weed species shifts. Species shifts can be due to lack of control in the absence of tillage or it may be natural tolerance to a herbicide. With the evolution of glyphosate-resistant weed species worldwide, effective weed control programs now need to alleviate the intense selection pressures associated with using a single MOA and also provide acceptable control of glyphosate-resistant species. Technologies such as the Liberty Link® (LL) cotton system are being used along with different herbicide rotations to help manage glyphosate-resistant species and further sustainable agriculture. Incorporating a residual herbicide in a cotton weed

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control program applied either preemergence (PRE), POST, or post-directed (PD), may broaden the weed spectrum and provide extended weed control (Werth et al., 2008). Recently, these management strategies have increased as a result of resistance evolution, and it is hypothesized that species shifts may be occurring as a result; however, research incorporating these practices is limited and needs to be addressed. The objective of this research was to evaluate weed species presence in LL and Roundup Ready Flex® (RRF) cotton rotations under different herbicide management programs over a 3-year period.

RESEARCH DESCRIPTION

Research was conducted in a 15-acre cotton field at the Northeast Research and Extension Center at Keiser, Ark., in 2007, 2008, and 2009 to evaluate the effect of herbicide programs in LL and RRF 3-year cotton rotations. The experimental design was a split-plot with cotton rotation as the main plot and herbicide program as the sub-plot. There were four 3-year cotton rotations: (1) LL-LL-LL, (2) LL-RR-LL, (3) RR-RR-RR, and (4) RR-LL-RR. Each year, ST 4554 B2/RRF (all years) and Fibermax 955 B2/LL (2007 and 2008) or Fibermax 1735 B2/LL (2009) was planted. The three herbicide programs were: (1) a total POST with no residual herbicides (P-P-P) consisting of either glufosinate at 0.53 lb ai/acre or glyphosate at 0.78 lb ae/acre (1× rate of each) applied to 1- to 3-lf cotton, followed by (fb) 5- to 6-lf cotton, followed by ≥ 10-lf cotton at LAYBY; (2) a residual PRE (R-P-P) of *S*-metolachlor at 1.25 lb ai/acre + fluometuron at 2.0 lb ai/acre, followed by either glufosinate or glyphosate at the 1× rate at 5- to 6-lf cotton, followed by ≥ 10-lf cotton at LAYBY; and (3) a residual PRE + LAYBY (R-P-R) consisting of *S*-metolachlor + fluometuron PRE, followed by either glufosinate or glyphosate POST at the 1× rate at 5- to 6-lf cotton, followed by a residual of flumioxazin at 0.063 lb ai/acre + MSMA at 2.0 lb ai/acre at ≥ 10-lf cotton at LAYBY. To estimate the soil seedbank before initiating the experiment, eight subsamples, consisting of five soil cores taken from between rows 3 and 4, and rows 5 and 6, at distances of 100, 200, 300, and 400 feet (40 cores/plot) were taken in April 2007. Seed traps were placed in the same location of original soil cores in early August each year through harvest to catch any seed rain resulting from experimental treatments.

RESULTS AND DISCUSSION

Seed from a total of 16 weed species were detected. Palmer amaranth (Table 1), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv] (Tables 2 and 3), large crabgrass [*Digitaria sanguinalis* (L.) Scop], and prickly sida (*Sida spinosa* L.) (Table 4) were the dominant weed species, accounting for over 92% of the total seed counted. In 2007, the main effect of cotton rotation was significant, showing higher Palmer amaranth seed production in the LL rotations (58 and 134 seed/ft^2) when compared to the RRF rotations (5 seed/ft^2) (Table 1). In

2008 and 2009, there was an interaction between cotton rotation and herbicide program for Palmer amaranth seed production, with the lowest Palmer amaranth seed production in RRF rotations where a residual herbicide was applied PRE (Table 1). Barnyardgrass and prickly sida seed production was highest each year in the LL systems (Tables 2, 3, and 4). In 2009, the highest barnyardgrass seed production was in a total-POST herbicide program, regardless of cotton rotation (124 seed/ft^2) (Table 3).

PRACTICAL APPLICATION

After only 3 years of continuous RRF cotton, the total-POST glyphosate program had higher Palmer amaranth seed production (55 seed/ft^2) than a total POST glufosinate program (27 seed/ft^2) (Table 1). Regardless of cotton system, a PRE herbicide followed by two POST herbicide applications is needed for long-term Palmer amaranth control and seed suppression. For long-term barnyardgrass control and seed reduction in a LL system, a PRE herbicide is needed followed by either two POST glufosinate applications or followed by a POST glufosinate application at midseason followed by a residual herbicide at LAYBY.

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Table 1. Palmer amaranth seed counts for the main effect of cotton rotation in 2007, and the interaction of rotation and herbicide program in 2008 and 2009 at the Northeast Research and Extension Center, Keiser, Ark.

Year	Rotation	P-P-P	R-P-P	R-P-R	Main Effect
		----------seeds/ft^2----------			
2007					
	LL-LL-LL				58 ab[z]
	LL-RR-LL				134 a
	RR-RR-RR				5 b
	RR-LL-RR				5 b
2008					
	LL-LL-LL	77 bc[z]	83 bc	105 ab	
	LL-RR-LL	4 d	14 d	145 a	
	RR-RR-RR	11 d	1 d	27 cd	
	RR-LL-RR	150 a	49 c	55 c	
2009					
	LL-LL-LL	27 c[z]	39 bc	57 b	
	LL-RR-LL	26 c	33 c	144 a	
	RR-RR-RR	55 b	0 d	20 c	
	RR-LL-RR	31 c	2 d	28 c	

[z] Letters of significance to compare within a year (P = 0.05).

Table 2. Barnyardgrass seed counts for the main effect of cotton rotation in 2007 and the interaction of rotation and herbicide program in 2008 at the Northeast Research and Extension Center, Keiser, Ark.

Year	Rotation	P-P-P	R-P-P	R-P-R	Main Effect
		----------seeds/ft^2----------			
2007					
	LL-LL-LL				8 a[z]
	LL-RR-LL				9 a
	RR-RR-RR				2 b
	RR-LL-RR				1 b
2008					
	LL-LL-LL	94 a[z]	14 bc	30 bc	
	LL-RR-LL	2 c	1 c	22 bc	
	RR-RR-RR	0 c	0 c	3 c	
	RR-LL-RR	74 a	6 c	c	

[z] Letters of significance to compare within a year (P = 0.05).

Table 3. Barnyardgrass seed counts for the main effect of herbicide program in 2009 at the Northeast Research and Extension Center, Keiser, Ark.

Herbicide Program	Barnyardgrass
	(seeds/ft$^{2)}$
P-P-P	124 a[z]
R-P-P	25 b
R-P-R	12 b

[z] Letters of significance to compare across herbicide programs (P = 0.05).

Table 4. Prickly sida seed counts averaged over herbicide programs for 2007, 2008, and 2009 at the Northeast Research and Extension Center, Keiser, Ark.

Rotation	2007	2008	2009
	----------seeds/ft^2----------		
LL-LL-LL	7 a[z]	18 a	49 a
LL-RR-LL	6 a	3 b	45 a
RR-RR-RR	0 b	2 b	1 b
RR-LL-RR	2 ab	6 ab	0 b

[z] Letters of significance for comparing across rotations within a year (P = 0.05).

Spatial Movement of Glyphosate-Resistant Palmer Amaranth in Roundup Ready Flex® Cotton

G.M. Griffith[1], J.K. Norsworthy[1], and T. Griffin[2]

RESEARCH PROBLEM

The first report of a glyphosate-resistant (GR) weed in North America was horseweed in 2000 (VanGessel, 2001). Since 2000, there have been eight other species confirmed GR in the United States. During this time, many weed scientists have shifted their research efforts to managing resistant weeds and preventing resistance evolution in other species. There are now five confirmed GR weed species in Arkansas. Of particular concern to producers is how fast GR populations disperse across the landscape.

BACKGROUND INFORMATION

Biological characteristics of Palmer amaranth such as season-long emergence (Jha and Norsworthy, 2009), growth rates up to 7.5 cm/day (Norsworthy et al., 2008), and the fact that a single female plant can produce up to 600,000 seed/plant (Keeley et al., 1987) make Palmer amaranth an extremely competitive plant. It was because of these characteristics that Palmer amaranth was named the most troublesome weed in Arkansas in 2005. Since confirmation of GR Palmer amaranth in 2006 (Norsworthy et al., 2008), GR Palmer amaranth has evolved across the state of Arkansas, rapidly spreading across large acreage farms in short periods of time. There are several seed dispersal mechanisms that contribute to in-field GR Palmer amaranth patch expansion, including bed preparation, planting, late-season herbicide applications, furrow-irrigation and rainfall, cotton harvest and stalk destruction, and movement via animals and humans. The objective of this research was to evaluate GR Palmer amaranth patch expansion in a Roundup Ready Flex® cotton production system, utilizing technologies such global positioning systems (GPS) and geographic information systems (GIS) for data collection and analysis. Because GR Palmer amaranth data were collected from a field-scale landscape, it was hypothesized that inherent spatial variation exists.

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RESEARCH DESCRIPTION

In February 2008, 20,000 GR Palmer amaranth seeds collected from Lincoln County, Ark., were sown into a single circular 1-m^2 area in four 0.6- to 1.2-ha fields (G2, G4, G5, and G6), representing seed production from a single GR Palmer amaranth that survived to maturity in 2007. Glyphosate was applied as needed (4 applications) to control all other species in the field. In 2008 and 2009, the final density of Palmer amaranth was taken using a 1.0-m^2 grid, collecting densities in a Cartesian coordinate system using a continuous scale of 0, 1, 2, 3, 4, 5, and 6 (>5) Palmer amaranth/m of row. Spatial seed cotton yield data were collected using a yield monitor and GPS. Palmer amaranth density data were subjected to exploratory spatial data analysis (ESDA) using GeoDa 0.9.5-i (Arizona State University software). Row-standardized spatial weights matrices were created based on either queen (8 directions) or rook (4 directions) contiguity. These spatial weight matrices were used in Moran's I test for global spatial autocorrelation, as well as LISA (local indicator of spatial association) to determine if significant local clustering occurred.

RESULTS AND DISCUSSION

In 2008, over 28 cm of rain fell in the month of March, and it is believed this rainfall resulted in longitudinal seed movement as far as 114 m downslope. This resulted in a GR female Palmer amaranth setting seed and creating a separate GR Palmer amaranth patch in 2009. Longitudinal movement was greater in 2009, likely a result of cotton harvest, stalk shredding, tillage, and increased seed production from 2008 survivors. In 2008, Palmer amaranth patches increased in size from the initial 1-m2 (2007) to a total infested area in each field of 26 to 36 m2. In 2009, GR Palmer amaranth had expanded to the borders of all four fields, infesting 955 to 1248 m2 in fields G6 (12%) and G5 (24%), respectively. Longitudinal spread was as far as 237 m in 2009, while lateral movement occurred up to 30 m from the source. Results from Moran's I for Palmer amaranth density indicate significant spatial autocorrelation in all four fields, regardless of spatial contiguity used (Table 1). A map from LISA analysis gives the reader a visual representation of significant clustering in field G6 in 2008 and 2009 (Fig. 1). Yield maps from field G6 indicate a similar pattern in yield reduction resulting from increased Palmer amaranth competition in 2008 and 2009 (Fig. 2). Future research will consist of developing a spatial regression model to more accurately determine the correlation between Palmer amaranth density and cotton yields.

PRACTICAL IMPLICATION

The evolution of resistant weeds has impacted agricultural production systems around the world. Research is now focused on managing resistant weeds as well

as decreasing the risk of new resistance evolution. To expand our abilities in these areas, further development of new technologies is needed to ensure large-scale adoption. Research projects such as this one investigate new possibilities incorporating GPS and GIS technology for managing resistant weeds such as Palmer amaranth, which can rapidly spread from field to field and farm to farm.

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Table 1. Moran's I test for global spatial autocorrelation in fields G2, G4, G5, and G6 in Fayetteville, Ark., at the Arkansas Agricultural Research and Extension Center.

		Moran's I Test for Spatial Variation	
		Selection Criteria for Weighted Matrices	
		Queen Contiguity[1]	Rook Contiguity[1]
Field	Year	Value	Value
G2	2008	0.4816	0.5928
G4	2008	0.5592	0.6785
G5	2008	0.5671	0.6383
G6	2008	0.5074	0.5984
G2	2009	0.7781	0.8093
G4	2009	0.7285	0.7629
G5	2009	0.7422	0.7736
G6	2009	0.7087	0.7513

[1] All test statistics were significantly different from zero at α = 0.01

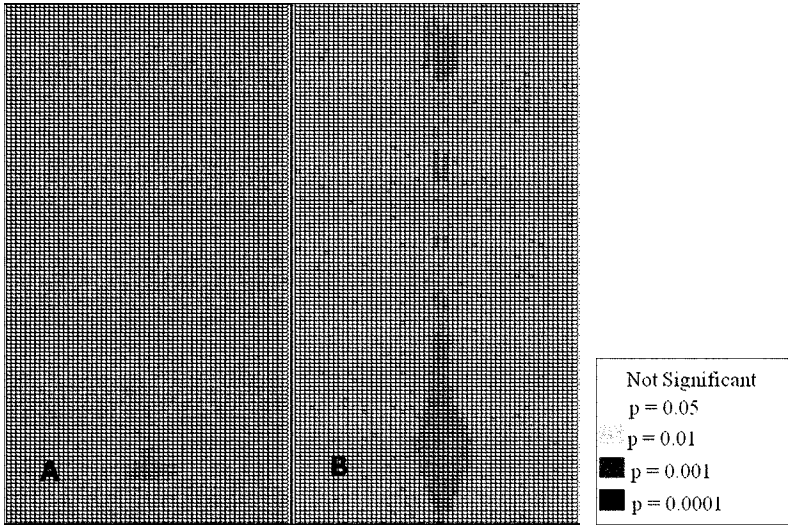

Fig. 1. LISA significance maps from field G6 using queen contiguity weighted matrices in 2008 (A) and 2009 (B).

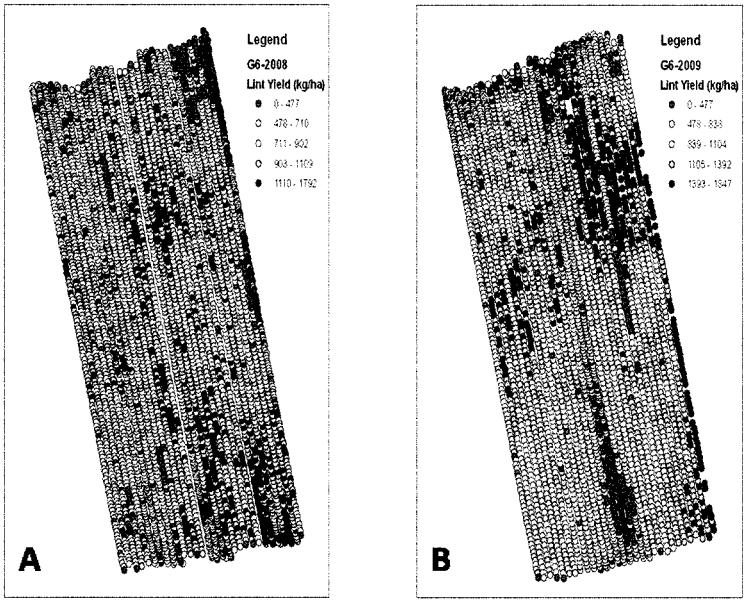

Fig. 2. Lint yield maps from field G6 at the Arkansas Research and Extension Center in Fayetteville, Ark. in 2008 (A) and 2009 (B).

The Spread and Population Genetics of Glyphosate-Resistant Palmer Amaranth in Arkansas

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RESEARCH PROBLEM

One of the emergent concerns in weed management in crop production is the evolution of glyphosate-resistant Palmer amaranth. Glyphosate-resistant Palmer amaranth spreads rapidly over a short period of time. Recently, glyphosate-resistant Palmer has been reported in Tennessee, North Carolina, New Mexico, Alabama, Mississippi and Missouri. In eastern Arkansas, 15 counties were reported to have glyphosate-resistant Palmer just two years from initial documentation in 2005. Doherty (2009, unpublished data) identified 21 counties throughout Arkansas as being infested with glyphosate-resistant Palmer. Researchers and producers are concerned with the evolution of glyphosate-resistant weeds because it renders glyphosate-resistant crop technology ineffective. New strategies are needed to manage resistant weeds sustainably, effectively and economically.

BACKGROUND INFORMATION

Amaranthus species are noted for their high genetic diversity, a characteristic that increases the likelihood to evolve herbicide resistance (Foes, 1998). Population genetics study would allow us to look at the divergence of Palmer populations relative to geographic location and crop management practices. Population genetics analyses provide indicators that would assist in the prediction of magnitude of dispersal and can be informative for management and containment practices.

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[3] Professor and extension weed specialist, Southeast Research and Extension Center, Monticello.

RESEARCH DESCRIPTION

Sampling. Mature seedheads of Palmer amaranth were collected from Mississippi, Lonoke, Craighead, Crittenden, Lee, Phillips, Poinsett, St. Francis and Jackson counties in Arkansas in 2008. Twenty (20) plants were collected in each field and referred to as one population. These samples were believed to have escaped from glyphosate-based weed control programs.

Plant materials. A composite sample was made from 10 plants selected randomly within a population. For the foliar herbicides, seeds were sown in pots containing commercial soil medium. Ten uniform-size seedlings were sprayed per treatment replication. For the soil-applied herbicides, seeds were sown in pots containing silt loam soil.

Experiment setup. Experimental units (pots) were arranged in a split-plot design, replicated four times. Herbicide rate was the main factor and population as the sub-factor. Herbicides were analyzed as separate experiments.

Herbicide treatments. Foliar herbicides evaluated were pyrithiobac (Staple 3.2LX); glyphosate (Roundup Weathermax) and fomesafen (Flexstar) applied at 0.25×, 0.5×, 1×, 2×, 4×. Soil-applied herbicides were pendimethalin (Prowl), diuron (Direx), S-metolachor (Dual Magnum), and fomesafen (Reflex) sprayed at 0.25×, 0.5×, 1×, 2×. The 1× rates were: pyrithiobac, 0.065 lb ai/acre + 0.25% NIS; glyphosate, 0.75 lb ae/acre; fomesafen (foliar), 0.235 lb ai/acre + 1% COC; pendimethalin and Direx , 1.0 lb ai/acre; S-metolachor , 1.27 lb ai/acre and fomesafen (soil), 0.25 lb ai/acre.

Herbicide application. The herbicides were applied using a motorized 2-nozzle boom, 18-in nozzle spacing, delivering 20 GPA. Foliar application was made at 3-4 leaf stage.

Parameters evaluated. Mortality and injury rating were recorded 2 and 4 wk after herbicide application. Dry shoot biomass was recorded 4 wk after treatment.

Sequencing of the EPSPS gene

Three populations (AR-Gr, AR-MIS_B; resistant and SC-Cl; susceptible) were examined to compare patterns of polymorphisms in the EPSPS gene of Palmer amaranth from different production systems and localities. Total RNA was extracted from young leaf tissues by Purelink™ RNA Mini Kit (Invitrogen,Carlsbad, Calif.). The RNA was used for complementary DNA synthesis with Oligo-DT primers and ImProm-II™ Reverse Transcription System (Promega, Madison, Wis.). Degenerate primers were designed based on the conserved EPSPS regions of other species including cotton, tall waterhemp, Italian ryegrass, goosegrass and rigid ryegrass. This information was then used to design specific primers for Palmer, generating several gene fragments. The final primer pair used was EPSF5 (GCC AAG AAC ACA AAG CGA AAT TCA GAG) and EPSR5 (CTA TTA GTC TCA AAT CAA AAC CTT CGG CG), obtained from Gaines et al. (2010), which generated about 1.5 kb sequence in all three populations. The EPSF5 × EPSR5 gel purified product was ligated into pCR 2.1 TOPO plasmid (Invitrogen). Plasmids were transformed into competent *E. coli* cells and transformed cells were cultured

overnight in liquid LB media. Clones containing the target gene were sequenced. Sequences were aligned with the EPSPS gene sequence of *Amaranthus rudis* using the Sequencher v. 7.0 and BioEdit v.7.0.

RESULTS AND DISCUSSION

Effectiveness of Cotton Herbicides on Glyphosate-resistant Palmer Amaranth Populations in Arkansas: Foliar-applied Herbicides

Glyphosate. Glyphosate-resistant Palmer amaranth was observed in Mississippi, Lonoke, Crittenden and Craighead populations (Table 1). LON-A, MIS-B and CRI-A populations were resistant to 2× rate of glyphosate. Escaped plants were noted in the 4× rate of the MIS-B population. The LD95 of LON-A was 1.31 lb ae/acre, and 2.18 lb ae/acre for the MIS-B population, indicating a significant number of escapes at the 1× rate.

Pyrithiobac. All Palmer amaranth populations tested were resistant to the 1× rate; the highest mortality was only about 60% (Table 2). None of the populations were controlled 100% even at the 4× rate. This confirms ALS-resistant Palmer populations are widespread in Arkansas (Bond et al. 2006; Burgos et al. 2001). The LD_{50} and GR_{50} ranged from 0.078 to 0.237 lb ai/acre and 0.114 to 0.286 lb ai/acre, respectively. At the labeled rate of 0.065 lb ai/acre, these populations could be classified as intermediate to highly resistant to ALS-inhibitor herbicides.

Fomesafen. Flexstar controlled the Palmer amaranth populations 100% at the 1× rate or less (Table 3). Herbicide activity was observed within 4 h after application. This herbicide is a valuable tool for management of glyphosate-resistant and ALS-resistant Palmer amaranth in Arkansas.

Soil-applied Herbicides

Pendimethalin. Prowl inhibited the germination of Palmer amaranth at the labeled rate except for LEE-C population with 88% mortality rating (Table 4). At the 1× rate, the LEE-C population was injured 82% (Table 5) implying that Palmer amaranth has evolved increased tolerance to Prowl. On the other hand, Prowl showed residual control 4 wk after treatment (WAT) on other populations.

Diuron. Direx remains to be a good herbicide for Palmer amaranth. Seedling emergence was inhibited 100% even at 0.5× rate (Table 6). Control was noted as early as 2 WAT. Germination was inhibited until 4 WAT.

Fomesafen. A 100% mortality rating was recorded for all Palmer amaranth populations at the 0.5× rate or less when fomesafen was applied pre-emergence (Table 7). Seedling emergence was controlled 100% up to 4 WAT.

S. Metolachor. Palmer amaranth was controlled 100% at 1× or less up to 4 WAT (Table 8).

Sequencing of the EPSPS Gene

Preliminary information from two resistant (GR and MIS-B) and one susceptible (CL) population indicated that there are multiple alleles/isoforms of EPSPS; at least four were detected in the plants examined thus far. EPSPS clones were 98% identical at the nucleotide level between populations. There were 34 nucleotide polymorphisms detected in the susceptible (CL5) population compared to 14 nucleotide variations in the resistant MIS-B3 (Table 10). This indicates that tremendous selection pressure resulted in a more homologous EPSPS gene of the resistant population. Most of the mutations were silent such that the translated amino acid sequence is 98-99% identical across and within population. The Palmer amaranth EPSPS is 90% homologous in amino acid sequence relative to *Amaranthus rudis*. Divergence and diversity profile is shown in Figs. 1 and 2. This parameter measures and compares the diversity within and between populations. The peaks manifest regions in the gene that are polymorphic such that the higher peak indicates greater nucleotide variation. On the other hand, the flat lines/valleys are conserved regions of the gene. The divergence and diversity profile indicates that the susceptible population is more diverse than the resistant populations as demonstrated by more peaks and fewer flat lines than the resistant populations (Figs. 1 and 2). The Ka/Ks ratio was estimated. Non synonymous mutations (Ka) are mutations that resulted in a change in amino acid while Ks are silent mutations. This parameter is measuring the rate of sequence change in a gene; and indicates that selective evolutionary pressures are acting on the gene. A ratio significantly greater than 1 indicates positive selective pressure. A ratio around 1 indicates either neutral evolution at the protein level or an averaging of sites under positive and negative selective pressures. A ratio less than 1 indicates pressures to conserve the protein sequence. The overall Ka/Ks profile is: CL vs. *A. rudis* = 0.467, GR vs. *A. rudis* = 0.447 and MIS-B vs. *A. rudis* 0.410. At this point, significant differences could not be detected in the Ka/Ks profiles between populations because of the small data set generated.

PRACTICAL APPLICATION

- ALS herbicides are no longer reliable due to the widespread occurrence of ALS-R Palmer amaranth.
- Pendimethalin, diuron, fomesafen and S-metolachor are viable options for the control of glyphosate-R Palmer amaranth in cotton.
- Understanding the diversification and spread of this species is critical in dealing with the issue of resistance to herbicides, which has become a threat to crop production.

ACKNOWLEDGMENTS

The authors acknowledge Cotton Incorporated for funding this project. We also acknowledge the support afforded by the Division of Agriculture, the University of Arkansas Extension Agents for their assistance in collecting the samples, and the technical advice from Dr. Patrick Tranel, University of Illinois.

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Table 1. Response of Arkansas Palmer amaranth populations to glyphosate (Roundup WeatherMax).

Population	% Mortality-			LD95 (lb ae/acre)	GR50[1] (lb ae/acre)
	1x	2x	4x		
Mississippi (MIS-A)	95	100	100	0.44	<0.25
Mississippi (MIS-B)	68	83	95	2.18	2.73
Lonoke (LON-A)	60	95	100	1.31	0.82
Crittenden (CRI-A)	88	98	100	1.03	0.32
Craighead (CRA-B)	100	100	100	0.55	<0.25
Craighead (CRA-A)	98	100	100	0.43	0.30
Phillips (PHI-S)	100	100	100	0.42	<0.25
Lee (LEE-B)	100	100	100	0.25	<0.25
Lawrence (LAW-C)	100	100	100	0.43	0.39
Jackson (JAC-A)	100	100	100	0.25	<0.25
Poinsett (POI-A)	100	100	100	0.21	<0.25
St. Francis (STF-A)	100	100	100	0.38	<0.25
Check population (CL-86)	100	100	100	0.19	<0.25

[1] Labeled rate = 0.75 lb ae/acre.

Table 2. Response of Arkansas Palmer amaranth populations to pyrithiobac (Staple 3.2 LX, fall 2008 samples.

Population	% Mortality			LD50 (lb ai/acre)	GR50[1] (lb ai/acre)
	1x	2x	4x		
Mississippi (MIS-A)	55	58	75	0.128	0.234
Mississippi (MIS-B)	3	3	8	0.151	0.194
Lonoke (LON-A)	52	55	58	0.214	0.232
Crittenden (CRI-A)	48	58	55	0.078	0.286
Craighead (CRA-B)	0	13	3	0.194	0.114
Craighead (CRA-A)	63	90	93	0.217	0.217
Phillips (PHI-S)	10	40	35	0.215	0.177
Lee (LEE-B)	15	3	8	0.208	0.146
Lawrence (LAW-C)	28	45	15	0.210	0.219
Jackson (JAC-A)	0	55	43	0.180	0.217
Poinsett (POI-A)	0	8	8	0.237	0.237
St. Francis (STF-A)	3	3	0	0.176	0.175
Check population (CL-86)	7	82	74	0.076	0.130

[1] Labeled rate = 0.065 lb ai/acre.

Table 3. Response of Arkansas Palmer amaranth populations to fomesafen (Flexstar), fall 2008 samples.

Population	% Mortality			LD50 (lb ai/acre)	GR50[1] (lb ai/acre)
	0.25x	0.50x	1x		
Mississippi (MIS-A)	78	100	100	0.05	<0.25
Mississippi (MIS-B)	70	93	100	0.05	0.28
Lonoke (LON-A)	95	100	100	0.03	<0.25
Crittenden (CRI-A)	93	95	100	0.03	<0.25
Craighead (CRA-B)	95	100	100	0.03	<0.25
Craighead (CRA-A)	78	98	100	0.05	0.27
Phillips (PHI-S)	85	90	100	0.05	<0.25
Lee (LEE-B)	88	78	100	0.06	<0.25
Lawrence (LAW-C)	75	90	100	0.05	<0.25
Jackson (JAC-A)	68	100	100	0.05	<0.25
Poinsett (POI-A)	88	100	100	0.05	<0.25
St. Francis (STF-A)	73	90	100	0.06	0.28
Check population (CL-86)	95	100	100	0.03	<0.25

[1] Labeled rate = 0.235 lb ai/acre.

Table 4. Response of Arkansas Palmer amaranth populations to pendimethalin (Prowl)[1].

Population	% Mortality				
	0x	0.25	0.50x	1x	2x
Mississippi (MIS-A)	0	94	97	100	100
Mississippi (MIS-B)	0	92	97	100	100
Lonoke (LON-A)	0	82	84	100	100
Crittenden (CRI-A)	0	60	62	100	100
Craighead (CRA-B)	0	89	98	100	100
Craighead (CRA-A)	0	88	90	100	100
Phillips (PHI-S)	0	65	96	100	100
Lee (LEE-A)	0	94	100	100	100
Lee (LEE-B)	0	24	65	100	100
Lee (LEE-C)	0	69	84	88	100
Lawrence (LAW-C)	0	16	75	100	100
Jackson (JAC-A)	0	56	63	100	100
Poinsett (POI-A)	0	74	96	100	100
St. Francis (STF-A)	0	81	88	100	100

[1] Labeled rate = 1.0 lb ai/acre.

Table 5. Response of Palmer amaranth populations to different rates of pendimethalin (Prowl)[1].

	% Injury				
Population	0x	0.25	0.50x	1x	2x
Mississippi (MIS-A)	0	51	76	100	100
Mississippi (MIS-B)	0	30	65	100	100
Lonoke (LON-A)	0	15	38	100	100
Crittenden (CRI-A)	0	20	45	100	100
Craighead (CRA-B)	0	5	88	100	100
Craighead (CRA-A)	0	0	74	100	100
Phillips (PHI-S)	0	0	88	100	100
Lee (LEE-A)	0	55	100	100	100
Lee (LEE-B)	0	0	30	100	100
Lee (LEE-C)	0	31	51	82	100
Lawrence (LAW-C)	0	0	55	100	100
Jackson (JAC-A)	0	0	40	100	100
Poinsett (POI-A)	0	20	88	100	100
St. Francis (STF-A)	0	0	31	100	100

[1] Labeled rate = 1.0 lb ai/acre.

Table 6. Response of Arkansas Palmer amaranth populations to direx (Diuron)[1].

	% Mortality			
Population	0x	0.25	0.50x	1x
Mississippi (MIS-A)	0	100	100	100
Mississippi (MIS-B)	0	98	100	100
Lonoke (LON-A)	0	100	100	100
Crittenden (CRI-A)	0	100	100	100
Craighead (CRA-B)	0	100	100	100
Craighead (CRA-A)	0	100	100	100
Phillips (PHI-S)	0	100	100	100
Lee (LEE-A)	0	100	100	100
Lee (LEE-B)	0	100	100	100
Lee (LEE-C)	0	100	100	100
Lawrence (LAW-C)	0	100	100	100
Jackson (JAC-A)	0	100	100	100
Poinsett (POI-A)	0	100	100	100
St. Francis (STF-A)	0	100	100	100

[1] Labeled rate = 1.0 lb ai/acre.

Table 7. Response of Arkansas Palmer amaranth populations to fomesafen (Reflex)[1].

	% Mortality		
Population	0x	0.25	0.50x
Mississippi (MIS-A)	0	100	100
Mississippi (MIS-B)	0	93	100
Lonoke (LON-A)	0	100	100
Crittenden (CRI-A)	0	98	100
Craighead (CRA-B)	0	100	100
Craighead (CRA-A)	0	98	100
Phillips (PHI-S)	0	100	100
Lee (LEE-A)	0	100	100
Lee (LEE-B)	0	100	100
Lee (LEE-C)	0	100	100
Lawrence (LAW-C)	0	100	100
Jackson (JAC-A)	0	100	100
Poinsett (POI-A)	0	97	100
St. Francis (STF-A)	0	100	100

[1] Labeled rate = 0.25 lb ai/acre.

Table 8. Response of Arkansas Palmer amaranth populations to S-metolachor (Dual Magnum)[1].

	% Mortality		
Population	0x	0.25	0.50x
Mississippi (MIS-A)	0	100	100
Mississippi (MIS-B)	0	98	100
Lonoke (LON-A)	0	100	100
Crittenden (CRI-A)	0	100	100
Craighead (CRA-B)	0	100	100
Craighead (CRA-A)	0	98	100
Phillips (PHI-S)	0	98	98
Lee (LEE-A)	0	100	100
Lee (LEE-B)	0	91	98
Lee (LEE-C)	0	90	100
Lawrence (LAW-C)	0	90	92
Jackson (JAC-A)	0	92	98
Poinsett (POI-A)	0	92	98
St. Francis (STF-A)	0	100	100

[1] Labeled rate = 1.27 lb ai/acre.

Table 9. Palmer amaranth sample information.

Population	I.D.	Cropping History
Clarendon, South Carolina	CL	Not been exposed to glyphosate
Mississippi, Arkansas	MIS-B	Roundup Ready soybean for 10+ years
Lincoln, Arkansas	GR	Continuous cotton

Table 10. Nucleotide polymorphism within population.

Susceptible

	1							10								20								30			
CL5_A	A	C	T	G	T	T	A	T	T	A	T	T	G	T	C	A	T	T	C	A	G	A	G	C	T	A	G	A	G	G	A	G	A	C
CL5_B	T	G	C	A	A	C	*	C	G	C	C	*	A	A	T	G	*	C	T	G	A	T	T	T	A	C	C	G	A	C	*	C	G	T
CL5_C	*	*	*	*	*	*	*	*	*	*	*	*	A	*	*	*	*	*	T	*	*	*	*	*	*	*	*	*	A	*	*	*	*	T
CL5_D	*	*	*	*	*	*	G	*	*	*	*	C	A	*	*	*	C		T	*	*	*	*	*	*	*	*	*	A	*	G	*	*	T

Resistant

	1										10				
MIS-B3_A	A	A	C	T	C	A	T	G	A	C	G	G	C	A	
MIS-B3_C	G	*	T	C	T	G	*	A	G	T	A	A	*	*	
MIS-B3_D	*	*	T	*	T	*	*	A	*	T	A	*	T	*	
MIS-B3_F	*	G	T	*	T	*	C	A	*	T	A	*	*	C	

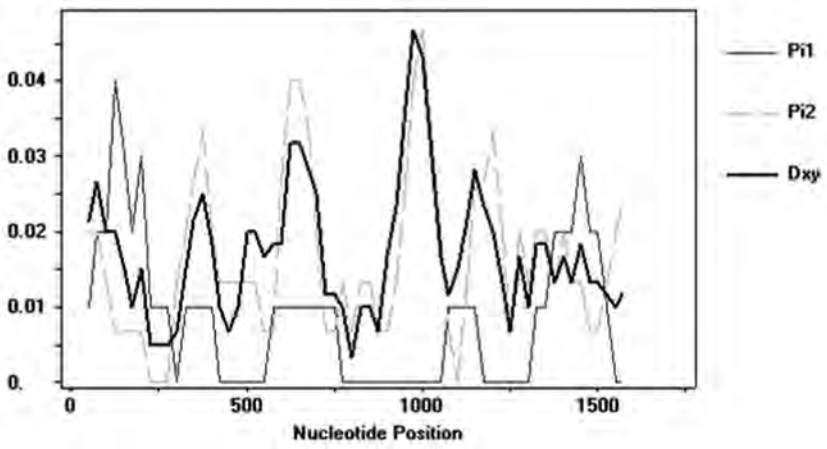

Fig. 1. Diversity and divergence profile between MIS and CL population.

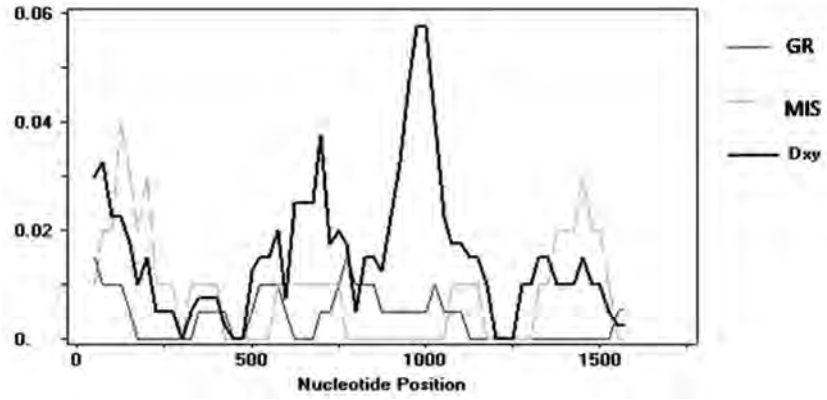

Fig. 2. Diversity and divergence profile between GR and MIS population.

Palmer Amaranth Control with Dicamba and Glufosinate as Influenced by Weed Size and Herbicide Rate

R.C. Doherty, K.L. Smith, J.A. Bullington and J.R. Meier[1]

RESEARCH PROBLEM

Palmer amaranth (*Amaranthus palmeri*) is known to be glyphosate-resistant and one of the most common and troublesome weeds in Arkansas cotton production. Glufosinate is known to provide good control of 1-4 inch Palmer amaranth, but control of larger weeds is erratic. Dicamba can also provide control of small Palmer amaranth, but not much is known about the control of larger plants. The objective of this study was to provide data that would support the use of dicamba and glufosinate-resistant cotton to gain optimum control of glyphosate-resistant Palmer amaranth.

BACKGROUND INFORMATION

Glufosinate-resistant cotton was commercially released in 2004. Currently Monsanto is testing glufosinate/dicamba resistant cotton, which could provide opportunity for controlling glyphosate-resistant Palmer amaranth with over the top herbicide applications. More information was needed on control of Palmer amaranth with glufosinate and dicamba as affected by herbicide rate and weed size.

RESEARCH DESCRIPTION

A trial was established in Rohwer, Ark. on the Southeast Research and Extension Center in a Hebert silt loam soil in 2009 to evaluate Palmer amaranth control. The trial was arranged in a randomized complete block design with four replications. Parameters evaluated were visual ratings of Palmer amaranth control form 0-100 with 0 being no control and 100 being complete control. Evaluations were based on weed size at application. Two rates of each herbicide were applied at four timings. Dicamba was applied at 0.25 and 0.5 lb ae/acre and glufosinate

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was applied at 0.53 and 0.73 lb ai/acre. The application timings were 3-6, 6-9, 9-12, and 24-28 inch Palmer amaranth.

RESULTS

Forty days after treatment, dicamba applied at 0.25 and 0.5 lb ae/acre to 3-inch Palmer amaranth and dicamba at 0.5 lb ae/acre applied to 6-inch Palmer amaranth provided 99 to 100% control (Fig. 1). Dicamba at 0.25 lb ae/acre applied to 6-inch Palmer amaranth provided 75% control. Dicamba applied at 0.25 and 0.5 lb ae/acre to 9-inch Palmer provided less than 65% control and less than 40% control of 12-inch Palmer. Seed suppression was noted with both rates when applied to weeds less than 24 inches. Dicamba applied at 0.25 and 0.5 lb ae/acre to 24-28-inch Palmer amaranth provided less than 40% control and did not suppress seed production.

Glufosinate applied at 0.53 and 0.73 lb ai/acre provided 100% control of 3- and 6-inch Palmer amaranth (Fig. 2). Glufosinate applied at 0.53 and 0.73 lb ai/acre provided greater than 90% control of 9, 12, 24, and 28-inch Palmer amaranth. All glufosinate treatments suppressed Palmer amaranth seed production.

PRACTICAL APPLICATIONS

Dicamba and glufosinate can be used to control and suppress seed production of glyphosate-resistant Palmer amaranth. The stacked genetic technology of glufosinate/dicamba resistant-cotton may prove to be a valuable asset in controlling and preventing seed production of glyphosate-resistant Palmer amaranth in Arkansas. Glufosinate and glufosinate-resistant cotton have already made an impact on cotton production and in the control of glyphosate-resistant weeds in Arkansas. The information from this trial will be used to make recommendations throughout the state.

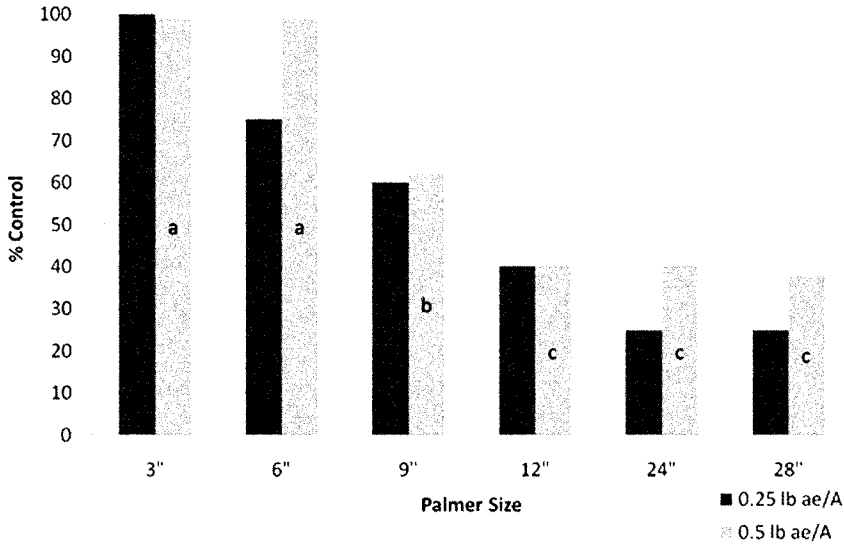

Fig. 1. Dicamba control of Palmer amaranth at 40 days after application.

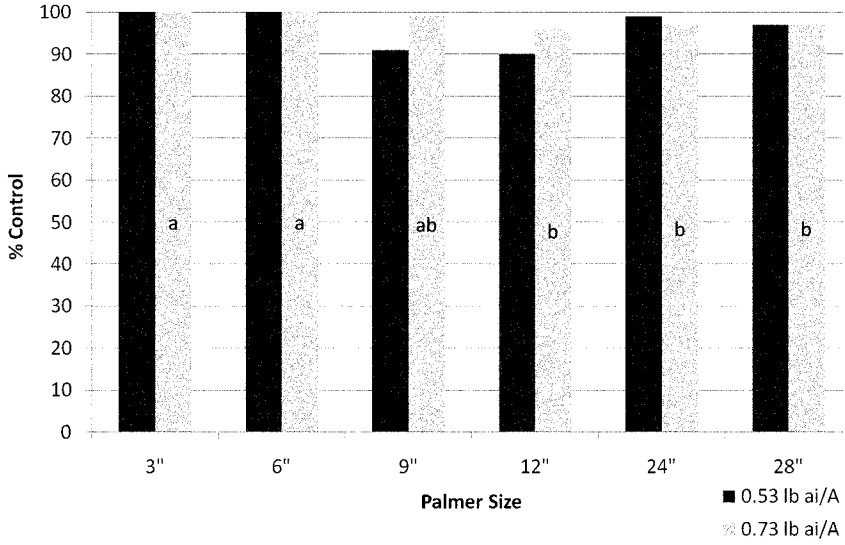

Fig. 2. Glufosinate control of Palmer amaranth at 40 days after application.

Use of Staple® LX with Other Residual Herbicides for Weed Management in Mid-South Cotton

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RESEARCH PROBLEM

Roundup Ready technology provided cotton producers an effective and convenient weed management tool. However, glyphosate does not provide effective control of some broadleaf and grass weed species. In addition, because of the increasing number of glyphosate-resistant weed species, farmers cannot rely solely on glyphosate for weed management and need to use alternative herbicide programs. Therefore, there is a need to develop an effective alternative herbicide program in cotton.

BACKGROUND INFORMATION

Cotton is the third most important agronomic crop in Arkansas, with an annual market value of $350 million (USDA, 2009). Weeds are a major limiting factor in cotton production. The top-ranking weed species in Arkansas cotton are horseweed (*Conyza canadensis*), Palmer amaranth (*Amaranthus palmeri*), morningglories (*Ipomoea* spp.), and annual grasses (Norsworthy et al., 2007). Cotton is a poor competitor with early-season weeds because of its slow growth and wide row spacing resulting in slow canopy closure. Therefore, cotton weed management heavily relies on herbicides. The introduction of glyphosate-resistant cotton cultivars shifted cotton growers to a total-postemergence program based on glyphosate. This is because glyphosate is a broad-spectrum herbicide with application flexibility and no carryover. However, the drawbacks of glyphosate include poor activity on certain weed species and increased number of glyphosate-resistant weeds (Powles, 2008). Therefore, herbicides with alternative modes of action should be included in cotton weed management programs and can be either preemergence or postemergence herbicides or both. However, postemergence

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herbicide options are limited in cotton because of crop sensitivity and weed size-dependent herbicidal activity. Therefore, it is imperative to develop an effective and broad-spectrum preemergence weed management program in cotton. Staple® LX (pyrithiobac) is an ALS-inhibitor herbicide and can be a good candidate for a residual program because of its soil activity on a number of broadleaf and grass weeds (Anonymous, 2007). Keeping these points in view, we hypothesize that integration of Staple LX with other preplant (PP) and preemergence (PRE) herbicides will improve early-season weed control in cotton. Therefore, the objective of this study was to evaluate the effectiveness of PP and PRE herbicide programs with and without Staple LX in cotton.

RESEARCH DESCRIPTION

A field experiment was conducted at the Lon Mann Cotton Research Station, Marianna, Ark., in 2009 to evaluate the cotton response and weed control efficacy of different residual herbicide programs with and without Staple LX in cotton. Roundup Ready Flex cotton (*Gossypium hirsutum* L.) cv. ST4554 B2RF was planted on 20 May 2009, in 38-inch rows. Experimental plots were 50 ft long and 12.7 ft wide, consisting of four rows of cotton. The experiment was organized in a randomized complete block design with nine different residual herbicide programs replicated four times. The residual herbicide programs included various combinations of PP (Reflex, Direx) and PRE (Direx) herbicides, applied alone or in combination with Staple LX (Table 1). In addition, a non-treated control was included for comparison. Because residual herbicide programs were evaluated up to 4 wk after planting (WAP) in this study, the entire test site was sprayed with multiple over-the-top applications of Roundup PowerMax at 22 oz/acre beginning 4 WAP. Data were collected on percentage cotton injury and weed control at biweekly intervals up to 4 WAP and seedcotton yield at harvest. The major weed species evaluated were broadleaf signalgrass, pitted morningglory, and Palmer amaranth. All data were subjected to analysis of variance, and means were separated by Fisher's protected LSD ($\alpha = 0.05$). Injury and weed control data were subjected to arcsine square-root transformation to stabilize the variances before analysis and were back-transformed for presentation purposes.

RESULTS AND DISCUSSION

Cotton injury was ≤25% in all herbicide programs at 4 WAP, with no significant difference in injury from PP/PRE herbicides applied with or without Staple LX (Fig. 1). This indicates that addition of Staple LX did not increase injury to cotton from any of the PP/PRE herbicide combination. This is because Staple LX is labeled for PRE application in cotton at the rates tested in the present study (Anonymous, 2007). Staple LX improved early-season control of broadleaf signalgrass and pitted morningglory up to 17 percentage points, especially in

programs including Reflex preplant and no preemergence herbicide (Figs. 2 and 3). These results are supported by previous studies in which Staple LX had shown excellent residual activity on pitted morningglory (Scroggs et al., 2007). Direx PP followed by Direx PRE and Reflex PP with or without Direx PRE provided effective control of Palmer amaranth (Fig. 4). However, Staple LX failed to improve Palmer amaranth control from any of the residual herbicide programs. This is because Direx PP followed by Direx PRE or Reflex PP are sufficient for effective control of Palmer amaranth, and therefore no improvement was observed from addition of Staple LX (Culpepper and Smith, 2009). Another possible reason of ineffectiveness of Staple LX could be the existence of ALS-resistant Palmer amaranth at the experimental site. ALS-resistant Palmer amaranth is widespread in Arkansas (Bond et al., 2006). Seed-cotton yield was not different from the check treatment in any of the herbicide programs because the entire test site was sprayed with multiple glyphosate applications following 4 WAP and therefore removed weed interference throughout season in all treatments.

PRACTICAL APPLICATION

This research demonstrates the benefit of incorporating Staple LX into herbicide programs consisting of weak residual herbicides for a target species. For example, Reflex PP has marginal activity on annual grasses and pitted morningglory and the addition of Staple LX is beneficial. However, there is no advantage of using Staple LX with a strong residual herbicide program. For example, Palmer amaranth control from Direx PP followed by Direx PRE or Reflex PP was not improved by the addition of Staple LX. Moreover, addition of Staple LX in any herbicide program will increase the cost of weed management. Therefore, cotton producers should develop their herbicide program keeping in mind the weed flora present and cost of weed management.

ACKNOWLEDGMENTS

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Table 1: Herbicide programs consisting of various combinations of preplant and preemergence herbicides, along with their rate/acre and herbicide codes.

Preplant herbicide	Preemergence herbicide	Herbicide code
Roundup PowerMax (22 oz)and Clarity (8 oz)	Gramoxone Inteon[1] (40 oz)	Rup+Cla fb Gra
Roundup PowerMax (22 oz) and Clarity (8 oz) + Direx (16 oz)	Gramoxone Inteon (40 oz) + Direx (16 oz)	Rup+Cla+Dir fb Gra+Dir
	Gramoxone Inteon (40 oz) + Direx (16 oz) + Staple LX (1.7 oz)	Rup+Cla+Dir fb Gra+Dir+Stp
Roundup PowerMax (22 oz) and Clarity (8 oz) + Reflex (16 oz)	Gramoxone Inteon (40 oz)	Rup+Cla+Rfx fb Gra
	Gramoxone Inteon (40 oz) + Staple LX (1.7 oz)	Rup+Cla+Rfx fb Gra+Stp
Roundup PowerMax (22 oz) and Clarity (8 oz) + Reflex (16 oz)	Gramoxone Inteon (40 oz) + Direx (16 oz)	Rup+Cla+Rfx fb Gra+Dir
	Gramoxone Inteon (40 oz) + Direx (16 oz) + Staple LX (1.7 oz)	Rup+Cl+Rfx fb Gra+Dir+Stp
Roundup PowerMax (22 oz) and Clarity (8 oz) + Reflex (16 oz)	Gramoxone Inteon (40 oz) + Direx (24 oz)	Rup+Cla+Rfx fb Gra+Dir
	Gramoxone Inteon (40 oz) + Direx (24 oz) + Staple LX (1.7 oz)	Rup+Cla+Rfx fb Gra+Dir+Stp

[1]Gramoxone Inteon applied with crop oil concentrate 1% v/v.

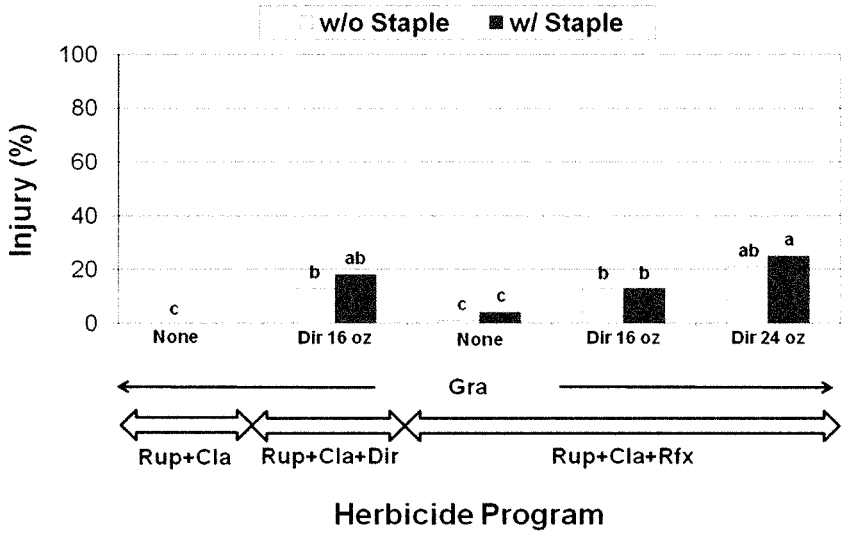

Fig. 1. Cotton injury at 4 wk after planting as influenced by the combination of preplant and preemergence herbicides with and without Staple LX. Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05). See Table 1 for herbicide codes.

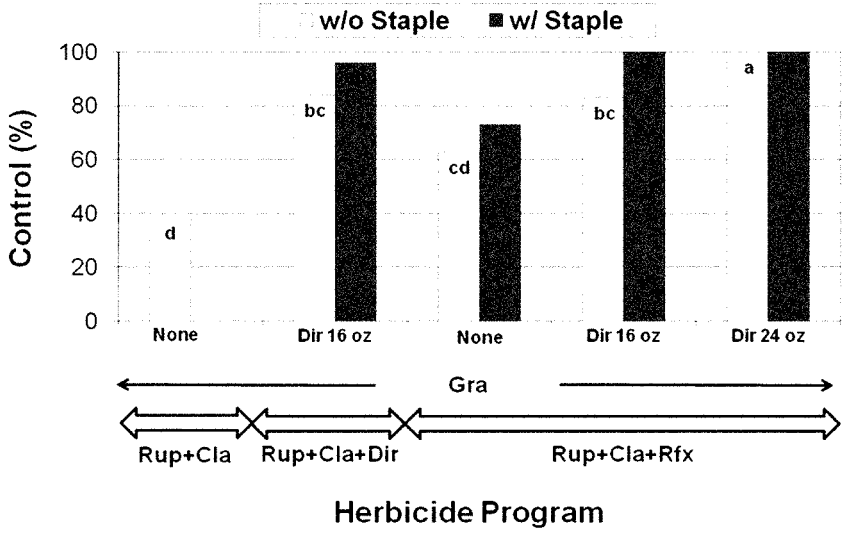

Fig. 2. Broadleaf signalgrass control in cotton at 4 wk after planting as influenced by the combination of preplant and preemergence herbicides with and without Staple LX. Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05). See Table 1 for herbicide codes.

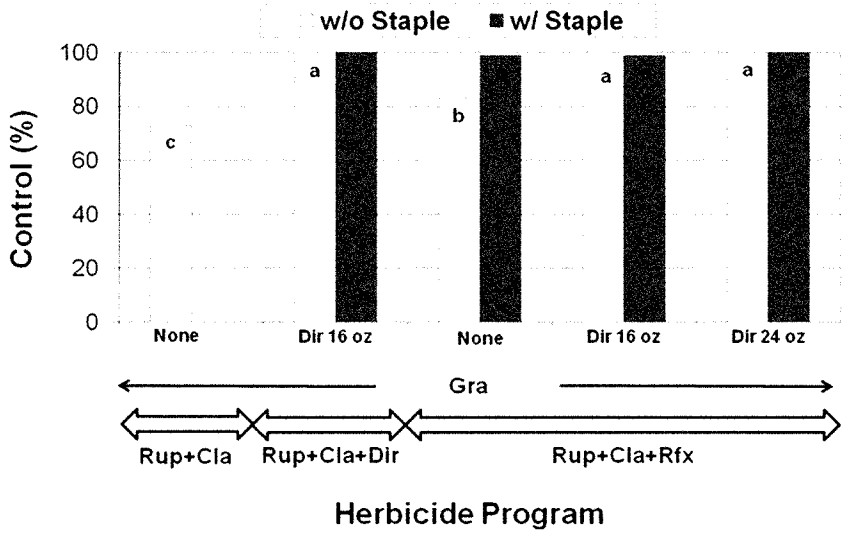

Fig. 3. Pitted morningglory control in cotton at 4 wk after planting as influenced by the combination of preplant and preemergence herbicides with and without Staple LX. Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05). See Table 1 for herbicide codes.

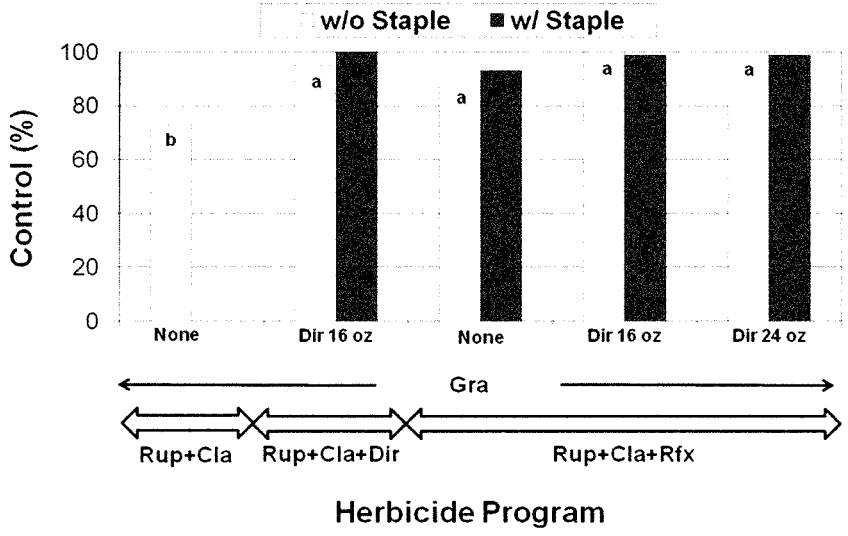

Fig. 4. Palmer amaranth control in cotton at 4 wk after planting as influenced by the combination of preplant and preemergence herbicides with and without Staple LX. Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05). See Table 1 for herbicide codes.

Non-Glyphosate Programs for Palmer Amaranth Control in Cotton

S.K. Bangarwa, J.K. Norsworthy, G.M. Griffith, J. DeVore, J. Still, and M.J. Wilson[1]

RESEARCH PROBLEM

Palmer amaranth (*Amaranthus palmeri*) is a major problematic glyphosate-resistant weed in Arkansas cotton. Palmer amaranth is highly competitive, causing considerable yield reduction and decreasing harvesting efficiency of cotton. Cotton growers can no longer rely on glyphosate for Palmer amaranth control. Therefore, an effective non-glyphosate weed management program is urgently needed.

BACKGROUND INFORMATION

Glyphosate has been the foundation of broad-spectrum weed control in glyphosate-resistant cotton production in Arkansas. However, the continuous use of glyphosate and lack of crop rotation resulted in a serious problem of glyphosate-resistant Palmer amaranth in Arkansas cotton. A total of 630,000 acres of cotton in the mid-south and southeastern U.S. is infested with glyphosate-resistant Palmer amaranth (Nichols et al., 2009). Palmer amaranth is a major problematic glyphosate-resistant weed in cotton because of its competitive growth habit and prolific seed production. Palmer amaranth can reduce lint yield up to 92% and decrease the harvesting efficiency (Rowland et al., 1999; Smith et al., 2000). There is an urgent need to develop an effective, season-long non-glyphosate herbicide program in cotton. We hypothesize that sequential application of residual herbicides with alternative modes of action will provide effective, season-long control of glyphosate-resistant Palmer amaranth. Therefore, the objective of this study was to evaluate crop tolerance and efficacy of sequential residual herbicide programs against Palmer amaranth in cotton.

RESEARCH DESCRIPTION

A field experiment was conducted at the Lon Mann Cotton Research Station, Marianna, Ark. in 2009 to evaluate the cotton response and Palmer amaranth control

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efficacy of different non-glyphosate herbicide programs in cotton. Roundup Ready Flex cotton (*Gossypium hirsutum* L.) cv. ST4554 B2RF was planted in late May on a 38-inch row spacing. Experimental plots were 50 ft long and 12.7 ft wide, consisting of 4 rows of cotton. The experiment was organized in a randomized complete block design with a 3 by 3 factorial arrangement of treatments, replicated four times. The treatment factors included: 1) three preplant (PP)/preemergence (PRE) herbicides - Reflex PP (1.0 pt/acre), Cotoran PRE (1.5 pt/acre), and Prowl H_2O PRE (2.1 pt/acre); 2) two postemergence (POST) herbicides – Dual Magnum (1.3 pt/acre) at 1-lf and 4-lf cotton; 3) two post-directed (PD) herbicides (Suprend at 1.25 lb/acre and none). A layby application of MSMA (2.7 pt/acre) + Direx (1.6 pt/acre) was made in all herbicide programs at 12-lf cotton. In addition, a non-treated control was included for comparison. Data were collected on percent cotton injury and Palmer amaranth control at biweekly intervals from 4 to 10 wk after planting (WAP). Percent injury and Palmer amaranth control data were subjected to arcsine square-root transformation to stabilize the variances, and back-transformed for presentation purposes. All data were subjected to three-way analysis of variance, and means were separated by Fisher's protected LSD (α = 0.05).

RESULTS AND DISCUSSION

Cotton injury was minimal ($\leq$ 2%) in all herbicide programs (data not shown). Herbicide programs including Reflex PP controlled Palmer amaranth 76% to 91% throughout the season (Figs. 1-4). Herbicide programs including Cotoran PRE and Prowl H_2O PRE provided no more than 60% and 31% control of Palmer amaranth at 4 WAP, respectively (Fig. 1). However, Palmer amaranth control in these two programs further declined later in the season, with no more than 37% control at 6 WAP (Fig. 2). Weed control in all programs was similar for Dual Magnum POST applied either at 1-lf or 4-lf cotton, regardless of PP/PRE treatment at 6 to 10 WAP (Figs. 2-4). However, the addition of Suprend PD improved Palmer amaranth control at 8 WAP in herbicide programs containing Reflex PP (Fig. 3). Reflex PP, regardless of POST and PD application, when followed by Direx + MSMA at layby controlled Palmer amaranth 84%. However, Palmer amaranth control was 0% in plots treated with Cotoran and Prowl H_2O, even after application of POST, PD, and lay-by herbicides (Fig. 4). Therefore, season-long residual control is needed because Palmer amaranth emerges throughout the growing season, and once it emerges, control will be difficult due to its rapid growth (Jha and Norsworthy, 2009). Reflex is critical for early-season residual Palmer amaranth control. However, for consistent season-long control, a system approach with sequential applications of residual herbicides is required (Culpepper and Smith, 2009; Steckel et al., 2009). Seed-cotton was not harvested because of interference in harvesting operation due to Palmer amaranth infestation.

PRACTICAL APPLICATION

This research demonstrates the importance of effective early-season residual herbicide programs for season-long Palmer amaranth management. Using Reflex PP, effective Palmer amaranth control can be maintained throughout the season with POST followed by PD herbicides. In contrast, use of a short-residual herbicide (Cotoran or Prowl H_2O) before or at planting will not provide season-long Palmer amaranth control even with the sequential application of residual POST and PD herbicides.

ACKNOWLEDGMENTS

Financial support for this research by Cotton Incorporated is appreciated. The technical support provided by the staff at the Lon Mann Cotton Research Station, Marianna, Ark., is gratefully acknowledged.

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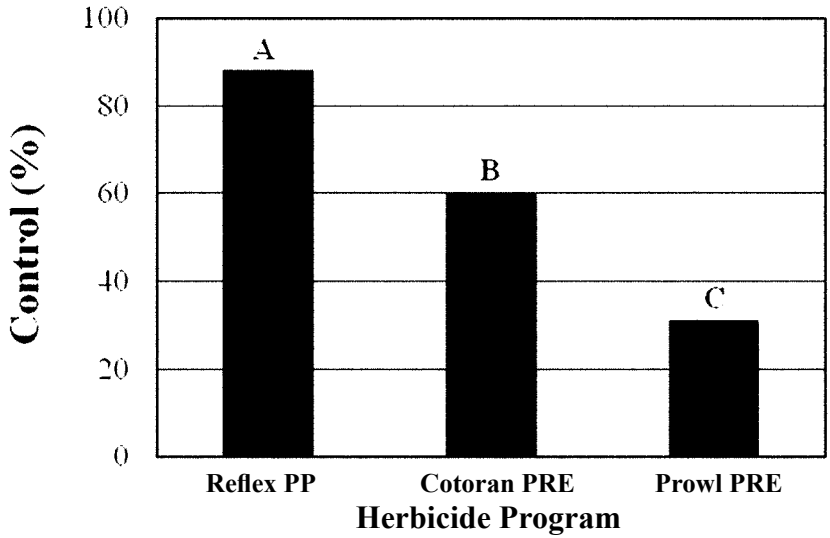

Fig. 1. Palmer amaranth controlin cotton at 4 wk after planting as influenced by preplant/preemergence (PP/PRE) herbicide program. Means with the same letter are not significantly different according to Fisher's protected LSD (α -= 0.05).

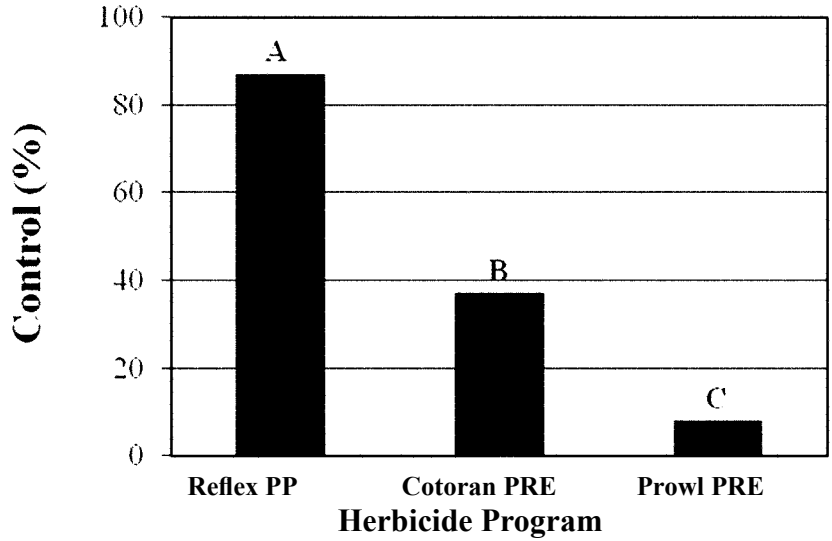

Fig. 2. Palmer amaranth control in cotton at 6 wk after planting as influenced by preplant/preemergence (PP/PRE) herbicides, averaged over postemergence (POST) herbicides (Dual Magnum at 1- and 4-lf). Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05).

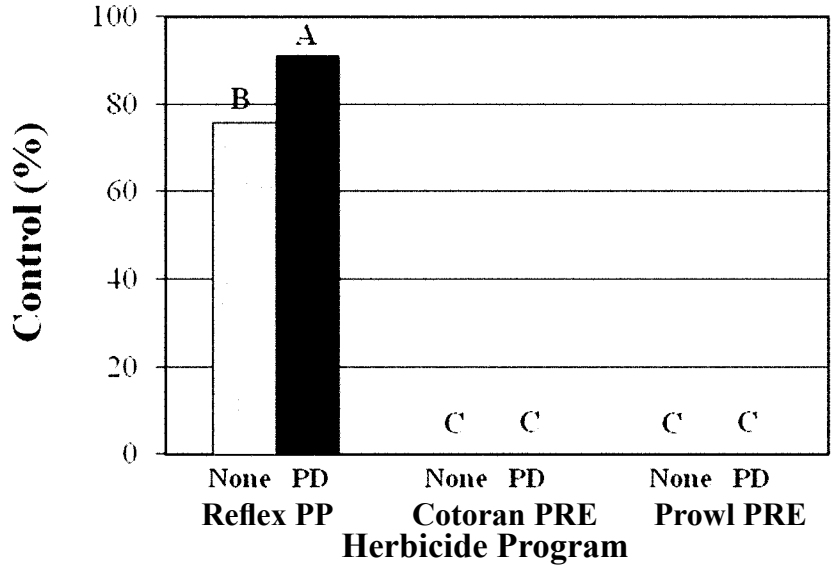

Fig. 3. Palmer amaranth control in cotton at 8 wk after planting as influenced by pre-plant/preemergence (PP/PRE) and post-directed (PD) (Suprend and none) herbicides, averaged over POST (Dual Magnum at 1- and 4-lf)herbicides. Means with the same letter are not significantly differentaccording to Fisher's protected LSD (α = 0.05).

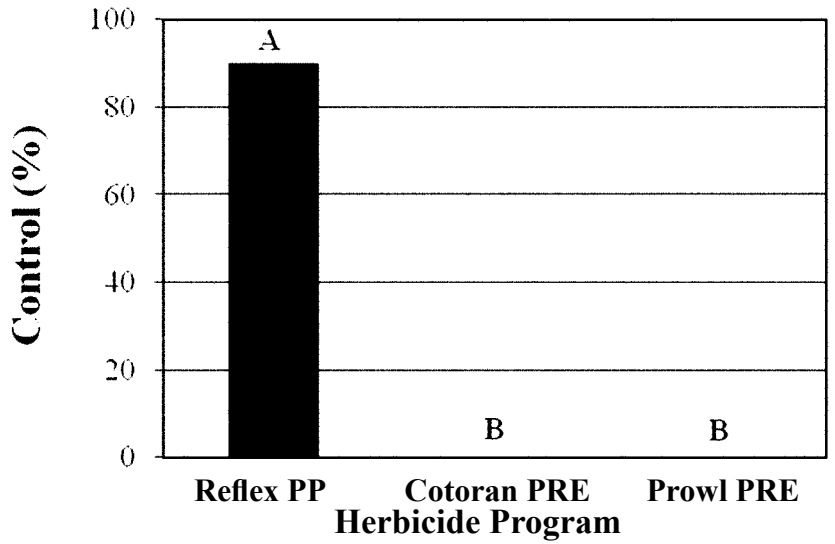

Fig. 4. Palmer amaranth control in cotton at 10 wk after planting as influenced by preplant/preemergence (PP/PRE) herbicides, averaged over POST (Dual Magnum at 1- and 4-lf) and PD (Suprend and none) herbicides. Means with the same letter are not significantly different according to Fisher's protected LSD (α = 0.05).

Changes in Root Architecture Caused by *Meloidogyne incognita* and *Thielaviopsis basicola* and Their Interaction on Cotton

J. Ma[1], J. Jaraba[1], T.L. Kirkpatrick[2], C.S. Rothrock[1]

RESEARCH PROBLEM

The root system is vital for the cotton plant to absorb nutrients and water from the soil and to anchor the plant. Two important soil-borne pathogens of cotton, *Meloidogyne incognita* (root-knot nematode), and *Thielaviopsis basicola* can adversely affect root systems resulting in suppressed growth and less efficient water and nutrient uptake and transport. In fields where these pathogens occur together, disease severity increases dramatically. Quantitative analysis of the effects of these pathogens on root architecture, or at differing soil bulk densities has not been reported. Because root-knot causes gall formation and *T. basicola* infection results in loss of root cortical tissue, an investigation of the severity of these pathogens in the presence of a soil compaction layer is needed to fully understand their potential for crop damage and yield loss.

BACKGROUND INFORMATION

In many Arkansas cotton fields, factors such as traffic across the field, shallow tillage, extremely dry weather, or certain soil types, may result in a compacted soil layer, sometimes called a plow pan or hardpan. This layer can affect water infiltration, and in some cases, the penetration and exploration of the soil by cotton roots. Measurement of soil bulk density (dry soil weight divided by soil volume) is often used to describe the degree of compaction of these layers. Physical inhibition of roots to penetrate and explore soil can be exacerbated by root damage caused by the root-knot nematode (*Meloidogyne incognita*) and *Thielaviopsis basicola*, the causal agent of cotton black root rot. Root knot nematode infection results in the formation of root galls that can reduce the absorptive area and volume of roots and interfere with water and mineral translocation (Kirkpatrick et al., 1995). Similarly, *T. basicola* infection causes cotton seedling disease by affecting the cortical portion of roots, resulting in necrosis and loss of feeder roots (Rothrock,

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[2] Professor, Southwest Research and Extension Center, Hope..

1992). A synergistic relationship between these two pathogens has also been reported (Walker, 1998). Topological aspects of root systems may be useful in quantifying root architectural changes brought about by these pathogens, in differing soil bulk densities.

REARCH DESCRIPTION

Experiments were carried out under controlled environments using a 24 ◦C day time and 15 ◦C night temperature regime for the first 22 days after planting (DAP), followed by 26◦ day and 19◦ night temperatures for the remainder of the experiment. Field soil from Ashley County, Ark. (54% sand, 42% silt, and 4% clay) was pasteurized before inoculation. Two bulk densities: 1.25 g/cm^3 soil and 1.5 g/cm^3 soil were used. Four different treatments were set up for each bulk density as follows: (1) untreated control; (2) inoculation with 4 eggs/cm^3 soil of *M. incognita*; (3) inoculation with 40 chlamydospore chains/cm^3 soil of *T. basicola*; (4) inoculation with both pathogens (same rates as treatment 2 and 3). The experiment was organized in a randomized complete block design and there were four replications in each treatment. The experiment was conducted twice. At 44 DAP, all the cotton seedlings were dug and root systems were washed out carefully. WinRHIZO software was utilized to scan the entire root system and determine various morphological aspects including surface area, root volume and links[1], and the topological parameters of magnitude[2], exterior path length[3] *(Pe)* and altitude[4].

RESULTS AND DISCUSSION

Because these experiments were conducted in a controlled environment, soil bulk density did not affect root parameters; so to better present the changes in root architecture caused by *M. incognita* and *T. basicola* and their interaction, we will show pathogen main effects, using combined bulk densities ($p < 0.05$) (Tables 1 and 2). The least significant difference was used to compare the means. Infection of cotton seedlings by *M. incognita*, *T. basicola*, or both pathogens decreased the number of root links resulting in smaller root volume (Table 3). Compared to healthy root systems, topological parameters, including magnitude, total exterior path length *(Pe)*, and altitude were lower after infection by either *M. incognita* or *T. basicola*. Damage from both pathogens was greater than with either pathogen alone, particularly on root volumes.

[1]Link is the length between two nodes or junctions of two root branches.
[2]Magnitude is the numbers of first order root.
[3]Exterior path length *(Pe)* is the sum of the number of exterior links.
[4]Altitude is the number of links in the longest path from any exterior link to the base link.

SUMMARY

The changes in root architecture ultimately resulted in ineffective branching of the whole root system which likely reduced the capability of the roots to absorb water and nutrients from the soil. This certainly would affect aboveground plant growth, especially under unfavorable environmental or soil conditions that are common in the field. We plan to explore these effects in the field where this method of quantifying the changes in architecture of diseased cotton roots should enable the quantitative assessment of the effect of root pathogens on plant growth, development and yield.

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Table 1. Impact of *M. incognita* on root magnitude, surface area, no. of links, altitude and exterior path length.

Treatment *M. incognita*	Magnitude	Surface Area (cm^2)	No. of Links	Altitude	Exterior PathLength
0[1]	91.197 a[2]	32.010 a	1802.6 a	80.813 a	3581.5 a
4	53.994 b	22.534 b	1161.0 b	59.290 b	1963.4 b
P value	<0.0001	0.0003	0.0045	0.0065	0.0026

[1]0 = no nematodes (control); 4 = 4 *M. incognita* eggs/cm^3 soil.
[2]Means within columns followed by the same letter do not differ by LSD ($p < 0.05$).

Table 2. Impact of *T. basicola* on magnitude, surface area, no. of links, altitude and exterior path length.

Treatment *T. basicola*	Magnitude	Surface Area (cm^2)	No. of Links	Altitude	Exterior PathLength
0[1]	93.931 a	35.787 a	2166.4 a	85.375 a	4073.0 a
40	51.171 b	18.634 b	785.4 b	54.581 b	1456.0 b
P value	<0.0001	<0.0001	<0.0001	0.0002	<0.0001

[1]0 = no *T. basicola* (control); 40 = 40 40 chlamydospore chains/cm^3 soil.
[2]Means within columns followed by the same letter do not differ by LSD ($p < 0.05$).

Table 3. Changes in root volume caused by *M. incognita, T. basicola*, or both pathogens.

Treatment[1]		Root Volume (cm^3)
M. incognita	*T. basicola*	
0	0	0.548a
4	0	0.631a
0	40	0.411b
4	40	0.219c

[1]Treatments: 0 = soil not infested, 4 = eggs/cc soil of *M. incognita*, 40 = chlamydospores. chains/cc soil of *T. basicola*. Means within columns followed by the same letter are not significantly different by LSD ($p < 0.05$).

Molecular Diversity and Polymorphism Information Content of Selected *Gossypium hirsutum* Accessions

M.V. Sharma, S.K. Kantartzi, and J.M. Stewart[1]

RESEARCH PROBLEM

The narrow genetic base of cultivated cotton germplasm is hindering the cotton productivity worldwide. The objective of the present study is to evaluate the genetic diversity within *Gossypium hirsutum* accessions using simple sequence repeat (SSR) markers.

BACKGROUND INFORMATION

Effective use of *Gossypium hirsutum* L. lines in cotton genetic improvement programs depends on the extent of genetic variation for desirable alleles and the accurate characterization of the variability among germplasm accessions. Marker assisted selection has provided the potential for efficient development of disease and pest resistant plants.

Association mapping is used to identify chromosomal regions containing disease-susceptibility loci or loci involved in other phenotypic traits of interest like fiber quality. It has been advocated as the method of choice for mapping complex-trait loci. Such studies are very limited in cotton and therefore are important for cotton breeding. *Gossypium hirsutum* accessions with resistance to reniform nematodes from the USDA collection were evaluated and genotyped with SSR markers.

RESEARCH DESCRIPTION

Both genetic diversity and association mapping is based on the strength of association between the genetic marker and phenotype. For the current study, we have used 96 accessions, screened for partial reniform nematode resistance using chromosome specific primers sets. These accessions are from the USDA collection.

[1] Graduate assistant, post doctoral associate, professor, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville

Genomic DNA was obtained from the greenhouse grown plants using DNeasy plant mini kits. Polymerase chain reaction (PCR) was performed and polymorphisms at each locus were assessed by electrophoresis of the PCR products in a vertical gel system on a polyacrylamide gel. The profiles produced by SSR markers were scored manually: each allele was scored as present (1) or absent (0) for each SSR locus (Table 1).

Genetic diversity was calculated at each locus for allelic Polymorphism Information Content (PIC), with program CERVUS version 2.0 based on allelic frequencies among all 96 genotypes analyzed. The PIC values for each SSR were estimated by determining the frequency of alleles per locus using the following formula:

$$PIC = 1 - \sum x_i^2$$

where x_i is the relative frequency of the ith allele of the SSR loci. Markers were classified as informative when PIC was ≥ 0.5.

For association analysis, the Excel spreadsheet was run through softwares STRUCTURE and TASSEL. The program STRUCTURE implements a model-based clustering method for inferring population structure using genotypic data consisting of unlinked markers. TASSEL (Trait Analysis by aSSociation, Evolution and Linkage) uses most advanced statistical methods to maximize statistical power for finding a Quantitative Trait Locus (QTL).

RESULTS AND DISCUSSION

For the genetic diversity, the primer sets yielded 177 alleles of which 173 were polymorphic and were amplified by 48 SSR primers. The mean number of alleles per locus was 3.40 (StDev 0.995), but the number varied from 1 to 4. The PIC values ranged from 0.00 to 0.95 and the relation with the number of alleles is shown in Fig. 1. Seventy-two percent of markers used had PIC values of 0.50 or greater. In our study, the majority (80%) of the informative SSRs contained at least 10 repeats. Although contradictory references also exist (e.g., Struss and Plieske 1998), a similar positive relationship between the number of tandem repeats and the level of polymorphism also was observed in tomato (Smulders et al., 1997) and maize (Vigouroux et al., 2002).

CONCLUSION

Analysis of genetic distance and population structure provided evidence of no significant population structure in the *G. hirsutum* accessions. The results provide preliminary insight into the SSR informativeness of the cotton genome and are very useful as a framework for future studies in cotton that will accelerate

development of superior cotton cultivars. These tests between SSR markers using their PIC values suggests that the majority of the informative SSRs were present between these accessions as their PIC values were 0.5.

These results provide preliminary insight into the cotton genome and are very useful as a framework for future 'association studies' in cotton that will accelerate development of superior cotton cultivars through the AMAS program. These tests between 52 markers using a general linear methodology suggest that a significant association between these accessions does not exist. A more detailed study of the population structure must to be done in order to find more associations among the accessions.

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Table 1. Scoring for the presence of nematodes.

Accessions	Primer 0827	Primer 0834	Primer 0946	Primer 1047	Primer 1064
TX1	1	1	1	0	1
TX5	1	1	1	1	1
TX9	0	1	1	1	1
TX10	0	1	1	1	1
TX11	0	1	1	1	1
TX16	1	1	1	1	1
TX17	1	1	1	1	1
TX18	0	1	1	1	1
TX19	1	0	1	0	1

Methodology for Rapid Differentiation of Genotypes of Cotton (*Gossypium* spp.*)* with Molecular Markers

A. Acuña and J.M. Stewart [1]

RESEARCH PROBLEM

There is a wide range of genotypes of cotton in the world and only a few genebanks that collect all genotypes. There are not enough methodologies to differentiate genotypes; for that reason it becomes necessary to implement tools in order to facilitate the rapid identification of genotypes with cotton breeding purposes. To ensure the improvement of most phenotypic traits, the molecular identification of plant material is required, which is necessary to integrate the tools of molecular biology and traditional methods (Kohel and Yu, 2002).

BACKGROUND INFORMATION

The differentiation of species of the GenBank can be made, using molecular markers, which are a successful tool for this objective (Kohel and Yu, 2002). Historically molecular markers have been a tool in genetic and molecular studies as they are a reliable source for differentiation between species and genetic background, they are not likely to be affected by environmental conditions, they are useful in any stage of the plant's life and they exhibit high polymorphism. (Magalhães et al., 2006). According to Burke and Stewart (2004), the use of phenotypic characteristics have been used amply for breeders and geneticists; at the same time, this phenotypic characteristic presents a major problem when the species come from the cytoplasmatic lines or from common ancestors because the morphological characteristics are minimal and cannot be differentiated. For that reason, it is necessary to develop molecular markers that give the possibility of differentiation. This study developed a molecular key from specific molecular markers for the differentiation of genotypes of cotton (*Gossypium* spp.).

RESEARCH DESCRIPTION

The species A *(G. herbaceum)*, B1 *(G. anomalum)*, B3 (G. capitis- veridis) C1 (*G. sturtianum)*, D1 (*thuberi*), E2 (*somalence*), F (*longicalix*) and G (*australe*),

[1] Graduate student and professor, respectively, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

within the genome D differentiated genotypes D1, D4 (*G. aridum*), D5 (*G. raimondii*), D2-1 (*G. armorianum*), D3-d (*G. davidsonii*), D8 (*G. trilobum*) were evaluated with mitochondrial markers. The differentiation was performed on isolated DNA from young leaves of each species. We worked with the extraction kit DNeasy® Plant Mini Kit (250) from Qiagen Sciences (Germantown, Md.), according to the specifications of the manufacturer. Markers were designed to the evaluation of the sequences through the use of the program CLC Sequence Viewer 5. Primers of AD_1 and AD_2 were obtained from the evaluation of the alignments between the sequences of *Gossypium barbadense* (accession number NC 008641) and *Gossypium hirsutum* (accession number NC 007944) from NCBI and with the alignment of the sequences of the specific locus of each species obtained from Cronn et al., 2002. The analysis of amplification products was performed in 3% Metaphor® gels (Cambrex Bio Science Rockland, Inc., Me.) stained with ethidium bromide.

RESULTS AND DISCUSSION

The evaluation of the different genotypes of cotton with each marker allowed us to obtain a distinctive band for each species (Table 1). In Fig. 1, it can be seen how genotypes that have the D genome present a 400 bp band feature, which appears through amplification with marker-TrnK matk.

PRACTICAL APPLICATIONS

Due to the genetic closeness of their common ancestor, it was not possible to separate the A and G genomes; for this reason the development of new markers is necessary for differentiation of each genome with a specific band; probably with the use of single nucleotide polymorphisms (SNPs), favorable results can be obtained. This is a molecular key tool for the molecular differentiation of these genotypes and facilitates this development through the work of genetic improvement. The methodology developed in this research is reliable and accurate for the use of molecular markers in the development of molecular codes. Molecular markers not influenced by the environment show genetic stability and can be used in several laboratories in different locations and produce the same answer.

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Table 1. Primer set design.

Marker	*Primer forward*	*Primer reverse*	*Annealing Temperature*
TrnK-matK	CCGATTTGTGCGTATATCCAG	ATACTCGGCCAATCCCCTCT	55
TrnT-TrnL	AGATTTCATTTAATCGATCGA	TTTCTATGGGTTGCATCT TTTT	47
Rpl16 BR	GATTATGAATAGATCGAAATG	GCCATCCTCCCCGATAAAT	55
COX 2/2-3	TAGAACAGCTTCTACGACG	GGTTTACTATGGTCAGTGC	55
Arboreum	CCCTTCGAGTATTCCACCCAA	TCCTTTCCCCCTTCTTTCAT	52
Somalense 1751	TCGTGCTGAGAAAGGGATTT	TTCGATGCGGAATCAATGTA	55

KEY

1. Run Genomes (A-B-C-D-E-F-G), with primer TrnT - TrnL

1.1. If found band between 200bp to 250bp found genome…..B

1.1.1. Run genomes (B1, B3) with primer Rpl16 BR

1.1.1.1 If band between 400 to 450 bp found genome…… B1

1.1.1.2 If not band between 400 to 450 bp found genome……B3

1.2. If no band between 200 to 250 bp go to…..2

2. Run genomes (A-C-D-E-F-G), with primer TrnK- matK

2.1. If band of 400 bp is genome…..D

2.1.1. Run genomes (D1- D2/1- D3/D-D4-D5-D8) with primer TrnT- TrnL

2.1.1.1 If band of 450 bp found genome.....D8

2.1.2. Run genomes (D1- D2/1- D3/D-D4-D5)with primer TrnK-matK

2.1.2.1 If band of 450 bp found genome….D2-1

2.1.3. Run genome (D1- D3/D-D4-D5) with primer COX 2/ 3

2.1.3.1 If band of 1100 bp found…..D1

2.1.4. Run genome (D3/D-D4-D5) with primer Somalense

2.1.4.1 If not band of found genome…….D5

2.1.5. Run genome (D3/D-D4) with primer Rpl 16 + Eco RI and MseI

2.1.5.1 If band of 120 bp found genome…….D4

2.1.5.2 If not band of 120 bp found genome…..D3-d

2.2. If not band of 400 bp go to ……3

3. Run genomes (A-C-E-F-G), with primer COX2 / 3

3.1. If band of 1200 bp found genome ……F

3.2. If not band 1200 bp go to……4

4. Run genomes (A-C-E-G), with primer Rpl 16 + Eco RI and Mse I

4.1. If band of 120 bp found genome……C

4.2. If not band of 120 bp go to…..5

5. Run genome (A-E-G), with primer Arboreum

5.1. If not band of 300 bp found genome.....E

5.2. If band of 300 bp go to ……6

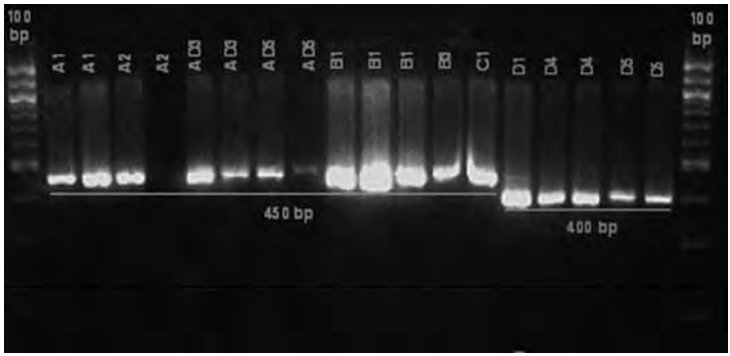

Fig. 1. Primer set TrnK matk, and differentiation of the D genome with the presence of the 400 bp band.

Economical Weed Control Solutions in the Presence of Glyphosate-Resistant Palmer Amaranth

K.J. Bryant, K.L. Smith, R.C. Doherty, J.A. Bullington and J.R. Meier[1]

RESEARCH PROBLEM

Weeds that are resistant to glyphosate threaten the progress of no-till adoption by cotton farmers. Glyphosate-resistant pigweed is believed to be the greatest obstacle cotton farmers have faced thus far in the war on Roundup resistance. Weed scientists with the University of Arkansas Division of Agriculture are examining alternatives for producing cotton in the presence of this pest. This study examined those weed management alternatives from an economics perspective in an effort to identify the economic incentives that cotton farmers face when deciding to increase or decrease their no-till acres in cotton.

BACKGROUND INFORMATION

The advent of glyphosate-resistant (GR) cotton cultivars, and especially flex cotton, has made no-till cotton much more feasible in Arkansas the last ten years. In 2009, 99% of the cotton acreage in Arkansas was planted with a Roundup Ready or Roundup Ready Flex cotton variety (USDA, 2009). Being able to spray cotton with a broad spectrum herbicide over-the-top that is effective on pigweed has allowed our farmers to eliminate mechanical weed control.

Palmer amaranth is known to be glyphosate resistant and one of the most common and troubling weeds in Arkansas cotton production. In 2008, 215,475 cotton acres were infested with glyphosate-resistant palmer amaranth (Doherty et al., 2009).

RESEARCH DESCRIPTION

Cotton plots were planted in Arkansas in 2008 and 2009 in cotton fields infested with GR pigweed by University of Arkansas weed scientists (Smith,

[1] Director, extension weed specialist/professor, program technician, program technician, and program technician, respectively, Southeast Reserch and Extension Center, Monticello.

2009). Multiple weed control strategies were compared and the percent control of Palmer amaranth was rated for each treatment. The weed control strategies employed both Roundup Ready Flex varieties and Liberty Link varieties. Yield data were not collected in either year.

The cost per acre for each weed control strategy was calculated using a computerized budget generator program. Input costs used were those from the 2009 Cost of Production Estimates for Arkansas cotton (Stiles and Barber, 2008). The cost per acre and percent weed control were then graphed and the efficient set of weed control alternatives was determined.

RESULTS AND DISCUSSION

Of nine Roundup systems examined in 2008, three comprise the efficient set and two of those gave weed control levels of 98% or greater (Table 1). The strategy that consisted strictly of four in-season Roundup applications cost $62 per acre in material and application and resulted in 93% control of Palmer amaranth. Treatment six incorporated some residual herbicides pre-emergence, at the one leaf stage, at the eight leaf stage and at lay-by for a cost of $97/acre and resulted in 98% control. Treatment four incorporated some different residual herbicides at those same time periods and obtained 100% control at a cost of $114/acre.

Of seventeen Liberty Link systems examined in 2008, five comprise the efficient set and three of them resulted in 99% to 100% control of palmer amaranth (Table 2). Using the Liberty Link system, 100% control of GR pigweed was obtained at a cost of $67/acre in material and application. This is $47/acre less than the Roundup Ready Flex alternative that gave 100% control.

Liberty Link varieties have not yielded as well as the Roundup Ready Flex varieties in Arkansas to date (Bourland et al., 2009), so planting Liberty Link cotton to combat GR pigweed and maintain a no-till system often results in a reduction in gross revenue. In the 2008 Arkansas cotton variety test, only one Liberty Link variety was included in the two-year average lint yields for 2007-2008. It yielded 200 pounds less than the top five yielding cultivars in the test. The cost savings of the Liberty Link system reported here will only support a 65 to 90 pound per acre yield reduction.

In 2009, nine of the Liberty Link systems were repeated and nine Roundup Ready Flex systems were examined. The weed control results for the Liberty Link system are presented in Table 2. The Roundup Ready Flex strategies were somewhat different than those examined in 2008 so they are not directly comparable. The Roundup Ready Flex systems for 2009 are presented in Table 3. In 2009, 100% control was obtained for only $82/acre.

PRACTICAL APPLICATION

The ability to control glyphosate-resistant pigweed in cotton without mechanical tillage is imperative if no-till cotton production is to remain economically viable in

Arkansas. This study obtained 100% control of glyphosate-resistant pigweed using residual herbicides and hooded-directed sprays, but no mechanical weed control. However, this results in a $22 to $50/acre increase in herbicide and application cost in a Roundup Ready Flex system and two post-directed applications. This same level of control was also obtained in a Liberty Link system with only a $9 increase in cost. Cotton yield data was not collected in this study, making it impossible to calculate returns over weed control for each of the systems.

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Table 1. Cost and percent control of glyphosate-resistant palmer amaranth utilizing a Roundup Ready Flex cotton cultivar, Ark. 2008.

Treatment[1]	Cost of herbicide and application	Percent control on 9/8/2008
1	$ -	0%
9	***$ 62.19***	***93%***
8	$ 84.97	89%
6	***$ 97.27***	***98%***
7	$ 99.74	94%
2	$ 107.83	94%
3	$ 107.83	93%
4	***$ 113.91***	***100%***
5	$ 113.91	95%

[1] Treatments in bold italics indicate those comprising the efficient set. For details on the materials, rates and timings of each treatment see Smith, 2009.

Table 2. Cost and percent control of glyphosate-resistant palmer amaranth utilizing a Liberty Link cotton cultivar, Ark. 2008 and 2009.

Treatment[1]	Cost of herbicide and application	Percent control on 9/8/2008	Percent control on 8/27/2009
1	$ -	0%	0%
8	***$ 58.16***	***78%***	
9	***$ 61.67***	***86%***	***88%***
4	***$ 63.73***	***99%***	
10	$ 65.08	75%	
3	***$ 67.07***	***100%***	
2	***$ 67.14***	***100%***	***100%***
17	$ 71.77	80%	94%
6	$ 77.34	100%	
16	$ 80.77	98%	100%
7	$ 82.04	98%	
5	$ 82.11	100%	100%
14	$ 82.26	86%	100%
12	$ 85.62	99%	
15	$ 85.70	88%	
11	$ 89.03	100%	100%
13	$ 97.21	96%	100%

[1] Treatments in bold italics indicate those comprising the efficient set. For details on the materials, rates and timings of each treatment see Smith, 2009.

Table 3. Cost and percent control of glyphosate-resistant palmer amaranth utilizing a Roundup Ready Flex cotton cultivar, Ark. 2009.

Treatment[1]	Cost of herbicide and application	Percent control on 8/27/09
2	$ -	0%
17	***$ 60.84***	***65%***
11	***$ 68.88***	***98%***
18	$ 69.72	71%
16	$ 77.90	94%
12	***$ 82.30***	***100%***
15	$ 82.76	99%
13	$ 86.84	99%
14	$ 89.18	96%

[1] Treatments in bold italics indicate those comprising the efficient set. For details on the materials, rates and timings of each treatment see Smith, 2009.

Effect of Deep Tillage and Rye on Palmer Amaranth Seed Burial and Emergence in Cotton

J. D. DeVore, J.K. Norsworthy, J.A. Still, G.M. Griffith, and D.B. Johnson

RESEARCH PROBLEM

Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) is fast becoming a major concern of Arkansas crop producers. Palmer amaranth is causing many problems in Arkansas cotton fields by lowering yields and reducing harvesting efficiency. With Arkansas cotton producers relying heavily on glyphosate-resistant cotton, an alternative solution to controlling resistant Palmer amaranth is needed.

BACKGROUND INFORMATION

For several years, many farmers have been relying on glyphosate as their primary herbicide for weed control. During this time, weeds such as Palmer amaranth have evolved resistance to glyphosate due to repeated applications annually. Glyphosate-resistant Palmer amaranth is the most problematic weed for cotton producers across the South. Some of the reasons Palmer amaranth is so troublesome are: season-long emergence (Jha et al. 2006), high competitiveness and rapid growth rate of up to 6 ft or more (Garvey 1999; Norsworthy et al. 2008), resistance to herbicides, and exorbitant seed production (Keeley et al. 1987). This rapidly growing weed can greatly reduce cotton lint yields by as much as 92% at only 0.08 plant/ft^2 (Rowland et al. 1999). With ever-increasing production costs, an efficient and effective management strategy must be developed. Control is critical in small infested areas to prevent spread even further. It was reported by Griffith et al. (2009) that if glyphosate-resistant Palmer amaranth is not controlled in the first year of its occurrence, it is capable of moving up to 375 feet across a field from the original source in just one year. The importance of controlling an outbreak of glyphosate-resistant Palmer amaranth is evident.

[1]Graduate assistant, associate professor, progrm technician, graduate assistant, respectively, Crop, Soil, and Environmental Sciences Department, Fayetteville.

RESEARCH DESCRIPTION

A field experiment was conducted at the Lon Mann Cotton Research Station in Marianna, Ark., in which a rye cover crop was tested in combination with deep tillage and no tillage to determine the impact on Palmer amaranth emergence and soil seedbank numbers. This experiment was organized in a randomized complete block design with a two by two factorial arrangement of treatments replicated four times. The first factor was no tillage and deep tillage using a mouldboard plow. The second factor was no cover and a rye cover crop. A 22 ft^2 area was marked in the center of each plot (8 rows by 200 ft) by GPS. Once marked, 500,000 glyphosate-resistant Palmer amaranth seed were placed within the 22 ft^2, and then the plot was disked twice. Half of the plots were deep tilled and half were not (factor A – tillage). During the growing season, five counts were taken to determine the number of Palmer amaranth that emerged within the center of the plot. Soil cores were taken at 0 to 6 inches and 6 to 12 inches in the fall of 2008 immediately after deep tillage and again in the fall of 2009. Evaluation of the seed content in these cores is ongoing in the greenhouse.

RESULTS AND DISCUSSION

Both the tillage and the cover crop reduced Palmer amaranth emergence in cotton but the combination of the two provided the greatest control with an 85% reduction in emergence (Table 1). With an average of 2.4 to 2.9 plants/ft row, there was no impact on stand counts among the treatments. Yield was not impacted for both the cover crop and no cover crop treatments, averaging 2400 to 2430 lbs/A of seedcotton. Obviously, cover crops and deep tillage will not eliminate glyphosate-resistant Palmer amaranth; however, use of these tools will likely reduce the risks of failures associated with residual herbicides. Additional efforts should focus on the integration of the best practices identified in this research with use of residual herbicides.

PRACTICAL APPLICATION

This research demonstrates the importance of using cultural practices as a means of controlling glyphosate-resistant Palmer amaranth. Using these methods in combination with a non-glyphosate herbicide program could effectively control resistant Palmer amaranth. However, these data do not suggest that all cotton producers should move back to deep tillage practices on vast acreage as it is not environmentally sound, nor is it going to remain an effective form of weed control if deep tillage is implemented year after year. These data suggest that if a producer has an outbreak of resistant Palmer amaranth, then a one-time turning of the soil with a mouldboard plow in the infested area should effectively bury most of the Palmer amaranth seed where it can then be managed using a cover crop and a non-glyphosate herbicide program.

ACKNOWLEDGMENTS

Support for this research provided by Monsanto and the staff at the Lon Mann Cotton Research Station, Marianna, Ark., is gratefully acknowledged.

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Table 1. Palmer amaranth emergence in cotton.

Tillage	Cover crop	Counting date: May 21 2009	Jun 15 2009	Jul 9 2009	Aug 4 2009	Aug 19 2009	Total emergence
		#/plot					
None	None	2064 a[1]	1751 a	518 a	31 a	20 a	4384 a
None	Rye	471 b	611 b	387 a	28 a	3 a	1500 b
Mouldboard	None	631 bc	626 b	346 a	26 a	2 a	1631 b
Mouldboard	Rye	108 c	298 c	216 a	23 a	0 a	645 c

[1] Means within a column followed by the same letter are not significantly different (P = 0.05). Different letters within each column represent a statistically significant difference in mean emergeance between treatments.

Crop Protection and Tillage – Focusing Management to Build Sustainable Cotton Systems

T.G. Teague[1], C. Shumway[1], S. Green[1], J. Bouldin[2], and L. Fowler[3]

RESEARCH PROBLEM

Conservation tillage has become a standard practice for many Midsouth cotton producers. Cover crops of wheat, oats or rye often are used in these systems to reduce damage associated with wind and blowing sand. Cover crops also can enhance weed management. Presence of cover crops also can result in reductions in thrip infestations in cotton compared to conventionally tilled systems. Interest in nitrogen-fixing legume cover crops has increased in response to high costs of fertilizer.

BACKGROUND INFORMATION

One concern among producers and their crop advisors is the potential for outbreaks of pest insects such as tarnished plant bugs in low-till systems because of increased availability of plant hosts in spring, as well the "low spray" environments in the post-boll weevil era. As managers examine ways to reduce costs and increase use of their on-farm mechanization and technology investments, they may consider increasing use of preventative approaches for pest control to reduce the management intensive practices of scouting and crop monitoring required for an Integrated Pest Management (IPM) strategy. In this report, we summarize results from year two of a planned multi-year study comparing crop protection practices across different tillage systems.

RESEARCH DESCRIPTION

The experiment was installed in fall 2007 at the Cooperative University Research Station on the Judd Hill Foundation Farm near Trumann, Ark. It was

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[2] Assistant research professor, Ecotoxicology Research, Arkansas State University, State University.
[3] Farm foreman, Northeast Research and Extension Center, Keiser.

arranged as a split-plot design with 3 tillage systems, 1) conventional, 2) no till, or 3) no till + legume/cereal cover crop (cover crop), considered main plots. The crop protection regimes were considered sub-plots. Treatment details for the 2009 sub-plot treatments are listed in Table 1. A summary for the first year results can be found in Teague et al. (2009).

Cruiser treated (thiamethoxam) cotton (*Gossypium hirsutum* L.) cv. Stoneville 4554 B2RF was planted on 19 May 2009 in the Dundee silt loam soil at 3 to 4 seeds/ft. Production practices were similar across all tillage treatments in-season with the following exceptions: for the cover crop treatment, disk bedders were used to reshape beds in October 2008 after the 2008 harvest, prior to reseeding wheat and clover. The balansa clover (Kaprath Seeds, Inc., Manteca, Calif.) and wheat mixture was seeded at 10 lbs wheat and 8 lbs coated clover seed/acre and was terminated using glyphosate in April 2009. In the conventional main plots, beds were reshaped on 17 April with disk bedders, and then flattened prior to planting with a DO-ALL fitted with incorporation baskets. Row middles (water furrows) were cleared with sweep plows prior to first furrow irrigation in the conventional treatments. No cultivations were made in any treatments. Main plots were 16 rows wide and 450 ft long. Sub-plots were 16 rows wide, 75 ft long with 10 ft alleys.

The COTMAN crop monitoring system (Oosterhuis and Bourland, 2008) was used to document differences in crop development among tillage and crop protection treatments from squaring until physiological cutout. Records of weekly damage assessments and crop response were collected for each crop protection input (pesticides). Extensive pest monitoring included direct and indirect sampling including use of pitfall traps, sweep nets, drop clots for insects, and late season plant mapping using the COTMAP procedure (Bourland and Watson 1990). Plots were harvested with a 2-row research cotton picker, and "grab" samples of seedcotton from each plot were pulled directly from the picker basket during harvest. These samples were ginned on a laboratory gin and submitted to the Fiber and Biopolymer Research Institute at Texas Tech University for HVI fiber quality determinations. All plant monitoring, yield and fiber quality data were analyzed using ANOVA with mean separation using protected LSD.

RESULTS AND DISCUSSION

The no-till planter employed in 2009 resulted in even and efficient planting, and unlike the 2008 season, there were no differences in plant stand establishment observed among tillage systems. Plant stand density at 35 days after planting was 10.6 plants/3 ft across treatments. Squaring initiation was observed earlier in the conventional system compared to no-till and cover crop treatments (Fig. 1); similar observations were made in 2008. Pre-flower sympodial development, depicted in COTMAN growth curves, did not vary among systems in 2009 (Fig. 2). There were no differences in first position square or boll retention among pesticide treatments or tillage indicating low levels of crop damage associated with fruit feeding pests. Plant bug numbers did exceed action thresholds after flowering

(Fig. 3), but numbers were kept below action levels with insecticide applications in appropriate treatments. Final end-of-season plant mapping results from COTMAP sampling showed no retention differences (Table 2). No differences in boll rot or hard lock were associated with either insecticide or fungicide treatment (data not shown).

Significantly higher yields were associated with the cover crop system compared to the no-till and conventional systems, which were not significantly different from one another (Fig. 4). Pest conditions were such that automatic pesticide programs offered no yield benefits in any of the three tillage systems in 2009 (Table 3). Plant bug numbers did exceed thresholds late season, but numbers increased near the time of the flowering date of the last effective boll population and were insufficient to affect yield. The fungicide, Headline, did not protect foliage or bolls such that a yield response was measurable. A lack of yield response to the fungicide was notable in a year with high rainfall coupled with variable temperatures (Table 4). No yield response to the fungicide was observed in 2008.

Results from HVI analyses in 2009 showed no differences in fiber quality associated with tillage system, but crop protection inputs did affect micronaire and uniformity (Table 4). Micronaire values from samples from insecticide treated plots were significantly lower than those from the untreated check. It is likely that late-season insecticide applications protected upper canopy bolls from plant bug feeding during the August infestation. Those late upper canopy bolls produced fiber with lower micronaire values. Blending fiber from those bolls with older bolls during harvest lowered overall values. Similar factors may have affected fiber uniformity, which was significantly lower in plots receiving fungicide.

CONCLUSIONS

The cover crop system resulted in a significantly higher yield than either no-till or conventional tillage in 2009. In the first year of the study in 2008, yields were reduced with low-till and cover crops; lower yields likely were related to crop stand establishment and delayed growth in the first 35 days after planting. Changes in planter configuration in 2009 as well as delayed date of planting (because of rains) resulted in uniform stand among treatments and warmer soil conditions for early season plant development. A specific explanation for the higher yields associated with cover crops is unknown, but the ongoing work to evaluate changes in soil physical and chemical properties for each of the tillage systems may provide some clues.

Automatic applications of insecticides and fungicides did not improve yield in either year. Such an approach to cotton production in the 21st century is neither economically or environmentally sustainable. A sustainable cotton system incorporates an IPM strategy. Automatic, preventative foliar applications of pesticides result in unneeded additional expense and pose risks for environmental contamination. Automatic applications increase risk of pest resurgence and

secondary pest outbreaks, and they can lead to selection of resistant pest populations. Crop monitoring, scouting, and applying chemical control options only when needed are a distinguishing characteristic of the cotton culture of Arkansas where IPM has a long and prominent history. An IPM strategy is a key component in a sustainable cotton system.

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Table 1. Pesticide application descriptions including product, rate, and timings for the four pest control sub-plot treatments in 2009 JH trial.

Treatment Description	Pesticide (rate/acre) application date
Early, Mid, & Late season Insecticides[1]	Centric (2oz) 19 June; Trimax (1.5 oz) 26 June, 8 July; Centric (2oz) 20 July; Bidrin (6 oz), 10 Aug and Bidrin XP (10.6 oz) 18 Aug
Early, Mid & Late season Insecticides + Fungicide[2]	Centric (2oz) 19 June; Trimax (1.5 oz) 26 June, 8 July, Centric (2oz) 20 July; Headline (9 oz) 20 July, 10 Aug; Bidrin (6 oz), 10 Aug and Bidrin XP (10.6 oz) 18 Aug
Threshold Insecticide[3]	Centric (2oz) 20 July; Bidrin (6 oz), 10 Aug and Bidrin XP (10.6 oz) 18 Aug
Untreated Check	

[1] Automatic insecticide applications were directed at preventing tarnished plant bug and stink bug infestations. All applications were made with a tractor mounted high clearance sprayer equipped with 8 row boom. Insecticides included were Trimax (imidacloprid), Bidrin (dicrotophos), and Centric (thiamethoxam).

[2] Headline fungicide (pyraclostrobin) was applied for prevention/control of foliar diseases and boll rot.

[3] Insecticide was applied for plant bug control using the UA MP144 recommended action threshold of a mean 3 bugs per drop cloth sample. Final insecticide application occurred at cutout + 160 DD60s.

Table 2. Results from final end-of-season plant mapping using COTMAP for tillage main plot effects- 2009[1].

	Mean per plant for management treatment				
Category	**Conventional**	**Cover Crop**	**No Till**	***P > F***	**LSD_{05}**
1st Sympodial Node	7.1	7.2	6.8	*0.13*	
No. Monopodia	2.0	2.1	1.9	*0.49*	
Highest Sympodia with 2 nodes	11.6	10.9	11.0	*0.25*	
Plant Height (inches)	43.0	42.1	42.6	*0.86*	
No. Effective Sympodia	10.1	9.6	9.6	*0.12*	
No. Sympodia	15.0	14.4	14.3	*0.26*	
No. Symp. with 1st Position Bolls	4.9	5.2	4.8	*0.29*	
No. Symp. with 2nd Position Bolls	1.3	1.4	1.2	*0.51*	
No. Symp. with 1st & 2nd Bolls	1.2	0.8	0.9	*0.28*	
Total Bolls/Plant	10.1	9.2	8.6	*0.16*	
% Total Bolls in 1st Position	61.6	65.4	67.4	*0.05*	*4.56*
% Total Bolls in 2nd Position	24.5	22.9	23.6	*0.70*	
% Total Bolls in Outer Position	6.1	3.7	3.7	*0.01*	*1.25*
% Total Bolls on Monopodia	7.6	8.0	5.3	*0.10*	
% Total Bolls on Extra – Axillary	0.1	0.0	0.0	*0.44*	
% Boll Retention - 1st Position	41.1	41.2	39.7	*0.65*	
% Boll Retention - 2nd Position	21.4	19.3	18.7	*0.42*	
% Early Boll Retention	44.3	40.7	38.7	*0.13*	
Total Nodes/Plant	21.1	20.6	20.2	*0.22*	
Internode Length (inches)	2.0	2.1	2.1	*0.34*	

[1] Means of 10 plans per plot.

Table 3. Crop protection treatment effects on yield and fiber quality measures (HVI) in 2009[1].

Yield and Fiber Quality Category	Crop Protection Treatment					
	Automatic insecticide	Automatic insecticideplus fungicide (Headline)	Insecticide (threshold)	Untreated Check	P>F	LSD_{05}
Lint yield (lb/acre)	1087	1167	1111	1088	0.47	
Micronaire	4.0	3.9	3.9	4.3	0.02	0.27
Length	1.1	1.1	1.2	1.1	0.30	
Uniformity	83.5	82.5	83.2	83.4	.02	0.58
Strength	29.3	29.3	29.6	30.1	0.08	
Elongation	7.2	7.4	7.5	7.5	0.49	
Rd	68.6	69.4	69.2	70.1	0.16	
+b	8.4	8.5	8.4	8.5	0.92	
Leaf	7.1	6.7	7.6	6.7	0.21	

[1] Samples were taken from picker basket, ginned on laboratory gin, and sent to Texas Tech for HVI testing.

Table 4. Average monthly heat unit (DD60s) and precipitation accumulation, 1960-2007 for Northeast Arkansas[1] compared to 2009 on-farm measurements at Judd Hill.

	Heat Units (DD60s)		Rain (inches)		2009 Deviation from Average	
Month	Average	2009	Average	2009	Heat Units	Rainfall
June	532	620	3.89	4.62	88	0.73
July	644	542	3.67	8.25	-102	4.58
August	583	506	2.85	3.83	-77	0.98
September	363	368	3.73	4.75	5	1.02
October	127	35	3.3	12.38	-92	9.08
					-162	16

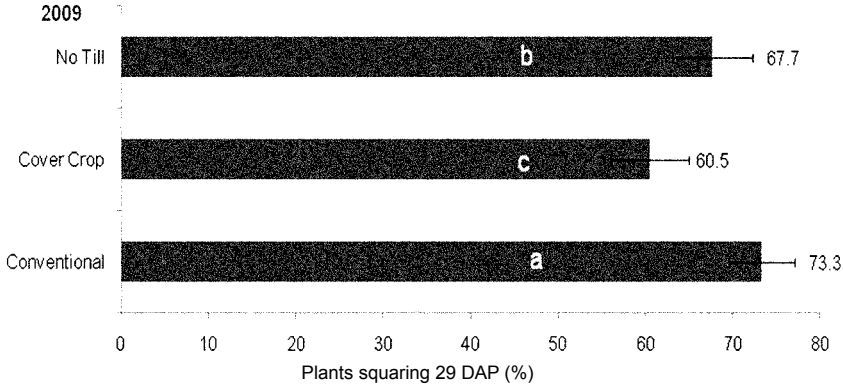

Fig. 1. Effect of tillage system on squaring. Plants in the conventional tillage treatment had highest mean % of plants (±SEM) squaring early season compared to no-till and cover crop treatments at 29 days after planting indicating a significant developmental delay associated with tillage system.

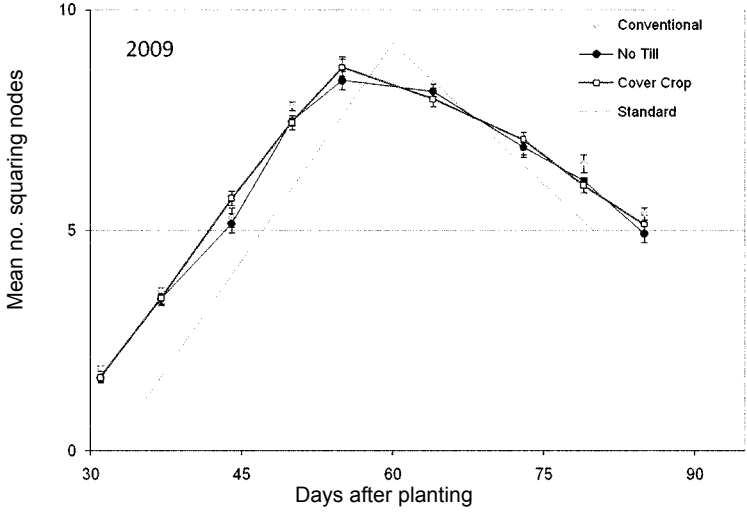

Fig. 2. COTMAN growth curves for tillage system main plots indicate similar mainstem nodal development among plants in the tillage treatments measured using the Squaremap procedure season long (means are based on 10 plant samples of 5 consecutive plants in two adjacent rows).

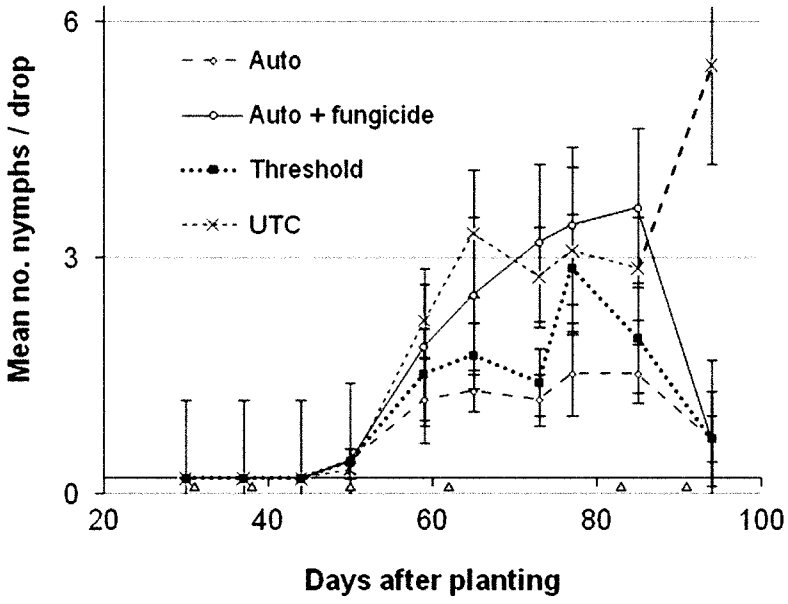

Fig. 3. Plant bug field population densities, monitored weekly using drop cloth sampling, increased after flowers around 60 days after planting. Insecticide application dates are indicated on the x-axis.

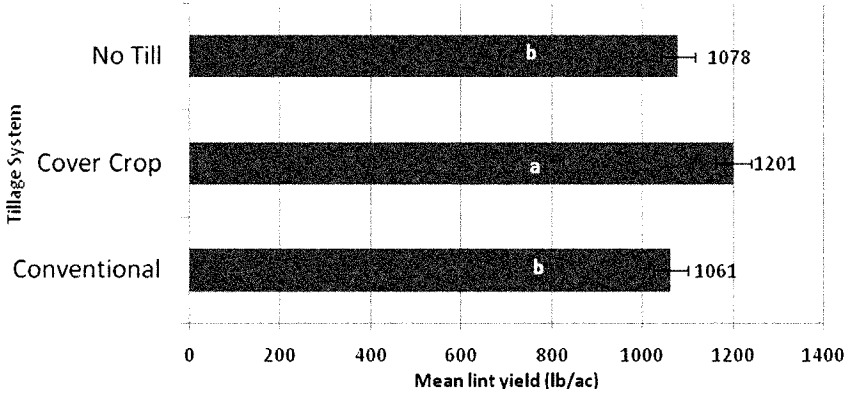

Fig. 4. Effect of tillage system on lint yield. Mean lint yield (±SEM) for 2009 main plot tillage treatments; highest yields were harvested in the cover crop system compared to conventional and no-till (P = 0.01; LSD05 = 38).

Three Year Summary Evaluating Twin-Row Spacing and Seeding Rates for Cotton at Marianna

T. Barber[1], F.M. Bourland[2], D. Stephenson[3], and J. Chapman[4]

RESEARCH PROBLEM

Cotton production costs especially costs associated with cotton seed and planting have increased at an alarming rate over the last several years. Varieties containing transgenic traits are planted across the majority of the acreage in Arkansas. With the rising costs of seed and technology fees, producers are looking for ways to reduce seeding rates without affecting yield. The ground work for a high yielding crop has to start with an accurate and efficient planting system to ensure an optimum stand. However, there are a variety of new systems and techniques to incorporate compared to the conventional system that has been used for so long. These new seeding patterns and rates may help stand consistency and may lower cost of seed due to lower use rates. This study was conducted to elucidate optimum cotton seeding configurations and rates that will maximize plant health and yield in three cotton seeding patterns.

BACKGROUND INFORMATION

Experiments were conducted at the Lon Mann Cotton Research Station in Marianna on a Calloway silt loam soil. Cotton was seeded at both locations with a John Deere 1700 MaxEmerge Vacuum planter equipped with a SeedStar hydraulic variable-rate seed drive (38-inch single row and 15-inch twin row) and a Monosem Precision NG Twin row Vacuum planter equipped with a Rawson Hydraulic variable-rate seed drive (7.5-inch twin row). Both planters are equipped with variable-rate seed drives to emulate the planters used by producers who wish to vary their seeding rates within a specific area.

Cotton (*Gossypium hirsutum* L.) cv. Stoneville 4554 B2RF was seeded in all planting patterns, seeding rates and configurations, between 15 May and 20 May each year at approximately 0.75-inches deep. Pest and crop management strategies

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[2] Director/professor, Northeast Research and Extension Center, Keiser.
[3] Assistant professor, Dean Lee Research Station, Alexandria, Louisiana.
[4] Program technician, Crop, Soil, and Environmental Sciences, Department, Little Rock.

were based on Arkansas Cooperative Extension Service recommendations. Conventional tillage and furrow irrigation was used. Raised beds were prepared using a 38-inch hipper-roller in the spring and just prior to planting. Following the use of the hipper-roller, bed leveling was not required because the hipper-roller provided a 20-inch wide bed.

Cotton emerged between 20 May and 25 May each year. Mixed fertilizer (P and K) was applied per soil sample results and 100 lb nitrogen was applied as a two-way split. Cotton was harvested in late October each year using a John Deere 9930 cotton harvester that was modified with spindle-harvester heads equipped to harvest 15-inch twin-row cotton.

RESEARCH DESCRIPTION

A randomized complete block arranged as a split-plot experimental design was implemented at both locations. Main-plots consisted of three cotton seeding patterns (all seeded atop a 38-inch bed): (1) single rows evenly spaced 38-inches apart; (2) twin rows spaced 7.5-inches apart, with each set of twin rows separated by 38-inches; and (3) twin rows spaced 15-inches apart, with each set of twin rows separated by 38-inches. Split-plots consisted of five cotton seeding rates (seeds per acre): (1) 35,000; (2) 45,000; (3) 55,000; (4) 65,000: and (5) 75,000.

Data collected included stand counts recorded 2-3 weeks after emergence (WAE), node above white flower (NAWF) counts collected in late-July, percent open boll collected in mid-September, plant structure and cotton boll distribution via plant mapping collected just prior to harvest, seed cotton yield, cotton lint yield, trash and seed percentages, seed and lint indices, seed per acre, and high volume instrument (HVI) measurement of cotton fiber length, uniformity, strength, and micronaire. Data were subjected to ANOVA using PROC MIXED. Main effect and interaction means for cotton seeding pattern and seeding rate were separated with Fisher's protected LSD at $P \leq 0.05$.

RESULTS AND DISCUSSION

Statistical analysis did not indicate a significant interaction with planting pattern and seeding rate when averaged over years therefore all data were reported based on main effects of either planting pattern or seeding rate. Plant structure and yield component data (Table 1) was recorded through plant mapping conducted prior to harvest. Data analysis revealed no statistical difference for the main effect of row configuration when evaluating the average number of vegetative (M) and fruiting (S) branches per plant. There were also no differences in first position fruit retention (P1), total nodes (TN) or average total bolls (TB) per plant. However significant differences were observed with second position fruit retention (P2) as well as plant height (HT), where standard 38 in rows and twin 7.5 in rows retained more fruit in second positions and were generally taller than the 15 in twin-row

patterns. In regard to seeding rates, the number of fruiting branches (S), second position fruit retention (P2) and average total bolls (TB) per plant were higher for the lower seeding rates of 35,000 seeds per acre. These data indicate that as seeding rate (ultimately plant density) increases, cotton plants have less branches and total bolls per plant; however, cotton seeded to achieve a high density of plants may have a greater number of bolls in the first position. This scenario is similar to ultra-narrow-row cotton (cotton seeded in consistently spaced 7 to 10 inch rows), in which the goal is to have short plants that typically produce one to two bolls in the first position. On the other hand, as seeding rate decreases, higher fruit retention was observed with fist and second position fruit, which explains the cotton plant's ability to compensate for lower populations.

Table 2 represents the effects on total bolls per plant across row configurations and seeding rates. Generally very similar results were found across all configurations except the 7.5 in twin-row pattern seeded at 35,000 seed per acre. An average of 15.1 total bolls per plant were recorded, which was significantly higher than any other row configuration for similar seeding rates.

Cotton lint yield was calculated by lint percentages, taken from a 10-saw microgin. Lint yield per acre or lint percent when combined over years was not significant across row configurations or seeding rates (Table 3). High volume instrument fiber quality analysis indicated that no differences in fiber micronaire, length, strength, and uniformity existed among any treatments. These fiber qualities were all with the normal range.

PRACTICAL APPLICATION

Results from this three year study at Marianna indicate that planting pattern and seeding rate will affect cotton maturity, growth and yield parameters, although overall lint yield was not different for any system. Twin-row planting, especially 7.5 in has become popular in grain crops. However, in regard to cotton development and yield on silt loam soils, it has not demonstrated an advantage over current 38 in single row patterns. One benefit of the twin-row system is early canopy development, which may be important for weed management and soil water retention. In regard to seeding rates, 45,000-55,000 seed/A has been the University of Arkansas recommendation for seeding rates and continues to produce maximum yields. However, under optimum conditions seeding rates could be reduced to 35,000 seed/A in order to save on seed costs without affecting yield potential. Such variables such as location, soil type, planting date, environmental conditions, and most importantly, grower preferences, would all need to be taken into consideration before committing to a planting system.

Table 1. Main effects of planting pattern and seeding rate on plant structure as determined by plant mapping.[1]

	Plant Structure and Yield Variables						
Planting pattern	**M**	**S**	**P1**	**P2**	**TN**	**HT**	**TB**
	#	#	#	#	#	#	#
38-inch single row	2.7	13.3	45.1	20.6	18.9	104	12.1
7.5-inch twin row	2.4	13.7	43.4	18.1	19.1	105	10.1
15-inch twin row	2.4	13.0	43.3	15.7	18.5	97	8.5
LSD (0.05)	NS	NS	NS	3.1	NS	6.0	NS
Seeding rate							
35,000 seeds/acre	3.3	14.4	46.5	23.6	19.8	106	14.6
45,000	2.7	13.5	44.7	19.4	19.0	100	10.7
55,000	2.4	13.2	44.3	17.0	18.6	101	9.6
65,000	2.1	12.9	43.0	16.3	18.4	105	8.9
75,000	2.0	12.0	41.0	14.3	18.3	98	8.2
LSD (0.05)	0.4	1.3	NS	3.8	0.8	NS	2.3

[1]Abbreviations: M, number of monopodial branches on main axis; S, number of sympodial branches on main axis; P1, first position boll retention; P2, second position boll retention; TN, average total number of nodes on the main axis above cotyledonary node; HT, plant heights at maturity (cm); TB, average total bolls per plant.

Table 2. Total bolls per plant averaged over years by row spacing and seeding rate as recorded from plant map data.

Seeding Rate	**38 in**	**7.5 twin**	**15 twin**
35,000	10.3	15.1	10.0
45,000	8.5	8.8	8.6
55,000	7.3	8.7	7.9
65,000	7.1	6.4	7.1
75,000	6.4	7.1	6.5
LSD (P = 0.05)		1.5	

Table 3. Main effects of planting configuration and seeding rate on cotton lint yield, turnout and fiber quality characteristics.[1]

	Yield and Fiber Quality						
	SC	LY	TO	MIC	LEN	TR	UNIF
Planting pattern	#	#	#	#	#	#	#
38-inch single row	3455	1420	41.3	4.52	1.12	29.7	83.7
7.5-inch twin row	3293	1381	40.9	4.48	1.12	29.5	84.0
15-inch twin row	3297	1385	42.0	4.58	1.12	29.6	83.4
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS
Seeding rate							
35,000 seeds/acre	3194	1373	42.2	4.44	1.12	29.9	83.6
45,000	3296	1400	41.4	4.57	1.12	29.4	83.9
55,000	3494	1437	41.4	4.53	1.12	29.7	83.7
65,000	3377	1371	41.1	4.54	1.12	29.4	83.8
75,000	3381	1395	41.0	4.53	1.11	29.5	83.6
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS

[1] Abbreviations: SC, Seed cotton yield per acre ; LY, cotton lint yield per acre; TO, turnout (percent); MIC, micronair; LEN, fiber length (in); STR, fiber strength (gr/text); UNIF, fiber length uniformity.

Evaluation of Selected Insecticides for Control of Tarnished Plant Bug (*Lygus lineolaris*) in Arkansas Cotton

D. Scott Akin and J. Eric Howard[1]

RESEARCH PROBLEM

Because of the success of the Boll Weevil Eradication Program (BWEP) and the widespread adoption of Bt cotton, the tarnished plant bug (*Lygus lineolaris* [Palisot de Beauvois]) (TPB) has been responsible for more yield loss and has been the target of more insecticide sprays than any other cotton pest in the mid-south in the last several years (Williams, 2008). As there are several cultural practices that can help manage plant bug numbers (e.g., management of wild hosts, variety selection), insecticides still play a major role in managing populations of this pest. With few insecticides on the market and fewer modes of action in the product pipeline, growers must sometimes resort to tank-mixtures of traditional insecticides for plant bug management (e.g., organophosphates) and insecticides that have activity, but are not generally recommended alone for tarnished plant bug management (i.e., pyrethroids). While not generally recommended as a long-term answer for tarnished plant bug management, this strategy can be used when presented with multiple-pest scenarios or extremely high numbers of plant bugs migrating into a field. Several companies have offered pre-mixes of a traditional plant bug chemistry with a pyrethroid. The objective of this study was to compare the efficacy of the available pre-mix insecticides as well as current "standards" for TPB control.

RESEARCH DESCRIPTION

This experiment was conducted at Moscow, Ark. in 2009 to evaluate selected pre-mix insecticides for control of TPB under typical grower conditions. Treatments included Endigo (lambda-cyhalothrin + thiamethoxam) at two rates, Leverage 360 (imidacloprid + cyfluthrin) at two rates, Leverage 2.7 (imidacloprid + cyfluthrin) at two rates, Hero (zeta-cypermethrin + bifenthrin) at two rates, one rate of Brigadier (bifenthrin + imidacloprid), one rate of Orthene (acephate), and one rate of Bidrin 8 (dictrophos). The plots were 6 rows × 50-ft long and treatments

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were arranged in a randomized complete block design with four replications. Two applications were made and plots were evaluated at 3 and 6 days after treatment 1, and 3 and 7 days after treatment 2. Insect data were collected by shake sheet, evaluating 10 row-ft (2 drops) per plot. Data were analyzed using Agronomic Research Manager 8 (Gylling Data Management, Brookings, S.D. 57006) with Duncan's New MRT ($\alpha = 0.1$).

RESULTS AND DISCUSSION

Nymphs were the predominant life stage observed throughout the duration of the trial. Cotton was too tall for the efficient use of a sweep net (the most efficient method for capturing adults), and the shake sheet is more efficient at capturing nymphs. As a result, only nymph data are reported here. Cotton where this trial was located (Moscow, Ark.) was surrounded by corn, resulting in consistent and sustained plant bug numbers.

At 3 days after treatment 1 (3DAT1), most treatments significantly reduced the number of TPB nymphs compared to the untreated check (Table 1). The only treatments that did not were Leverage 360 evaluated at low use rates (highest labeled rate is 3.2 fl oz/acre) and the high rate of Hero, which is a pre-mix of two pyrethroids. At 6 DAT1, all treatments reduced numbers of TPB nymphs compared to the UTC except for the low rate of Leverage 360. Again, the labeled rate of this product is currently up to 3.2 fl oz/acre. These data demonstrate that while most treatments did significantly reduce TPB numbers at 6 DAT, all treatments were at or above threshold (6 TPB/10 row-feet) at this time. As is often the case in cotton surrounded by corn, a subsequent application may be needed.

At 3 days after treatment 2 (3DAT2), all treatments significantly reduced plant bug numbers below the untreated check. As importantly, all treatments reduced plant bug numbers below the treatment threshold as well at this time. The enhanced efficacy at 3 days after the 2nd treatment compared with the marginal efficacy 3 days following the 1st treatment suggests that subsequent applications may be needed for successful management of sustained or migrating TPB populations. At 7DAT2, most treatments continue to exhibit control of TPB from both a standpoint of keeping populations below threshold as well as significantly lower than the untreated check.

PRACTICAL APPLICATION

Results from this trial suggest that various pre-mix insecticides that contain a traditional organophosphate plus a pyrethroid were very similar in suppression/control of tarnished plant bug. However, few treatments were better than the organophospate standards alone throughout the duration of this particular trial. While pyrethroids have proven to assist with TPB control by tank-mixing with

organophosphates (Akin and Lorenz, personal observation), additional benefit can be noted when other pests (e.g., bollworm) are approaching or at threshold in the field.

LITERATURE CITED

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Table 1. Average numbers of tarnished plant bug nymphs per 10 row-feet for various insecticide treatments 3 and 6 days after 1st application.

	Number TPB nymphs-10 row-ft	
Treatment/Rate	**3 DAT1**	**6 DAT1**
Untreated	16.3 a[1]	16.8 ab
Endigo (4 fl oz/acre)	8.8 bc	9.5 de
Endigo (5 fl oz/acre)	7.0 c	9.3 de
Leverage 360 (2.6 fl oz/acre)	11.5 abc	16.3 abc
Leverage 360 (2.9 fl oz/acre)	13.5 ab	11.8 b-e
Leverage 2.7 (3.8 fl oz/acre)	6.3 c	9.8 cde
Leverage 2.7 (5.0 fl oz/acre)	10.3 bc	8.5 de
Hero (5.2 fl oz/acre)	9.5 bc	12.8 bcd
Hero (6.4 fl oz/acre)	11.8 abc	10.0 cde
Brigadier (6.4 fl oz/acre)	6.8 c	6.0 e
Orthene (0.75 lb ai/acre)	9.3 bc	11.0 b-e
Bidrin (6 fl oz/acre)	7.3 c	12.7 bcd

[1] Means in the same column not followed by a common letter are not significantly different (α = 0.1, Duncan's New MRT, ARM 8).

Table 2. Average numbers of tarnished plant bug nymphs per 10 row-feet for various insecticide treatments 3 and 7 days after 2nd application.

	Number TPB nymphs-10 row-ft	
Treatment/Rate	**3 DAT2**	**7 DAT2**
Untreated	15.8 a[1]	12.5 a
Endigo (4 fl oz/acre)	3.3 b	4.5 bc
Endigo (5 fl oz/acre)	5.8 b	5.5 bc
Leverage 360 (2.6 fl oz/acre)	5.3 b	4.5 bc
Leverage 360 (2.9 fl oz/acre)	5.0 b	5.5 bc
Leverage 2.7 (3.8 fl oz/acre)	5.0 b	8.8 ab
Leverage 2.7 (5.0 fl oz/acre)	5.8 b	5.8 bc
Hero (5.2 fl oz/acre)	4.8 b	4.5 bc
Hero (6.4 fl oz/acre)	5.3 b	1.8 c
Brigadier (6.4 fl oz/acre)	4.8 b	2.5 c
Orthene (0.75 lb ai/acre)	2.5 b	3.5 bc
Bidrin (6 fl oz/acre)	3.8 b	3.3 c

[1] Means in the same column not followed by a common letter are not significantly different (α = 0.1, Duncan's New MRT, ARM 8).

Evaluation of Selected Insecticides for Control of Tarnished Plant Bug (*Lygus lineolaris*) in Cotton, 2009

N. Taillon[1], G.M. Lorenz III[1], K. Colwell[2], H. Wilf[1]

RESEARCH PROBLEM

In recent years the tarnished plant bug (TPB), *Lygus lineolaris*, has become a key pest of cotton. Before 1995, TPB were controlled with insecticides targeting other insect pests such as the tobacco budworm and boll weevil. Since the widespread adoption of *Bt*-cotton and eradication of the boll weevil, we use insecticides targeting these pests less often. As a result, the TPB has become the primary insect pest of cotton in the Midsouth. Recently, TPB has become resistant to several classes of insecticides, further compounding the problem (Catchot, et. al., 2009). This multistate project was conducted to evaluate the efficacy of insecticides currently recommended for control of TPB in the Midsouth.

BACKGROUND INFORMATION

The first plant bug damage in cotton is usually caused by migratory adults entering fields from wild hosts. While the most familiar damage is to small squares, plant bugs also feed on larger squares, tender bolls, and blooms. Damage losses of 50 to 150 pounds of lint cotton can be common in a normal year. However, the impact on yields can be greater than 50 percent yield loss if these pests are abundant and left uncontrolled (Freeman, 1999). In 2009, yield losses due to the tarnished plant bug were estimated at 35,791 bales of cotton in Arkansas, and growers averaged 3.2 insecticide applications for the year at an average cost of $20.18/acre (Williams, et. al., 2009). In some areas of the state, growers treated 10-12 times to achieve control.

RESEARCH DESCRIPTION

The trial was located in Marianna, Ark. on the Lonn Mann Cotton Branch Experiment Station, and was planted to DPL 0924 BGII RF cultivar. Plot design

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[2] Program associate, Entomology, Little Rock Extension Office, Little Rock.

was a randomized complete block with four replications. Plot size was 12.5 ft. × 50 ft. Foliar insecticide applications were made with a mud master on 27 July, 4 and 11 August 2009. Samples were taken on 3, 7, 10, 14 and 17 August 2009. Insect numbers were determined with a 2.5 ft. black drop cloth by taking two drop cloth samples per plot (10 row ft). Square retention for each plot was taken by counting presence or absence of 25 squares on random plants at the third node down from terminal. Data was processed using Agriculture Research Manager Version 8, Gylling Data Management, Inc., Brookings, S.D. Analysis of variance was conducted and Duncan's New Multiple Range Test (P = 0.10) was performed to separate means.

RESULTS AND DISCUSSION

At seven days after the first application, all treatments failed to effectively reduce plant bug numbers compared to the untreated check (Table 1). At three days after the second application, all treatments had significantly fewer plant bugs than the untreated check (Table 2). Orthene, Bidrin, Vydate, Centric, Tri-Max Pro, Carbine, Leverage, and Endigo showed significantly better control than Intruder, Diamond, and Discipline. At seven days after the second application, Endigo had significantly better control than all other treatments, and all other treatments had significantly fewer plant bugs than the untreated check. At three days after the third application, all treatments had significantly fewer plant bugs than the untreated check while Endigo and Orthene showed significantly better control than all other treatments. At harvest, there was a trend for all treatments to have a higher yield than the untreated check; although, differences were not significant.

PRACTICAL APPLICATION

Regional trials such as these help determine the level of control for currently labeled insecticides for comparison in the future to determine if insecticide resistance is occurring. It will help to establish the need for more and different products for the most important insect pest in cotton in the Midsouth. Also, it will aid in improving recommendations for economic and effective control of tarnished plant bug for cotton producers in the Midsouth.

ACKNOWLEDGMENTS

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Table 1. Percent control after first application.

Treatments	% Control 7 DAT 8/3/2009	% Control 3 DAT 8/6/2009	% Control 7 DAT 8/10/2009	% Control 3 DAT 8/14/2009	% Control 7 DAT 8/18/2009	% Control Season Total
UTC	0.0 a[1]	0.0 c	0.0 d	0.0 f	0.0 d	0.0 f
Orthene .75 lb/acre	42.8 a	80.3 a	64.9 ab	93.5 a	91.4 a	84.4 a
Bidrin 6 oz/acre	67.0 a	81.1 a	59.7 ab	88.2 ab	84.4 ab	80.8 abc
Vydate 12 oz/acre	23.5 a	66.6 a	44.0 b	89.4 ab	74.7 b	74.2 cd
Centric 2 oz/acre	15.2 a	66.9 a	57.3 ab	86.8 abc	81.0 ab	74.9 bcd
Tri-Max Pro 1.5 oz/acre	42.6 a	74.7 a	48.9 ab	74.7 d	56.1 c	64.5 e
Carbine 2.5 oz/acre	37.5 a	73.6 a	22.1 c	83.1 bcd	58.0 c	64.6 e
Leverage 4.5 oz/acre	46.8 a	70.5 a	51.7 ab	78.6 cd	76.0 b	70.1 de
Intruder 1.1 oz/acre	23.1 a	36.0 b	50.6 ab	63.2 e	76.9 ab	63.8 e
Endigo 5 oz/acre	33.0 a	89.5 a	73.1 a	94.9 a	83.9 ab	83.7 a
Diamond 9 oz/acre	55.0 a	60.8 ab	53.9 ab	77.3 d	84.0 ab	76.9 a-d
Discipline 5.12 oz/acre	62.8 a	58.0 ab	66.6 ab	91.1 ab	87.9 ab	83.3 ab

[1] Numbers in a column followed by the same letter are not significantly different (P = 0.05).

Table 2. Harvest data.

Treatments	Lint lbs/acre
UTC	374.3 a[1]
Orthene .75 lb/acre	598.3 a
Bidrin 6 oz/acre	608.8 a
Vydate 12 oz/acre	592.8 a
Centric 2 oz/acre	527 a
Tri-Max Pro 1.5 oz/acre	547 a
Carbine 2.5 oz/acre	599.5 a
Leverage 4.5 oz/acre	627.8 a
Intruder 1.1 oz/acre	492.3 a
Endigo 5 oz/acre	559.3 a
Diamond 9 oz/acre	586 a
Discipline 5.12 oz/acre	505.5 a

[1] Numbers in a column followed by the same letter are not significantly different (P = 0.05).

Control of Tarnished Plant Bug, *Lygus lineolaris*, in Arkansas Cotton, 2009

K. Colwell[1], G.M. Lorenz III[2], H. Wilf[2], N. Taillon[2], B. Von Kanel[3]

RESEARCH PROBLEM

Arkansas cotton producers spent an average of $20.18/acre for control of tarnished plant bugs in Arkansas during the 2009 growing season (Williams, 2010). The purpose of this trial was to evaluate selected insecticides and insecticide combinations for control of plant bugs. With the increasing problems growers face with effective plant bug control, this study will improve recommendations for longer lasting and more economic control of the tarnished plant bug.

BACKGROUND INFORMATION

Tarnished plant bugs (*Lygus lineolaris*) are perennial pests of cotton in Arkansas. Insecticides are the primary control option for plant bugs in Arkansas cotton production. Levels of damage vary from year to year based on the magnitude of populations in Arkansas. In recent years, plant bug populations have shown increasing insecticide tolerance (Snodgrass, 1996). Therefore, it is important to continue evaluating the ability of new and existing insecticides to control plant bugs. The purpose of this study was to assess the performance of selected insecticides and insecticide combinations for plant bug efficacy.

RESEARCH DESCRIPTION

The trial was located in Haynes, Arkansas planted to DPL 0924 BGIIRF cultivar. Plot design was a randomized complete block with four replications with a plot size of four rows 38 in × 50 ft. Foliar insecticide applications were made with a mud master sprayer equipped with TXVS-6 cone jet nozzles with a spray volume of 10 GPA. Applications were made on 17, 27 July and 3 August, 2009. Samples were taken on 20, 23, 27 July, 3, 12, 18 August, 2009. Insect numbers

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were determined by using a 2.5 ft. drop cloth. Two drop cloth samples were taken per plot for a total of 10 row ft. per plot. Data was processed using Agriculture Research Manager Version 8 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted and Duncan's New Multiple Range Test (P = 0.10) was performed to separate means.

RESULTS AND DISCUSSION

At three days after treatment 1 (3DAT1), Orthene, Bidrin, Belay at 3 and 6 oz, Carbine, and Leverage reduced plant bug numbers compared to the untreated check (UTC) (Table 1). At six and ten days after the first application, no treatment differences were observed. Following the second application, Endigo, Orthene and Belay at 6 oz/a had fewer plant bugs at seven days after treatment two (7 DAT2) than the UTC (Table 2). After the third application was made and rated at 9DAT, all treatments reduced plant bug numbers below the UTC (Table 3). At fifteen days after treatment three (15 DAT3) of the third application, none of the treatments were providing adequate control of tarnished plant bugs.

PRACTICAL APPLICATION

The results of this study show many of the treatments currently labeled for plant bugs were ineffective for adequate plant bug control. This illustrates the problems growers are facing with this pest and indicate the increasing difficulty of managing plant bugs effectively and economically.

ACKNOWLEDGMENTS

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Table 1. Control of tarnished plant bugs: 1st application.

Treatment	3 DAT	6 DAT	10 DAT
UTC	8 a[1]	7 a	6 a
Endigo ZC 5 oz/a	5 abc	4 a	4 a
Orthene 1 lb/a	2 c	4 a	3 a
Bidrin 8 oz/a	3 bc	4 a	3 a
Belay 3 oz/a	4 bc	4 a	4 a
Belay 4 oz/a	6 ab	4 a	3 a
Belay 6 oz/a	3 bc	3 a	6 a
Belay 3 oz/a + Orthene 0.75 lb/a	5 abc	4 a	4 a
Carbine 2.3 oz/a	3 c	5 a	5 a
Carbine 2.3 oz/a (FB) Bidrin 8 oz/a (FB) Carbine 2.3 oz/a	5 abc	5 a	7 a
Leverage 5oz/a + NIS 0.25 % v/v	4 bc	5 a	4 a
Leverage 5 oz/a	3 bc	6 a	4 a

[1] Means followed by same letter do not significantly differ (P = 0.10, Duncan's New Multiple Range Test.

Table 2. Control of tarnished plant bug: 2nd application.

Treatment	7 DAT
UTC	11 ab[1]
Endigo ZC 5 oz/a	3 d
Orthene 1 lb/a	3 d
Bidrin 8 oz/a	6 bcd
Belay 3 oz/a	13 a
Belay 4 oz/a	5 bcd
Belay 6 oz/a	4 cd
Belay 3 oz/a + Orthene 0.75 lb/a	10 abc
Carbine 2.3 oz/a	11 abc
Carbine 2.3 oz/a **(FB) Bidrin 8 oz/a** (FB) Carbine 2.3 oz/a	5 bcd
Leverage 5oz/a + NIS 0.25 % v/v	5 bcd
Leverage 5 oz/a	5 bcd

[1] Means followed by same letter do not significantly differ (P = 0.10, Duncan's New Multiple Range Test).

Table 3. Control of tarnished plant bugs: 3rd application.

Treatment	9 DAT	15 DAT
UTC	21 a[1]	15 bc
Endigo ZC 5 oz/a	8 b	20 ab
Orthene 1 lb/a	4 b	5 c
Bidrin 8 oz/a	4 b	21 ab
Belay 3 oz/a	8 b	33 a
Belay 4 oz/a	11 b	11 bc
Belay 6 oz/a	11 b	15 bc
Belay 3 oz/a + Orthene 0.75 lb/a	6 b	7 bc
Carbine 2.3 oz/a	8 b	15 bc
Carbine 2.3 oz/a **(FB) Bidrin 8 oz/a** (FB) Carbine 2.3 oz/a	10 b	13 bc
Leverage 5oz/a + NIS 0.25 % v/v	13 b	15 bc
Leverage 5 oz/a	8 b	16 bc

[1] Means followed by same letter do not significantly differ (P = 0.10, Duncan's New Multiple Range Test).

Comparison of Foliar Applications to Seed Treatment and In Furrow Standards for Thrip Control in Cotton – 2009

N. Taillon[1], G.M. Lorenz III[1], K. Colwell[2], H. Wilf[1]

RESEARCH PROBLEM

Thrips are early-season cotton pests that have the potential to cause delayed maturity and yield loss in Arkansas cotton. The level of damage varies from year to year based on the severity of the thrips infestation (Hopkins et. al., 2001). A wide variety of insecticides and application methods are available for thrips control on seedling cotton. Foliar insecticide sprays are generally reserved for "as needed" supplemental control to the at-planting treatments (Freeman et. al., 2002). However, some growers try to control thrips by only using foliar applications. Foliar treatments for thrip control in cotton cost producers in Arkansas approximately $10.50/acre in 2009 (Williams et al., 2009). This project was designed to evaluate the efficacy of foliar insecticides in comparison to seed treatments and in-furrow applications for thrip management in cotton.

BACKGROUND INFORMATION

Thrip adults and larvae feed on leaves, terminals, and other tender plant parts. Ragged crinkled leaves with a silvery appearance are typical symptoms of thrip damage to young cotton. Leaves usually curl upward and appear burned along the edges as a result of feeding in the terminals. Thrip damage is usually on cotton seedlings and severe damage may stunt cotton growth and reduce yields. Thrips affected 100% of all Arkansas cotton acreage in the 2009 growing season (Williams et. al., 2009).

RESEARCH DESCRIPTION

The trial was located in Marianna, Ark. on the Lonn Mann Cotton Branch Experiment Station, planted to cotton (*Gossypium hirsutum* L.) cv. Phytogen

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375 WRF cultivar on 18 May, 2009. Plot design was a randomized complete block with four replications. Plot size was 12.5 ft. × 50 ft. At planting treatments included the seed treatments Aeris or Avicta, and an in-furrow treatment of Temik. All other treatments were foliar applications that had not received an at-planting seed or in-furrow insecticide, and were made on 2 and 9 June, 2009 with a mud master calibrated at 10 gal/acre. Samples were taken 8, 12 and 16 June, 2009 and thrip density was determined by collecting 5 plants per plot placed in ethyl alcohol using a wash technique. Data was processed using Agriculture Research Manager Version 8, Gylling Data Management, Inc., Brookings, S. D. Analysis of Variance was conducted and Duncan's New Multiple Range Test was performed (P = 0.10) to separate means.

RESULTS AND DISCUSSION

Foliar applications did not reduce thrip levels below that of the untreated check at six days after the first application (6DAT1) (Table1.) At three days after the second application (3DAT2), all foliar applications except Carbine reduced thrip numbers compared to the untreated check and were similar to seed treatments with most treatments reducing numbers below the in-furrow treatment. At seven days after the second application (7DAT2), all treatments reduced thrip numbers compared to the untreated check; while both seed treatments, Bidrin, Orthene, Dimethoate, Intruder and Centric had lower numbers of thrips compared to the Temik, Carbine, and Karate Z. Seasonal totals indicated there was no difference between the untreated check, Carbine, and both rates of Intruder. All other treatments significantly reduced the number of thrips, while seed treatments (Aeris and Avicta) provided the higher level of control.

PRACTICAL APPLICATION

Foliar insecticides are often needed for control of thrips when seed treatments and in-furrow applications lose activity, therefore; it is necessary to evaluate the efficacy of foliar treatments. This data indicates that foliar applications of insecticides can reduce thrip numbers but are not as reliable as seed treatments for control.

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Table 1. Foliar thrip counts at Marianna, 2009.

Treatments	6/8/2009 6 DAT1		6/12/2009 3 DAT2		6/16/2009 7 DAT2		Seasonal Total	
UTC	186.3	ab[1]	58.5	b	58.5	a	303.3	ab
Avicta 1 oz/cwt	6.8	d	15	d	16.3	c	38	e
Aeris 0.375 mg ai/ seed	10.8	d	11.5	d	17.8	c	40	e
Temik 5 lbs/a	28	d	39.8	c	31.8	b	99.5	de
Bidrin 0.2 lb ai/a	159.5	abc	13.8	d	18.5	c	191.8	cd
Orthene 0.2 lb/a	166.5	abc	10	d	13.8	c	190.3	cd
Carbine 1.1 oz/a	225	a	76.8	a	31	b	332.8	a
Dimethoate 0.25 lb ai/a	169	abc	12.8	d	14.3	c	196	cd
Intruder 0.6 oz/a	177.5	ab	15.3	d	17.5	c	210.3	bc
Intruder 1 oz/a	241	a	12.5	d	19.5	bc	273	abc
Centric 2.5 oz/a	77	cd	8.8	d	14.3	c	100	de
Karate Z 0.02 lb ai/a	125.8	bc	25.5	cd	31.3	b	182.5	cd

[1] Numbers in a column followed by the same letter are not significantly different (P = 0.05).

Soil Texture Affects *Meloidogyne incognita* and *Thielaviopsis basicola* and Their Interaction on Cotton

J. Jaraba[1], C.S. Rothrock[1] and T.L. Kirkpatrick[2]

RESEARCH PROBLEM

The root-knot nematode, *Meloidogyne incognita*, and the soilborne fungus *Thielaviopsis basicola*, the causal agent of black root-rot, are important plant pathogens of cotton in Arkansas. When *M. incognita* and *T. basicola* occur in the same field, greater damage may occur on cotton than when only one of the pathogens is present. Studying the relationship of soil factors on *M. incognita* Monfort et al. (2007) found cotton yield variability was explained by sand content and *M. incognita* populations in the cotton field examined. *T. basicola* populations also are influenced by soil texture. The objective of this research was to examine the influence of soil texture on the reproduction and damage potential of *M. incognita* and *T. basicola* and their interaction on cotton.

BACKGROUND INFORMATION

The root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, and the soilborne fungus *Thielaviopsis basicola* (Berk. and Broome) Ferris (syn. *Chalara elegans* Nag Raj and Kendrick), the causal agent of black root-rot, are important plant pathogens of cotton (*Gossypium hirsutum* L.) in Arkansas. A synergistic interaction between *M. incognita* and *T. basicola* has been described on cotton (Walker et al., 1998, 1999, 2000). Microplot studies found that soils infested with both *T. basicola* and *M. incognita* showed an increase in seedling death and a decrease in plant growth and yield compared to either pathogen alone (Walker et al., 1998). However, environmental factors play a large role in damage by either pathogen or their interaction. The objective of this study was to examine the influence of soil texture on the reproduction and damage potential of *M. incognita* and *T. basicola* and their interaction on cotton.

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RESEARCH DESCRIPTION

A soil from the Delta Branch Station, Clarkedale, Ark., (Dubbs-Dundee complex fine silty loam) with a long history of cotton monoculture was used to make four artificial soil textures (53%, 70%, 74% or 87% sand) by adding and mixing different volumes of soil and sand. Soils were steam pasteurized for 30 min. at 70 °C and added to tile microplots (45 cm by 30 cm wide and 75 cm deep) in 15-cm increments and packed to a bulk density of 1.1 g/cm^3. Microplots were located at the University of Arkansas Research and Extension Center, Fayetteville, Ark.

Soils were infested with *T. basicola* at 20 chlamydospores chains/g soil by mixing spores in the top 15 cm of soil. *M. incognita* eggs and second stage juveniles (J2s) were suspended in distilled sterile water, and applied into two 1-cm diameter by 5-cm-deep holes for each microplot to obtain a final rate of 4 or 8 eggs and J2s/g soil. Six treatments were applied in this study: the non-infested control, *T. basicola* alone, both rates of *M. incognita* alone, and all combinations of *M. incognita* and *T. basicola*. Fourteen fungicide-treated cottonseed of cultivar DP 444 BG/RR (Delta and Pineland, Scott, MS) were planted in each plot immediately following infestation on 16 May in 2006 and 2007, or cultivar DP 555 BG/RR on 17 May in 2008. Seed were treated with the fungicide seed treatment (triadimenol, thiram, and metalaxyl; 0.1, 0.312, and 0.155 g a.i./kg seed, respectively). Plots were watered when they reached approximately –10 joules/kg for the first 21 days and –30 joules/kg from 22 days until harvest.

At 12 days after planting (DAP), seedling emergence was assessed, and the number of plants was thinned to six plants. Two plants were arbitrarily sampled from each microplot for early season (22 to 28 DAP) and mid season (45 to 50 DAP) samples leaving 2 plants until harvest. Plants height was measured from the cotyledonary node to the tip of the main stem terminal. Plants were hand-harvested in each microplot to assess seed cotton production per plant.

M. incognita and *T. basicola* populations were assessed from soils at early-season, mid-season, and harvest. *T. basicola* populations were determined by the pour-plate technique using an amended TB-CEN medium (Specht and Griffin, 1985). Nematode soil populations were extracted at the Arkansas Nematode Diagnostic Clinic Laboratory, University of Arkansas Southwest Research and Extension Center using a semi-automatic elutriator (Byrd et al., 1976) followed by centrifugal flotation (Jenkins, 1964).

A randomized complete block design with a factorial arrangement of treatments and four replications per treatment was used. Statistical analyses were done using the General Linear Models (GLM) procedure with SAS (SAS Institute Inc., Cary, N.C.) by the appropriate model. Treatment means or appropriate interaction means were separated with Fisher's protected least significant difference (LSD) at $P = 0.05$. Treatments not receiving *M. incognita* were omitted from analyses for nematode populations and root galling, or *T. basicola* for fungal populations, root discoloration and colonization.

RESULTS AND DISCUSSION

Infestation levels of *M. incognita* and *T. basicola* used in this study were selected based on population levels of both pathogens detected in Arkansas cotton fields and previous studies (Walker et al., 1998, 2000). *M. incognita* and *T. basicola* reduced mid-season plant height in 2007 and 2008 (Table 1). Significant soil by *T. basicola* and *M. incognita* by *T. basicola* interactions were present for plant height at mid season in 2006. *T. basicola* reduced plant height in soils with the lowest sand content (48%) compared to the non-infested treatments. A similar trend was observed for the 53% sand soil texture. Co-infection of *T. basicola* and *M. incognita* caused more reduction in plant height than *T. basicola* or *M. incognita* alone in 2006 (Table 1). Soils with sand contents of 74% or 87% had lower seed cotton yield than 53% or 70% sand treatments in all three years (Table 2). Yield was lower in soils infested with *M. incognita* or *T. basicola* in two of the three years of this study (Table 2). In 2006, a *M. incognita* by *T. basicola* interaction occurred for seed cotton yield, with the high inoculum rate of the nematode with *T. basicola* reducing yields compared to the non-infested treatment (Table 2). Previous research has demonstrated the season-long effects of *M. incognita* and *T. basicola* and their interaction on cotton growth and yield (Walker et al., 1998).

M. incognita is a chronic pathogen that is more severe later in the cotton season when soil temperatures are warmer (Walker et al., 2000). Soil texture had little to no effect on *M. incognita* damage on plant development in these studies. Soil texture did affect nematode galling in 2008, with greater galling in soil textures having higher sand content than in one of the other soil textures (data not shown). In 2007, nematode reproduction was greater in soil with 53%, 74% or 87% sand than soils with 48% or 70% sand (Table 3). *T. basicola* affected harvest populations of *M. incognita* all three years with populations being influenced by a soil texture by *T. basicola* interaction in two of the three years. In 2007, *T. basicola* reduced *M. incognita* populations over all soils textures (Table 3). In 2006 and 2008, a soil by *T. basicola* interaction was present for nematode population at harvest (Table 3). In 2006, the *T. basicola* treatment resulted in a suppression of nematode reproduction in plots with sand contents lower than 87%, with significant nematode reductions in soils with 48%, 54% and 74% sand compared to soils infested with the nematode alone, while in 2008 this was found for 48% and 74% sand (Table 3). However, texture did not affect spring populations of the nematode. Koenning et al. (1996) found that the reproduction of *M. incognita* was greater in soils with sand contents of 58% or 91% compared to soils with sand contents of 48% or 53%. The content of clay particles in soils used by Koenning et al. (1996) was higher (29% to 30%) compared to clay content in the soil used in this study (9%). These differences may explain why *M. incognita* affected cotton over all soil textures in this study, suggesting damage may be limited in soils with higher clay contents, as has been demonstrated in previous studies (O'Bannon and Reynolds, 1961; Robinson et al., 1987; Starr et al., 1993). Monfort (2005) found *M. incognita* population densities and percent sand were the only soil factors that significantly explained cotton yield variability in a field study.

Walker et al. (1998, 2000) found that cotton growth and development was reduced by *T. basicola* early in the season. These results showed that although *T. basicola* was more important on early cotton growth and development, severe damage caused by the fungus to seedlings resulted in delayed plant maturity and reductions in cotton yield, results that agree with previous observations (Allen, 2001). Soil environmental conditions are important in the severity of black root rot on cotton and other crops. Severity of black root rot on cotton increases at soil temperatures less than 26 ºC and in poorly drained soils (Johnson and Hartman, 1919,; King and Presley, 1942; Rothrock, 1992). The variable impact of *T. basicola* on disease development and severity on cotton growth and yield among years may be related to differences in soil environment observed at or shortly after planting among the three years of this study. This is evident in 2007 when the lowest soil temperatures were recorded in May and June for the three years and *T. basicola* had the greatest impact on cotton growth and yield. *T. basicola* also had the greatest colonization of roots in 2007 compared to the other two years (data not shown). *T. basicola* populations at mid-season were reduced in the sandiest soil textures compared to several or all the other soil textures in all years (Table 4). Buchanan (2005), using a benomyl-resistant isolate of *T. basicola*, found the isolation frequency of *T. basicola* decreased in field soil at the same pathogen population as sand content increased to 76% sand compared to soil textures with lower sand contents from the same field.

PRACTICAL APPLICATION

M. incognita and *T. basicola* are widely distributed in Arkansas cotton fields at population levels that are able to decrease plant growth and yield. This study showed that soil texture plays an important role in the damage potential of *M. incognita* and *T. basicola* and their interaction on cotton plants. These results support previous studies that *T. basicola* and *M. incognita* distribution in cotton fields is influenced by sand content. The study also determined that soil textures had a greater impact on *T. basicola* reproduction and damage than *M. incognita*. Thus, population densities of *T. basicola* would be more likely to be present in areas where low sand contents predominate than in areas with higher sand contents within a cotton field, while soils with high sand contents would be more conducive to greater populations of *M. incognita*. This research should help indentify soil textures favorable for both pathogens that may increase disease severity and damage on cotton, since both pathogens are known to interact in a synergistic manner. Field textural maps have been used for the management of *M. incognita* by allowing growers to do site-specific nematicide application, thus reducing costs and the impact on the environment.

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Table 1. The effects of soil texture (soil), *Meloidogyne incognita* (Mi)[w], and *Thielaviopsis basicola* (Tb)[x] on mid-season season plant growth[y].

	Plant height (cm)			
Main effect	2006		2007	2008
Sand (%)	------0------Tb------20------			
48	36.8a[z]	26.0cd	23.6a	18.3c
53	32.5ab	28.5bc	23.3a	25.1b
70	26.3cd	28.5bc	22.7ab	29.0a
74	28.2bc	24.1cde	18.9bc	14.2d
87	22.1de	19.5 e	17.1c	19.2c
Mi	------0------Tb------20------			
0	33.8a	33.2a	29.1a	27.2a
4	26.3b	21.9c	17.2b	18.4b
8	27.4b	20.7c	18.0b	18.9b
Tb				
0			26.2a	22.5a
20			15.7b	20.4b

[w] Soils were infested at planting with 4 or 8 eggs and second stage juveniles of *Meloidogyne incognita*/g of soil.
[x] Soils were infested at planting with 20 chlamydospores chains of *Thielaviopsis basicola*/g of soil.
[y] Plant growth variables were measured 45 days after planting.
[z] Means in a column for a year and main effect or interaction followed by a common letter are not significantly different at $P \leq 0.05$.

Table 2. The effects of soil texture (soil), *Meloidogyne incognita*[x] (Mi), and *Thielaviopsis basicola*[y] (Tb) on yield.

	Seed cotton (g)			
Main effect	2006		2007	2008
Sand (%)				
48	37.6a[z]		39.7a	27.6ab
53	40.4a		46.2a	32.6a
70	38.3a		40.8a	33.7a
74	29.8b		29.1b	19.6b
87	24.9b		22.4b	23.9b
Mi	------0------Tb------20------			
0	40.6a	34.2ab	48.4a	34.3a
4	32.6ab	33.4ab	30.1b	27.1b
8	36.4ab	28.6b	28.7b	21.8b
Tb				
0			39.1a	30.9a
20			33.3b	24.5b

[x] Soils were infested at planting with 4 or 8 eggs and second stage juveniles of *Meloidogyne incognita*/g of soil.
[y] Soils were infested at planting with 20 chlamydospores chains of *Thielaviopsis basicola*/g of soil.
[z] Means in a column for a year and main effect or interaction followed by a common letter are not significantly different at $P \leq 0.05$.

Table 3. The effects of soil texture (soil), *Meloidogyne incognita*[w] (Mi), and *Thielaviopsis basicola*[x] on *Meloidogyne incognita* soil populations[y]

	Harvest Population (log)				
Main effect	2006		2007	2008	
Sand (%)	-----0-----Tb-----20-----			-----0-----Tb-----20-----	
48	2.9ab[z]	1.7cd	1.3b	2.5b	1.8c
53	2.8abc	1.6d	2.6a	2.7b	2.8ab
70	2.8abc	1.9bcd	1.3b	2.7b	3.0ab
74	3.1a	1.4d	2.4a	2.9ab	2.4bc
87	2.4abc	2.8ab	2.6a	3.0ab	3.5a
Mi					
4	2.4a		2.1a	2.8a	
8	2.3a		1.9a	2.7a	
Tb					
0			3.2a		
20			0.8b		

[w] Soils were infested at planting with 4 or 8 eggs and second stage juveniles of *Meloidogyne incognita*/g of soil.
[x] Soils were infested at planting with 20 chlamydospores chains of *Thielaviopsis basicola*/g of soil.
[y] Log10 + 1 transformed data. Treatments without *M. incognita* were dropped for this analysis.
[z] Means in a column for a year and main effect or interaction followed by a common letter are not significantly different at P ≤ 0.05.

Table 4. The effects of soil texture (soil), *Meloidogyne incognita*[w] (Mi), and *Thielaviopsis basicola*[x] (Tb) on *Thielaviopsis basicola* populations[y].

	----------Mid-season population (log)----------		
Main effect	2006	2007	2008
Sand (%)			
48	2.8a[z]	2.5bc	2.6a
53	2.5a	3.0a	1.6b
70	2.5a	2.9ab	1.7bc
74	2.2a	2.9ab	2.7a
87	1.4b	2.3c	1.1c
Mi			
0	2.4a	2.7a	1.7a
4	2.3a	2.7a	2.1a
8	2.1a	2.7a	2.1a

[w] Soils were infested at planting with 4 or 8 eggs and second stage juveniles of *Meloidogyne incognita*/g of soil.
[x] Soils were infested at planting with 20 chlamydospores chains of *Thielaviopsis basicola*/g of soil.
[y] Log10 + 1 transformed data. Treatments without *T. basicola* were dropped from the analyses.
[z] Means in a column for a year and main effect followed by a common letter are not significantly different at P ≤ 0.05.

Application of Cotton Burr/Stem in Thermoplastic Composites

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RESEARCH PROBLEM

Cotton gin waste (CGW) is a waste stream from a ginning operation that is rich in ligno-cellulosic fibers. Currently, there are no major commercial-scale applications for this material except for a small fraction that goes into either composting or is land applied. For a majority of gins across the country, CGW is a potential environmental liability and an expense to dispose of. Value-added products that can be made from CGW will generate a revenue stream for the ginners and producers while reducing the environmental burden. This study focuses on the application of plant fibers recovered from CGW in natural fiber reinforced thermoplastic composites. The thermoplastic composite material is investigated as an alternative to wood and wood polymer composites (WPC) for outdoor non-structural building applications such as deck boards, fences, landscaping products, and window and door components.

BACKGROUND INFORMATION

Thermoplastic composites reinforced with natural fibers offer a better choice for non-structural building materials subjected to outdoor weather conditions such as high moisture and temperature fluctuations. Wood is the most commonly used fiber filler in commercially available thermoplastic composites. (Bajwa et al., 2009a).With the ongoing focus on biomass energy, stagnation in the building sector and outsourcing of furniture industry, the U.S. is facing a growing shortage of wood fibers of desired quality. On the other hand, the U.S. cotton industry produces large quantities of cotton gin waste (CGW), which is rich in plant fibers. Some of these cellulosic fibers can impart desirable qualities to composites such as low specific gravity without large deterioration in strength. (Bajwa et al., 2009a; Bourne et al., 2007) Therefore, utilization of the cellulosic fibers from this agricultural waste stream can benefit the composite industry, agricultural industry, and the environment.

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Cotton gin waste contains cotton burrs or carpels, stems, leaves, motes, small seeds and some dirt. Approximately 40-70% of the cotton gin waste is made of cotton burrs and stems (CBS), with an additional 10-11% of motes or short fibers (Baker et al., 1994). During the ginning process, the CBS fraction can be easily separated from the rest of the waste stream if it is collected at the extractor (Holt et al., 2000). Preliminary research at the laboratory scale has shown great potential for using CGW as a fiber filler in thermoplastic composites (Bourne et al., 2007) and composition boards (Holt et al., 2009). However Bourne et al. (2007) used manual extrusion to manufacture the samples, and therefore, exhibited high variability in the composite properties. Also, the motes in the mixture created mixing problems. Therefore, this study was conducted with the objective to evaluate the potential of CBS as a fiber filler in thermoplastic composites through manufacturing using the extrusion process.

RESEARCH DESCRIPTION

A laboratory-scale experiment was conducted at the University of Arkansas Agricultural Experiment Station in Fayetteville. The experiments were designed to evaluate CBS as a potential fiber filler. Thermoplastic composite samples were manufactured with a twin screw counter-rotating extruder into approximately 1/4" by 1" profile. There were 4 fiber filler treatments that included CBS replacing the oak wood fiber used in a commercial WPC formulation by 0%, 25%, 50%, 70% and 100%. The 0% CBS is considered as the control. All composite materials used a total of 50% fiber filler, with the remaining being thermoplastics and other additives.

All fiber fillers were initially ground to a size distribution of 80-20 micron in size. The ground fibers were dried and mixed with the remaining ingredients (high density polyethylene and additives) in the required proportion, and then fed to the extruder. The extruded samples were water cooled and tested for physical properties such as specific gravity, water absorption, thickness swelling, coefficient of linear thermal expansion (CLTE) and mechanical properties such as flexural strength and modulus, hardness and nail withdrawal capacity. The ASTM standard D 1037-99 was used for testing mechanical properties. The CBS treatment means were compared against the control using Dunnett's test, which was performed with JMP software, SAS Institute, Inc., Cary, N.C.

RESULTS

Once the extruder settings were optimized for the CBS fiber, the composite samples showed good surface appearance similar to that of the control. The specific gravity of all CBS treatments averaged at or slightly below unity. The 25% CBS treatment showed a significantly lower specific gravity than the control. A low specific gravity is preferred for certain building materials. The 24-hr water

absorption of the 50% and 75% CBS treatments was significantly higher than the control, while the thickness swelling of the 75% CBS treatment was significantly higher than the control. Lower values for both water absorption and thickness swelling are preferred for building materials. All treatments exhibited a similar coefficient of linear thermal expansion (CLTE).

A comparison of strength properties of composite samples showed that the flexural modulus of elasticity (MOE) of 75% and 100% CBS treatments were significantly lower than the control. However, modulus of rupture (bending strength), hardness and nail withdrawal capacity for all CBS treatments were similar to that of control. Although the CBS treatments with high substitution rates (75% and 100%) experienced some loss of flexural modulus, it is not a major concern for non-structural building applications. The only major concern was the increased water absorption of the 50% and 75% CBS treatments, which affects thickness swelling as well.

PRACTICAL APPLICATION

The outdoor non-structural building products are a growing area of application for thermoplastic composites. This study indicates that the wood fibers in the WPC products can be replaced by CBS by 25% without any degradation in the physical and mechanical properties tested here. At higher CBS substitution rates, water absorption was a major problem, which can be remedied by pre-treating the fibers with specialty chemicals/processes to make them water-phobic. Although there was a slight decrease in the flexural modulus, that is not a major concern since the material is used primarily in non-structural building applications.

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Table 1. Physical and mechanical properties of thermoplastic composites reinforced with different combinations of CBS and oak wood.

Treatment (%CBS)	Spec. Gr. (ratio)	Water Abs (%)	Thick Swell (%)	CLTE (mm/m/°C)	MOE (MPa)	MOR (MPa)	Janka Hardness (N)	Nail Withdrawal Force (N)
0	1.01	3.51	0.92	12.5	1644.29	15.34	5004.00	992.65
25	0.97[a]	4.51	1.11	16.0	1424.70	14.68	5159.68	865.88
50	1.00	5.97[b]	1.94	13.5	1289.50	13.53	5241.23	913.32
75	1.00	7.69[b]	2.18[b]	15.5	1100.40[b]	11.77	5187.85	947.42
100	0.99	5.53	1.63	12.7	1062.41[b]	11.65	5829.85	1021.56

[a] Indicates a significant desirable difference from control.
[b] Indicates a significant undesirable difference in comparison to control (copyright: Bajwa et al., 2010).

Best Management Practices for Improved Water Quality in Cotton Production

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RESEARCH PROBLEM AND BACKGROUND INFORMATION

Sustainable farming practices are the focus of many cotton producers in the Midsouth. Varying tillage techniques can be used to reduce the runoff of sediment from soil surfaces. According to the U.S. EPA (2008), sediments are the leading contributor to non-point source pollution. Reducing the runoff of sediments from cotton-producing fields will have a positive impact on adjacent and connecting waterways (Phillips et al., 2006). High sediment loads have been shown to be detrimental to the population growth of certain crustaceans (Kirk and Gilbert, 1990) and the growth rate of fish (Bruton, 1985). Crop management practices such as conservation tillage (NT) or cover crops (CC) have also been shown to reduce pesticide and nutrient runoff (Werner et al., 2004). Best Management Practices (BMP) such as NT and CC retain pesticides and nutrients on the production field and may result in fewer chemical applications. Daniel et al. (1999) also measured increased cotton lint yields with some CC varieties. For BMPs to be sustainable, they must be examined in two ways—through improved cotton quality and production and reduced impact on the environment. While contaminants in runoff are mitigated in various ways both on the production field and after exiting the fields, this study focuses on the use of on-field BMPs to improve the quality of water runoff. Additional edge-of-field BMPs can further reduce contamination associated with agricultural runoff and further protect downstream ecosystems.

RESEARCH DESCRIPTION

Experimental Design

Replication of field plots located on the Judd Hill Cooperative University Research Farm included 16-row split-plots with three tillage systems: conventional tillage (T), no-till (NT), and NT + legume/cereal cover crops (CC). Cover crop termination occurred prior to the 19 May 2009 rain-delayed planting. The Dundee

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silt loam soil was planted with 3-4 Cruiser treated (thiamethoxam) Stoneville 4554 B2RF seeds/ft. Production practices remained constant across all treatments with special consideration for requirements that maintained each tillage treatment. Relevant chemical applications are listed in Table 1 and collection dates for runoff events are found in Table 2. Thirteen rows into each plot a 5-gallon bucket was placed flush with the ground with a plastic drop cloth used to funnel water into the collection bucket for sample collection (Fig. 1). Runoff was routed from the rows to the buckets by transecting trenches 30-cm deep and 30-cm wide. A 3-row buffer insured no cross-contamination of runoff between tillage treatments. A 10-L aqueous grab sample was extracted from each bucket following sampled runoff events. Water samples were analyzed at Arkansas State University Ecotoxicology Research Facility.

Water Quality

Water quality parameters included temperature (°C), dissolved oxygen (DO) (mg/L), pH, conductivity (µS/cm), alkalinity (mg $CaCO_3$/L), hardness (mg $CaCO_3$/L), total suspended solids (TSS) (mg/L), nitrites (mg/L), nitrates (mg/L), phosphates (µg/L), free ammonia (mg/L), and turbidity (NTU). Temperature, DO, pH, and conductivity were measured using a VWRTM SympHony meter. Alkalinity was determined using a potentiometric titration technique, with a 4.5 pH endpoint. Water hardness was determined using an EDTA titrimetric method. Nutrient analyses included the aqueous dissolved fraction and were prepared by filtering through a 0.45 µm filter. Nitrate, nitrite, and phosphate were then determined using low-flow Lachat™ methods with lower detection limits of 0.01 mg/L, 0.05 mg/L, and 0.5 µg/L respectively. Ammonia was measured using an Accumet® AR25 dual channel pH/Ion meter. Ammonia was then converted into free ammonia using an on-line ammonia calculator (Alleman, 1998) with temperature and pH as contributing factors. All water quality measurements followed the American Public Health Association (APHA, 2005) guidelines.

Ceriodaphnia Dubia Bioassays

Chronic 7-d bioassays using *C. dubia* utilized U.S. EPA guidelines (2002a). Test organisms were produced in-house and were ≤ 24 hours old at test initiation. Survival and reproduction were recorded daily for each individual. Survival was determined by the number of organisms surviving at test shut down. Reproduction was measured as the total number of neonates produced by each surviving adult. An extrapolated *C. dubia* acute static-renewal bioassay (EPA, 2002b) was also used when a chronic test measured complete lethality prior to the 7-d test termination.

Pimephales Promelas Bioassays

Chronic 7-d bioassays using *P. promelas* utilized US EPA guidelines (2002a). Test organisms were produced in-house and 4-5 replicates were used with at least eight larval fish (≤24 hours old) at test initiation. Survival was determined by the

number of organisms remaining at test shut down and growth was measured as the mean dry weight of surviving organisms.

Statistical Analyses

Results of aqueous bioassays were calculated using ToxCalc™ (1996), Tidepool Scientific, McKinleyville, Calif. Values for endpoints were obtained using hypothesis test approach with Steel's Many-one Rank Test. Kolmogrov D test was used to indicate normality and Bartlett's Test was used to indicate variance. Statistical correlations between toxicity endpoints and water quality parameters were calculated using ANOVA and regression analysis on MiniTab (1999).

RESULTS AND DISCUSSION

Water quality parameters sampled from field plots included a correlation of *C. dubia* response to TSS from the treatment types - T, NT, and CC. A strong correlation was measured between TSS and treatment type from the five rain events ($p = 0.018$) and the two surge irrigation events ($p = 0.036$) (Table 3). A TSS reduction of 360.4% was measured in the CC treatment as compared to T for all rain events. Likewise, an average TSS reduction of 271.8% was measured for the same treatment comparisons for the two surge irrigation events.

Nitrate measured in runoff from both rainfall and irrigation events were lower in CC treatments, however the mean nitrite for all runoff events was lowest in the T treatment (Table 4). Table 4 summarizes the mean values and ranges of all the nutrient values with the exception of the two events immediately following urea application. All nutrient measurements represent only the dissolved fraction as water samples were filtered through a 0.45 µm filter following collection.

Chronic bioassays using *C. dubia* measured no significant lethality correlated to any specific tillage treatment for the rain events (Table 5). Significant lethality was measured in the rain event on 2 October, but was measured across all treatments. Sublethal effects were a better indicator of effects of treatments; the 15 June, 4 July, and 16 July rain events had a moderate correlation between treatment type and reproduction (number of neonates produced) ($r^2 = 0.56$). The correlation between *C. dubia* reproduction and TSS is shown by runoff events and treatment types (Fig. 2). In a 7-d chronic *C. dubia* test using runoff from 19 August, 100% lethality was measured in NT and T treatments while CC experienced a 63% survival. One hundred percent mortality in all treatments was measured in the 2 October runoff event after 7 d, however, an extrapolated 48-hr acute test resulted in 80% survival in one of the three CC replicates. Although no significant mortality was measured in the 13 October runoff sample, significant reductions in reproduction were measured in all treatment types.

No significant lethality was measured using *P. promelas* following exposure to runoff water collected until the 19 August or 13 October samples (Table 5). One T treatment from the 2 October sample had a measured significant reduction in survival (65.6%) while the remaining T, NT, and CC replicates from that sample

were not significantly reduced. The same 2 October sample expressed significantly reduced *P. promelas* growth with one NT treatment and all three T treatments.

Measured water quality parameters in this study are similar to past studies with a reduction of TSS from fields with practices such as NT and CC. The 2008 sampling of these same plots and treatment types measured a correlation between turbidity and *C. dubia* reproduction ($p = 0.001$); in the 2008 studies, management practices directly affected water quality parameters and was measured by laboratory bioassays. Similar results in this 2009 study measured less transported sediment leaving the production field in NT and CC treatments with CC treatments allowing less soil to be transported from the production area as measured TSS. Although transported sediment (TSS) is known to carry phosphate loads that correspond to tillage and crop management (Sharpley et al., 1996) this was not measured in our study as only dissolved nutrients were measured in filtered runoff water. Turbid water decreased *C. dubia* reproductive abilities in this 2009 study and as has been reported in previous studies (Kirk and Gilbert, 1990). In that study, Kirk and Gilbert (1990) concluded that elevated turbidity was capable of reducing the population growth among cladoceran.

Reduced survival of bioindicator organisms in laboratory assays reflected the movement of pesticides from the production field. These hydrophobic chemicals are often attached to soils and transported through sediment movement during runoff events (Ghadiri and Rose, 1991) illustrating the environmental benefits cover crops provide for the protection of aquatic organisms. Soil retention on the production field is also demonstrated in decreased sediment movement into downstream waterways, illustrating the environmental sustainability of cover crops and conservation tillage practices. The 19 August irrigation event samples collected 24 hr following application of Bidrin XL resulted in 63% *C. dubia* survival in the 7-d chronic bioassay. This indicates that the CC treatment offered greater protection than NT and T, which resulted in 100% lethality to the test organisms. The 100% *C. dubia* lethality response among all CC, NT, and T replicates for the 2 October samples was most likely related to the tribufos application on 30 September. However, a 48-hr acute extrapolated endpoint from the 7-d chronic test revealed one replicate among the three CC samples with an 80% survival rate, while remaining CC replicates and all NT and T treatments demonstrated 100% lethality. In this same sampling event, survival and growth responses of *P. promelas* were similar as a single T replicate measured a significant decreased survival while all others measured no decrease. Also, a significant reduction in fish growth was measured in all the T replicates and one NT replicate. These results illustrate the greater sensitivity of cladocera to pesticides and the environmental benefits of CC to protect from effects of pesticide movement from treated fields. The final sample, 13 October followed another less intense application of DEF (Table 1) and the *C. dubia* toxicity responses demonstrated similar, yet less dynamic results when compared with the first DEF application. In that collection no lethality was observed, but reproduction was significantly inhibited in all treatments. The CC, NT, and T treatments produced 8.3, 4.6,

and 4.2 average neonates, respectively, and as with the other sampling events, suggested chemical runoff abatement with CC.

Improving water quality from cotton production fields can be achieved with on-field BMPs including NT and CC. It is also important to manage these practices to maximize the quality and quantity of cotton produced. Additional water quality protection is provided with a combination of on-field and edge-of-field BMPs that allow contaminants associated with runoff to be further mitigated after leaving the production field. Many edge-of-field BMPs such as vegetated agricultural ditches, constructed wetlands, and soil additives have also been studied by the authors for their ability to reduce runoff-related contaminants (Bouldin et al., 2004, 2006, 2007; Krauth et al., 2008).

CONCLUSIONS

The use of conservation tillage crop management in U.S. cotton production has been a significant step toward sustainable farming. Water quality improvement and reduced contaminants exiting production fields are increasingly important elements of sustainability. Additional practices that improve water quality by retention of agrochemicals on cotton production fields include the use of cover crops. Reduced soil disturbance concurrent with cover cropping during both the non-production and early-production seasons are viable options for reducing the movement of chemicals from the field. Studies have shown that using these Best Management Practices (BMPs) can improve water quality by retaining sediment, pesticides, and nutrients on the field. Certain cover crops have also shown an increased lint yield in cotton production.

This 2009 study was the second year of a multi-year study to compare water quality from three replicated small plot treatments—conventional tillage, conservation tillage, and conservation tillage + cover crops. The split-plot design included three randomly distributed 16-row replicates of each treatment. Water was sampled following five rain and two irrigation events as runoff exited each plot. Comparative analyses included bioassays with the indicator organisms, *Ceriodaphnia dubia* and *Pimephales promelas* according to U.S. EPA guidelines. A reduction in total suspended solids (TSS) was measured in runoff from cover crop plots indicating reduced soil erosion as compared to conventional tillage and conservation tillage alone. Bioindicator organisms responded negatively to elevated TSS from these plots.

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Table 1. Chemical applications to test plots at Judd Hill in 2009 including date and application method.

Date	Chemical	Application Method
2-Jun-09	Urea	8-row boom
2-Jul-09	Urea	8-row boom
18-Aug-09	Bidrin XP	8-row boom at 10.6 oz/acre
30-Sep-09	DEF (tribufos)	8-row boom
12-Oct-09	DEF (tribufos) and AIM	Aerial

Table 2. Water sampling events at Judd Hill in 2009 including runoff source and rainfall amount.

Date	Type of Event	Amount
15-Jun-09	Rainfall	0.70 inches
24-Jun-09	Irrigation	Surge - furrow
4-Jul-09	Rainfall	0.76 inches
16-Jul-09	Rainfall	2.97 inches
19-Aug-09	Irrigation	Surge - furrow
2-Oct-09	Rainfall	0.37 inches
13-Oct-09	Rainfall	2.80 inches

Table 3. Mean total suspended solids values measured in runoff water from irrigation and rainfall events at Judd Hill in 2009.

Treatment[1]	Event	TSS (mg/L)
CC	Rain	203.7
NT	Rain	364.4
T	Rain	734.2
CC	Irrigation	64.8
NT	Irrigation	118.6
T	Irrigation	176.1

[1]Treatment averages from rain events are based on 3 replicate samples.

Table 4. Nutrient means and ranges measured in filtered runoff water from irrigation and rainfall events at Judd Hill in 2009.

	PO_4 (mg/L) All Events			-------NO_3 (mg/L)*--------			-------NO_2 (mg/L)[1]--------		
		Ranges			Ranges			Ranges	
Treatment	Mean	high	low	Mean	high	low	Mean	high	low
CC	0.78	1.51	0.5	1.78	3.56	0.73	0.17	0.59	0
NT	0.57	1.55	0.23	2.98	5.19	1.37	0.19	0.63	0
T	0.73	1.54	0.27	2.23	5.18	0.99	0.06	0.14	0

[1]Events proceeded by urea applications 06/15/09 and 07/04/09 are excluded from nitrogen calculations.

Table 5. Survival, reproduction (*C. dubia*), and growth (*P. promelas*) (±SD) of bioassay organisms exposed to runoff from Judd Hill in 2009.

	C. dubia				*P. promelas*			
Runoff event	**Survival**	**± SD**	**Reproduction**	**± SD**	**Survival**	**± SD**	**Growth (mg)**	**± SD**
061509 CC	100.0%	0.0%	16.5	6.6	93.3%	10.6%	0.46	0.07
061509 NT	100.0%	0.0%	14.0[1]	4	98.1%	5.0%	0.46	0.07
061509 T	90.0%	30.5%	5.2[1]	3.4	79.1%	17.8%	0.38	0.1
062409 CC	95.0%	22.4%	46.2	11.9	100.0%	0.0%	0.45	0.05
062409 NT	97.0%	18.3%	32.5	8.6	99.2%	3.2%	0.43	0.04
062409 T	93.0%	25.4%	27.9	12.1	95.8%	6.1%	0.43	0.05
070409 CC	97.0%	18.3%	12.4	5.3	93.1%	9.5%	0.31	0.04
070409 NT	97.0%	18.3%	6.9[1]	4.5	97.5%	5.2%	0.33	0.08
070409 T	73.0%	45.0%	6.7[1]	6.1	97.5%	5.2%	0.34	0.04
071609 CC	100.0%	0.0%	22	8.5	98.3%	4.4%	0.43	0.06
071609 NT	100.0%	0.0%	16.4	9	95.0%	13.2%	0.44	0.05
071609 T	97.0%	18.3%	16.2	7.8	92.5%	11.4%	0.46	0.05
081909 CC	63.0%*	49.0%	10.5[1]	4.3	75.8%	29.7%	0.36	0.11
081909 NT	0.0%*	0.0%	-	-	31.7%*	45.0%	0.41	0.21
081909 T	0.0%*	0.0%	-	-	92.5%	9.2%	0.3	0.05
100209 CC	0.0%*	0.0%	-	-	92.7%	8.4%	0.25	0.03
100209 NT	0.0%*	0.0%	-	-	87.5%	7.5%	0.21	0.08
100209 T	0.0%*	0.0%	-	-	77.1%*	21.9%	0.12*	0.06
101309 CC	100.0%	0.0%	8.3[1]	2.9	97.5%	4.5%	0.29	0.05
101309 NT	100.0%	0.0%	4.6[1]	2.7	97.5%	4.5%	0.31	0.05
101309 T	90.0%	30.5%	4.2[1]	1.7	95.8%	9.0%	0.31	0.04

[1] Denotes significant difference from control at a = 0.05.

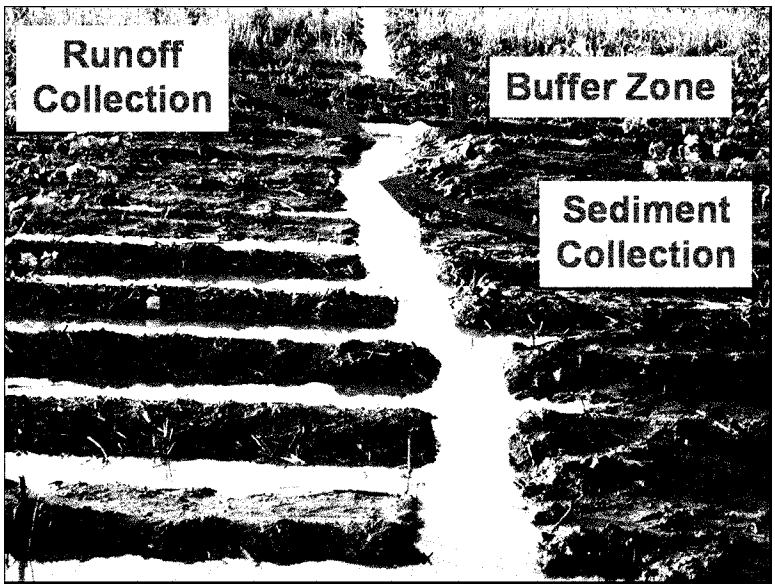

Fig. 1. Water collection design and upstream trap for sediment collection at Judd Hill in the 2009 crop production season.

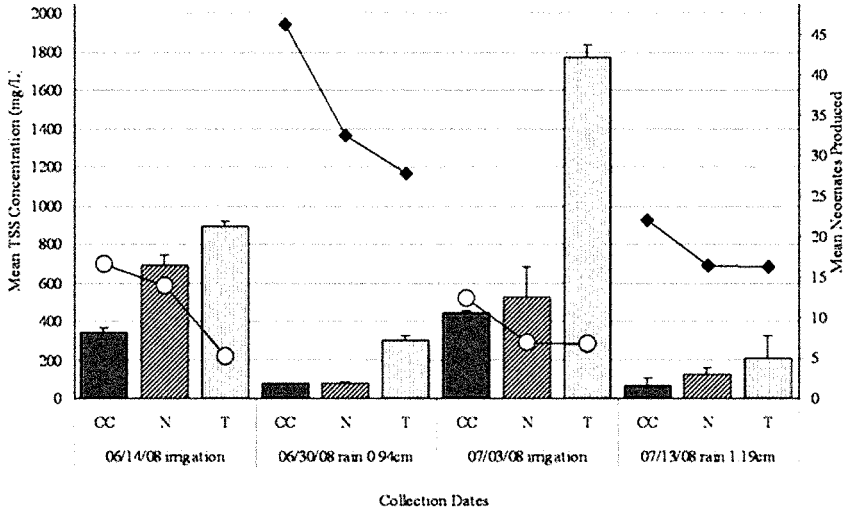

Fig. 2. Total Suspended Solids (TSS) and *C. dubia* reproduction for tillage treatments (CC, NT, and T) for four runoff events. The 19 August, 2 October, and 13 October rain events are omitted as organism lethality did not allow comparison of *C. dubia* reproduction. * indicates significant difference in reproduction from control.

Greenhouse Gas Emissions and Sequestration Estimates of Arkansas Cotton

L.L. Nalley, M. Popp and K. Brye[1]

RESEARCH PROBLEM

Scientists have raised the issue of rising greenhouse gas (GHG) emissions and their impact on global climate change for several decades. As the science underlying the climate models has become more robust, and as people have begun to feel the impacts of environmental stress more acutely, consumers and the general public have become more aware of the need for sustainability of products and their production practices. Given the ongoing discussion related to greenhouse gas (GHG) emissions and a recent policy push to reduce carbon emissions to mitigate potentially adverse climate change, policy makers and producers need more information on likely effects of various carbon policies on likely crop pattern changes.

BACKGROUND INFORMATION

To fulfill the objective of providing more information to producers, a life cycle assessment (LCA) on the carbon emissions and sequestration per acre for cotton production in Arkansas on a county level basis was conducted. The analysis included all cotton producing counties in Arkansas and covered both irrigated and non-irrigated production. An array of 17 regional production method and seed technology options, relevant to producers in 2007, were thus analyzed.

RESEARCH DESCRIPTION

Specific objectives for the study included: i) the use of county level yield information to derive estimates of above and below ground biomass production; ii) the development of a procedure to estimate how varying percentages of carbon from this biomass production would be sequestered across soil types using different tillage practices; iii) an estimation of farm income changes should producers be

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charged/paid for extra/reduced net carbon equivalent footprint relative to a 2007 best case scenario.

The Life Cycle Analysis (LCA) put forth in this study included both direct and indirect GHG emissions. Direct emissions are those that come from farm operations. Examples are carbon dioxide (CO_2) emissions from the use of diesel by tractors and irrigation equipment and the use of gasoline by farm trucks. Indirect emissions, on the other hand, are emissions generated off-farm as a result of the manufacturing of inputs used on the farm. Examples are GHG emissions from the use of natural gas in commercial fertilizer production.

Included in the LCA are GHG emissions of agricultural inputs involved in the production of commodities up to the farm gate (e.g., fertilizer, herbicides, pesticides, fuel, agricultural plastics and other chemicals). Excluded are emissions generated during drying, transport or processing of a commodity that occur after the farm gate. Also excluded from this study are embedded carbon emissions as a result of upstream production of equipment and tools used on-farm for agricultural production.

Previously reported carbon equivalent (CE) emission factors were used to estimate the amount of emissions generated as a result of input use by each cotton production practice. In essence, multiple GHGs (methane, carbon dioxide and nitrous oxide in this analysis) are associated with global warming and were converted to their carbon equivalents to obtain a "carbon footprint"–a process stemming from a rich engineering literature on carbon equivalence. Values provided by the U.S. Environmental Protection Agency were used for diesel and gasoline combustion emissions and combined with EcoInvent's life cycle inventory database through SimaPro to calculate the upstream emissions from the production of fuel. Values provided by Lal (2004), a synthesis of numerous studies measuring carbon emissions from farm operations, were used for all other inputs.

Using a methodology similar to Prince et al. (2001), pounds of carbon sequestered per acre could be estimated for each cotton production method in Arkansas. Sequestration as measured in this study was a function of soil type, tillage type, harvest index, shoot-to-root ratio, and lint yield. Given the estimation of carbon emissions and sequestration, a net carbon footprint (emissions-sequestration) could be estimated by county and by production type.

RESULTS AND DISCUSSION

Figure 1 illustrates the decomposition of the total GHG emissions by cotton production method and the difference in GHG emissions per acre between irrigated and non-irrigated production methods (highlighted with the letter D for dryland or non-irrigated production). Pumping water for irrigation requires a significant amount of energy (typically diesel) and contributes significantly to the total GHG emissions when comparing irrigated to non-irrigated production. The use of nitrogen fertilizer, and its subsequent N_20 emissions, is the other large component to the carbon footprint of cotton. The application of agricultural

chemicals (pesticide, fungicide, and herbicide) plays a relatively small role in the total carbon footprint compared to nitrogen fertilizer application and diesel fuel usage.

This single "carbon score", however, fails to take into account the efficiency of input use. As inputs remain constant and yield increases, carbon per pound of lint decreases. While some crop production methods (center pivot irrigation for example) have high levels of inputs (fuel), they also have a relatively high yield, and so the GHG emissions per pound of lint is much closer to the mean of low-input and low-yielding production practices of non-irrigated crops, for example. On the same note, as new seed technologies are adopted that have lower input usage while maintaining yield, GHG emissions per pound per bushel of crop will decline as well.

Table 1 highlights the fact that cotton is a net emitter of carbon in the state of Arkansas although the amount varies by production practice. Emissions range from a high of 513 lb/acre with a center pivot production method to a low of 362 lb/acre with a dryland production method. As discussed above often the highest emitters will be the highest sequesters of carbon, which can be beneficial if producers are given carbon offset credits. Sequestration estimates range from a high of 475 lb/acre using a center pivot method to a low of 251 lb/acre using a dryland method. Note, that these are averages for counties and hence are based on average yields reported in those counties. Also, yields are not adjusted across production method except for non-irrigated vs. irrigated production. The smallest net emitter was a furrow irrigated production method at 3.67 lb/acre meaning that this production method is nearly carbon neutral. If carbon offset payments, where producers are paid to reduce net carbon footprint, were instituted, cotton production practices with the lowest emissions and highest sequestration may thus be favored over those with high emissions and low sequestration.

PRACTICAL APPLICATION

Expected changes in climate change and energy policies have led to many analyses, some citing gains and others losses to agriculture. This study set out to estimate if cotton in the state of Arkansas was a net emitter or net sequester of carbon per acre by analyzing 17 cotton production methods. Using a cradle-to-farm gate Life Cycle Analysis, both direct and indirect carbon emissions were estimated including production practice details commonly aggregated in other studies. Results of this analysis illustrate the differences in emissions on a spatial basis, as well as by production (tillage, irrigation, etc.) practice. This analysis provides a baseline for comparisons across counties and across production practices to see how inputs and spatially specific production practices impact cotton GHG emissions. This estimate will prove valuable if a cap-and-trade or a carbon offset market is established for U.S. agriculture. While cotton is not estimated to benefit substantially from an offset market (only changes in production methods that reduce net carbon footprint compared to current GHG net carbon footprint are

awarded offset payments), this research does illustrate to producers, scientists and policy makers to what extent spatial and production method differences exist for the net carbon footprint in cotton production in Arkansas.

ACKNOWLEDGMENTS

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Table 1. Green House Gas (carbon equivalent) in pounds per acre for each of the 17 major cotton production methods in Ark.

Cotton Production Region	Production Practice	Carbon Equivalent Emissions (lbs/ac)[1]	Carbon Sequestration (lbs/ac)[2]	Net Emmissions (lbs/ac)
	BG/RR Center Pivot Stale Seed Bed 12 Row	469.5	356.3	113.2
	BGII/RRFlex Center Pivot No-Till 12 Row	458.13	232.59	225.54
(Northeast)	RRFlex Furrow Stale Seed Bed 12 Row	456.47	356.3	100.17
	LL Furrow Stale Seed Bed 12 Row	441.32	356.3	85.02
	RR Non-Irrigated Stale Seed Bed 8 Row	362.94	294.15	68.79
	BG/RR Furrow Conventional Till 12 Row	479.42	343.9	135.52
	BG/RR Center Pivot Stale Seed Bed 12 Row	469.5	343.9	125.6
(Central)	WS/RRFlex Furrow Stale Seed Bed 12 Row	458.17	343.9	114.27
	BGII/RRFlex Furrow Stale Seed Bed 12 Row	455.48	343.9	111.58
	BG/RR Furrow Stale Seed Bed 12 Row	455.48	343.9	111.58
	RR Non-Irrigated Stale Seed Bed 8 Row	348.42	272.8	75.62
	BG/RR Center Pivot Stale Conventional Till 8 Row	513.67	475.81	37.86
	BG/RR Furrow Stale Seed Bed 8 Row	480.62	378.96	101.66
(Southeast)	BG/RR Furrow Conventional Till 12 Row	479.48	475.81	3.67
	BGII/RRFlex Center Pivot Stale Seedbed 12 Row	470.63	378.96	91.67
	BGII/RRFlex Furrow Stale Seedbed 12 Row	455.48	378.96	76.52
	RR Non-Irrigated Stale Seed Bed 8 Row	363.3	251.54	111.76

[1] Emissions are based on parameter estimates from the literature. Significant uncertainty exists about N_2O emissions.
[2] Note that sequestration values are averaged across yield observations for counties in production for the region so added variation exists across counties and is not reported here.

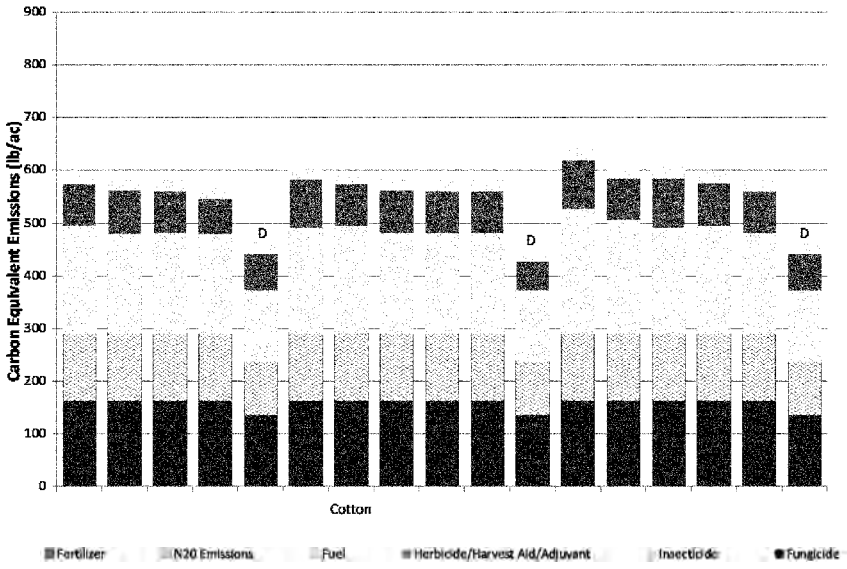

Fig. 1. Decomposition of the total greenhouse gas emission by cotton production methods and the difference in greenhouse gas emmisions per acre between irrigated and non-irrigated production methods. D = dryland or non-irrigated production. Descriptions of production practices from left to right are listed in Table 1 from top to bottom, respectively.

2009 Cotton Reserch Verification Program Report

T. Barber[1] and A. Flanders[2]

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Arkansas cotton acreage has been on the decline since 2006. In 2006 Arkansas cotton acres, reached 1.1 million acres compared to the 2009 acreage of 520,000 acres, which is an approximately 47% decline. The sharp cotton acreage decline can be attributed to the increasing costs and risk associated with producing a cotton crop compared to grain crops and the increased market value of grain crops when compared to cotton. To remain competitive in the global environment, Arkansas cotton producers must stay vigilant to maintain profitability under current production and marketing conditions. The cotton research and verification program was established in 1980 in order to help producers make timely and profitable management systems to increase yield on a field by field basis, thus increasing the management intensity of these fields. Although many things have changed in cotton production since the inception of the program, it remains a critical avenue to disseminate quality non-biased production data and profitable management decisions for Arkansas cotton producers.

RESEARCH DESCRIPTION

Cotton verification fields are selected based on communication with county agriculture agents who have responsibility for cotton in cotton producing counties. These agents then visit with cotton producers within their counties who are interested in conducting a verification field. The cotton verification program as a whole is an applied learning program that serves as a training and educational platform to keep county agents, cotton producers and crop consultants up-to-date on the latest cotton management recommendations from the University of Arkansas Division of Agriculture. Once agents, producers and fields are selected all management decisions for that field from soil samples to defoliation timing are made based on numerous years of solid data from the University of Arkansas Division Of Agriculture. In 2009 three fields were entered into the cotton verification program in Greene, Mississippi and Drew counties. Field sizes for

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these three fields were 35, 60 and 72 acres and varieties selected for 2009 were ST 4498B2RF, AM 1550 B2RF and DP 0935 B2F, respectively. Cotton was planted on 28 May in Greene county, 23 April in Mississippi and 28 April in Drew county. All phosphorous and potassium fertility recommendations were based on soil test results. Nitrogen rates were 90, 115 and 105 lbs/acre for Greene, Mississippi and Drew county locations, respectively. Cotton was irrigated at all locations.

RESULTS AND DISCUSSION

The budget summary for the 2009 cotton verification program (Table 1) reports yields, revenue, total costs and net returns for the three verification fields in 2009. Yields for 2009 were 1160 lb, 743 lb and 806 lb lint/acre for Mississippi, Greene and Drew counties respectively. These yields, although above the state average, were significantly reduced 20% to 50% from previous years in the program due primarily to several factors not limited to late planting date, late season rainfall totaling 30 inches or more for the months of September and August, and variety response to late-season rainfall. The 2009 growing season was a particularly difficult one for producers across the state.

Average cotton yields for the last five years have been over two bales of cotton or 1051 lb lint/acre. The 2009 average cotton yield was approximately 797 lbs lint/acre, which is a 24% reduction in average yield. The top three costs for producing cotton in the verification program were fertilizer, chemicals and seed. Seeding costs alone ranged from $72.58 to $95.29, which are the highest production costs for a single application. Reasons for increased chemical costs can be attributed to increased use of residual herbicides to combat glyphosate-resistant weeds and increased insecticide applications due to overwhelming plant bug pressure. In 2009 the number of applications for plant bugs was 4, 3 and 5 for Mississippi, Greene and Drew counties respectively. Traditionally the southern portion of Arkansas has higher pressure from plant bugs, however this year the Mississippi county verification field was surrounded by corn on three sides, thus increasing the plant bug pressure due to the bordering corn fields. On average the verification field lost $15.47 per acre in 2009, with only one field in Mississippi county showing profit. It is important to note that land rent is not included in these analyses. Overall production costs (total expenses) for 2009 were $548.24/acre before rent. Considering cotton to be priced or sold at the loan value, 1054 lb lint/acre is needed to break even on production costs. This reiterates the reason for the recent reduction in acres over the last three years. Although much of the loss in 2009 can be attributed to weather related reasons, producers margins are so tight that they are not willing to take the risk with this size of investment unless the market price increases to a point where some risk can be managed.

PRACTICAL APPLICATION

The cotton verification program provides the only real-world data and information on cotton production profitability based on non-biased extension recommendations. There are many other sources of information for cotton management available but this program is the only one that provides non-biased university based research data to backup management decisions. The program has been very successful over the last 30 years and will remain a constant source for questions and recommendations for cotton producers in the state of Arkansas.

Table 1. 2009 Cotton research verification budget summary ($/acre).

Crop Value	Mississippi County	Greene County	Drew County	Average
Yield (lbs.)	1160	743	806	903
$/lb	0.59	0.59	0.59	0.59
Revenue	**684.40**	**438.37**	**475.54**	**532.77**
Operating Expenses				
Seed, includes all fees	72.58	81.29	95.29	83.05
Fertilizer	90.32	103.13	142.27	111.91
Chemicals	127.06	126.04	114.79	122.63
Custom Services	6.00	15.00	15.00	12.00
Other	126.37	111.15	118.26	118.59
Total	**422.33**	**436.61**	**485.61**	**448.18**
Returns to Operating Expenses	**262.07**	**1.76**	**-10.07**	**84.59**
Capital Recovery				
Machinery and Equipment	87.37	74.02	86.99	82.7933
Overhead	18.41	15.07	18.31	17.2633
Total	105.78	89.09	105.30	100.06
Total Expenses	528.11	525.70	590.91	548.24
Net Returns	**156.29**	**-87.33**	**-115.37**	**-15.47**

Biodegradation of Three Cellulosic Fabrics in Soil

Mary Warnock[1], Kaaron Davis[2], Duane Wolf[2], and Edward Gbur[3]

RESEARCH PROBLEM AND BACKGROUND INFORMATION

The cellulosic fabrics cotton, rayon, and Tencel® are commonly used in the textile industry (Kroschwitz, 1990). The chemical composition of the fabrics is similar, but they differ in the arrangement of the cellulose polymers in the fabrics (Collier and Tortora, 2001). The basic polymer for all cellulosic fibers consists of repeating glucose units. For the cotton fabric, the cellulosic polymers within the cotton fibers have a high degree of polymerization (approximately 6,000 to 10,000 units), highly reactive hydroxyl (-OH) groups, and the ability to support hydrogen bonding with the 70% crystalline area. The remaining 30% of the fiber is amorphous. Like cotton, rayon is composed of cellulose, but the cellulose chains in rayon are shorter with the degree of polymerization being between 400 to 700 units. Thus, about 30% of the cellulose is crystalline with 70% being amorphous. Tencel® lyocell (generic classification) is a highly crystalline fiber with high strength capacity.

In 2007, over 9 Tg (10 million tons) of textile waste went into landfills in the U.S. (U.S. EPA, 2008). The anaerobic conditions found in landfills result in slow biodegradation rates of cellulosic materials. To divert fabric waste from landfills, an alternative method of fabric disposal would be application of cellulosic fabric waste to surface soil where aerobic conditions could result in enhanced biodegradation rates. Information on cellulosic fabric biodegradation rates in surface soil would also be valuable in providing estimates of the length of time that fabrics have been buried in soil, contributing useful data to forensic investigations (Janaway, 2008). The objective of this field study was to determine the biodegradation rates of 100% rayon, cotton, and Tencel® woven fabrics buried in an aerobic Captina silt loam soil.

RESEARCH DESCRIPTION

For the field biodegradation study, rayon, cotton, and Tencel® fabrics were cut into 25 × 25-cm units and placed in tulle having 1 × 2-mm mesh openings. The

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[2] Program associate, university professor, respectively, Crop, Soil, and Environmental Sciences, Fayetteville.
[3] Professor, Agricultural Statistics Laboratory, Fayetteville.

tulle, which was resistant to degradation, was used to hold the fabric specimens in tact as much as possible during the degradation process. The enclosed fabric samples were buried in a Captina silt loam soil (fine-silty, siliceous, active, mesic Typic Fragiudult) that had been tilled to a depth of 15 cm. The fabric was buried at a depth of 10 cm and oriented parallel to the soil surface. Plots were maintained vegetation free by an application of the herbicide Roundup®.

At 14, 28, 42, 77, and 112 days, five replications of each experimental fabric were carefully excavated, lightly brushed to remove soil particles, dried to a constant weight at 55 ºC, and a representative subsample of the fabric ashed at 650 ºC. All fabric weights were reported on a dry, ash-free weight basis. The initial weight of the fabrics at 0 days also was determined. During the field study, mean soil temperature at a depth of 10 cm was approximately 25 ºC and ranged from 14 to 34 ºC. Optimal soil moisture of approximately -33 kPa, which corresponded to 18% gravimetric moisture, was maintained through rainfall and supplemental irrigation during the study.

The constant decomposition rate of the fabrics in soil over time suggested that degradation followed zero-order kinetics where the rate was independent of the substrate concentration (Wolf and Wagner, 2005). The zero-order kinetics model [Eq. 1] was used to describe fabric biodegradation.

$$A_t = A_o - kt \qquad \text{[Eq. 1]}$$

where

- A_t is the amount of fabric remaining at any given time (mg dry, ash-free fabric)
- A_o is the initial amount of fabric added to the soil (mg dry, ash-free fabric)
- k is the zero-order rate constant (d^{-1})
- t is the time (d)

The percentage of fabric remaining was regressed on time and yielded a straight line with a slope of -k, the zero-order rate constant. Analysis of covariance was used to determine if the zero-order rate constants differed for the experimental fabrics. The half-life ($t_{1/2}$), or time required for 50% of the initial fabric to decompose, was calculated using [Eq. 2].

$$t_{1/2} = A_o/2k \qquad \text{[Eq. 2]}$$

RESULTS AND DISCUSSION

With optimal soil moisture of -33 kPa and soil temperature of approximately 25 ºC during the field study, rapid cellulose biodegradation would be expected (Janaway, 2008; Wolf and Wagner, 2005). The amount of fabric remaining over time demonstrated rapid biodegradation of rayon, intermediate biodegradation of cotton, and slow biodegradation of Tencel®. Plots of the percentage of fabric recovered vs. time showed that fabric biodegradation could be described by zero-

order kinetics (Fig. 1). The zero-order rate constants, or k values, were significantly different and followed the decreasing order of rayon > cotton > Tencel® (Table I). The calculated half-life values were 22, 40, and 94 days for rayon, cotton, and Tencel®, respectively. Rayon and cotton have been reported to be highly vulnerable to decomposition (Janaway, 2008). As the quantity of amorphous cellulose in the fabric increased and the length of the polymer chains decreased, availability of the cellulose substrate for microbial metabolism increased; thus, resulting in more rapid fabric biodegradation (Kaplan et al., 1970).

PRACTICAL APPLICATION

Aerobic, moist, warm soil conditions resulted in rapid fabric biodegradation and rates decreased in order of rayon > cotton > Tencel® with half-life values of 22, 40, and 94 days, respectively. Compared to landfilling, an alternative method of fabric disposal could be application and mixing with aerobic surface soil. By using the fabric biodegradation zero-order rate constants, it is possible to estimate the time fabrics have been buried in soil and such information would be useful for potential forensic applications. Determining cellulosic fabric biodegradation rates in soil has forensic and environmental implications.

For more details and additional information, the complete results from this study will be published in *AATCC Review*.

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Table I. Zero-order rate constants (k) and half-life ($t_{1/2}$) values for rayon, cotton, and Tencel® fabrics buried in Captina soil.

Fabric	Zero-Order Rate Constant (k)	Standard Error of Estimate	Half Life ($t_{1/2}$)	Standard Error of Estimate
	----------/day----------		----------days----------	
Rayon	2.624 a[1]	0.252	21.6	0.9
Cotton	1.238 b	0.107	40.2	2.0
Tencel®	0.528 c	0.063	93.6	8.1

[1]Rate constants followed by the same letter are not significantly different (P = 0.05).

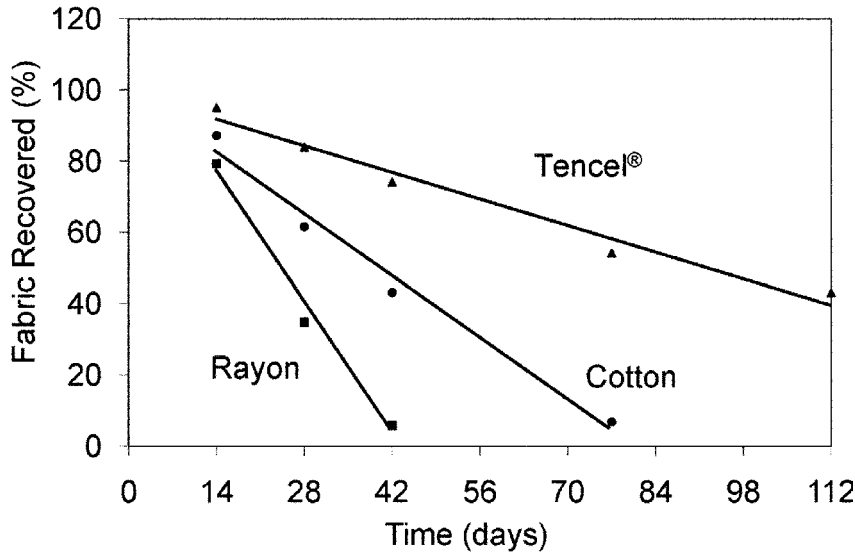

Fig. 1. Zero-order biodegradation of the rayon, cotton, and Tencel® fabrics in the field study.

APPENDIX I

STUDENT THESES AND DISSERTATIONS RELATED TO COTTON RESEARCH IN PROGRESS IN 2009

Acuña, Andrea. Identification of *Gossypium* species cytoplasm with molecular markers. (M.S., advisor: Stewart)

Alcobar, Ed Allan L. Genetic diversity and evolution of glyphosate-resistant palmer amaranth. (Ph.D., advisor: Burgos)

Bangarwa, Sanjeev. Integrated strategies for purple (*Cypreus rotundes* L.) and yellow nutsedge (*Cyterus esculentus* L.) management in tomato and bell pepper. (Ph.D., advisor: Norsworthy)

DeVore, Justin. Use of deep tillage and cover crops for improved weed management in cotton and soybean. (M.S., advisor: Norsworthy)

Greer, Amanda. Relationship between Telone II and Nitrogen Fertility in Cotton in the Presence of Reniform Nematodes. (M.S., advisor: Kirkpatrick)

Griffith, Griff. Erratic cotton responses to trifloxysulfuron and applications. (M.S., advisor: Norsworthy)

Groves, Frank. Inheritance of cotton yield components and relationships among yield, yield components, and fiber quality. (Ph.D., advisor: Bourland)

Hannam, Josh. Pathogens of the Tarnished Plant Bug, *Lygus lineolaris*, in Arkansas. (M.S., advisor: Steinkraus)

Kawakami, Eduardo. Agronomic, physiological, and biochemical effects of 1-MCP on the growth and yield of cotton. (M.S., advisor: Oosterhuis)

Loka, Dimitra. Effect of high night temperature on cotton gas exchange and carbohydrates. (M.S., 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)

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

Snider, John. Effects of high temperature stress on the anatomy and biochemistry of pollen-pistil interactions in cotton. (Ph.D., advisor: Oosterhuis)

Storch, Diana. Physiological and biochemical response of cotton to temperature stress during reproductive development. (M.S., advisor: Oosterhuis)

Tiwari, Rashmi. Molecular characterization of the diversity and natural hybridization of the *Gossypium* species of the arid zone of Australia. (M.S., advisor: Stewart)

Tseng, Te Ming. STS Polymorphisms and molecular mechanisms in seed dormancy of red rice (*Oryza sativa* L.) biotypes. (Ph.D., advisor: Burgos)

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

APPENDIX II

RESEARCH AND EXTENSION 2009 COTTON PUBLICATIONS

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ABSTRACTS

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